Oil price shocks, monetary policy and current account imbalances within a currency union

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Abstract

For more than two decades now, current-account imbalances are a crucial issue in the international policy debate as they threaten the stability of the world economy. More recently, the government debt crisis of the European Union shows that internal current account imbalances inside a currency union may also add to these risks. Oil price fluctuations and a contracting monetary policy that reacts on oil prices, previously discussed to affect the current account may also be a threat to the currency union by changing internal imbalances. Therefore, in this paper, we analyze the impact of oil price shocks on current account imbalances within a currency union. Differences in institutions, especially labor market institutions and trade result in an asymmetric reaction to an otherwise symmetric shock. In this context, we show that oil price shocks can have a long-lasting impact on internal balances, as the exchange rate adjustment mechanism is not available. The common monetary policy authority, however, can reduce such effects by specifying an optimum monetary policy target. Nevertheless, we also show that there is no single best solution. CPI, core CPI or an asymmetric CPI target all come at a cost either regarding an increase in unemployment or increasing imbalances.

Keywords: Current account deficit, Oil price shocks, DSGE models, Search and matching labor market, Monetary policy
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1. Introduction

Global current-account imbalances are a crucial issue in the international policy debate for more than two decades now. The IMF and the G7 countries repeatedly pointed out at the risks of significant imbalances for the stability of the world economy. These seem to have materialized in the government debt crisis that hit the European Union and especially the Eurozone after 2009. Imbalances between member states in the Eurozone seem to be even more worrying, as an adjustment of exchange rates that drives balances back to equilibrium is not available. Instead, real prices and wages have to adjust. The alignment of wages, however, depends on labor market institutions. As systems differ among member states, even a symmetric shock, like an oil price shock, can have asymmetric consequences and, thus, affect imbalances. Therefore, it is of crucial importance, from both a policy and a theoretical point of view to examine the impact of an oil price shock on currency-union members with asymmetric labor market institutions and to discuss possibilities for the joint monetary authority to reduce the negative consequences of these shocks.

In general, oil prices are volatile and hard to predict (Baumeister and Kilian, 2016). In the last two decades, the world economy experienced in between 1999 and 2008 a period of strong increasing oil prices and from 2008 onward a period of sharply decreasing oil prices. In June 2008, WTI crude oil was at 157,87 USD per barrel and dropped to 29,67 USD per barrel in January 2016. Today, in October 2017, the WTI crude oil price is at 52.10 USD per barrel with a forecast that it remains low for the foreseeable future. Resulting from this development, we should see an increase in internal imbalances in the currency union. In a nutshell, current account imbalances are traced back to the presence of asymmetric or symmetric shocks in specific institutional settings (Chen, Milesi-Ferretti, and Tressel, 2013; Kim and Yi, 2015).If two countries differ concerning the use of oil in production, decreasing oil prices improve the trade balance of oil-intensive exporters, leading to current account surpluses and an improvement in the net-foreign asset position of these countries. Furthermore, lower oil prices increase consumer spending and corporate profitability which increases aggregate demand. It is likely that countries that trade more and are faced with higher demand rise tradable production and shift more resources to the tradable sectors. This adds to the increase in current account imbalances. The current account is brought into equilibrium by real price and exchange rate adjustments. However, in a monetary union, the exchange rate adjustment mechanism is not available. Therefore, a higher aggregate demand has to increases wages and prices stronger in surplus countries compared to deficit countries for the current account balance to go back to equilibrium. The pace of adjustment, therefore, depends on institutions. Using a two-country DSGE model of a currency union with imperfect labor markets, we show this transmission mechanism of oil price shocks that either affects the stochastic component[1] of the oil price but not

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[1]The oil price in our model consists of two components, an endogenous component that

quantities or oil supply shocks that affect quantities and the endogenous part of prices but not the stochastic component. Our contribution to the literature is threefold: first, to all of our knowledge, we are the first to discuss oil price shocks in a currency union setting with imperfect labor markets, second, we discuss the possibilities of a central bank to reduce imbalances and, third, we discuss labor market reforms that could reduce the burden of real adjustments.

Despite that research papers on oil price shocks in currency unions are scarce, there is a vivid debate about the impact of oil prices on global imbalances either directly or through a contractionary monetary policy. The effect of oil price shocks on the current account was first discussed in the late 1970s. Agmon and Laffer (1978) analyzed wealth and income effects following the oil crises in 1973 and found that the trade balances and balances of payment of industrialized countries deteriorated markedly after the oil price shock. Kilian, Rebucci, and Spatafora (2009) confirm an increase in global imbalances driven by oil price shocks for the period before the economic and financial market crises. Schubert (2014), using time-nonseparable preferences, theoretically explains the deterioration and a gradual improvement over time. Like Agmon and Laffer (1978), Gao, Kim, and Saba (2014) see the adjustment burden on less energy-intensive products that react more elastic to changes in income than oil or energy-intensive products. Using a general-equilibrium model, Backus and Crucini (2000) show that oil accounts for much of the variation in the terms of trade over the last twenty-five years and that its quantitative role varies significantly over time. Kilian, Rebucci, and Spatafora (2009) pay attention to the non-oil tradable goods that are crucial in determining the size of the impact of oil price shocks on the current account. Le and Chang (2013) confirm these findings for Asian countries. In building a two-country DSGE model, Bodenstein, Erceg, and Guerrieri (2011) underpin these empirical results theoretically and add that the missing link can also be caused by the simultaneous occurrence of multiple shocks, as well as different sources of oil price movements and different propagation channels.

As prices of less oil-intensive products drop, Bernanke, Gertler, Watson, Sims, and Friedman (1997) see a tightening monetary policy as one of the reasons for a strong real effect and a fast adjustment of the current account. Leduc and Sill (2004) using a DSGE model, find that 40 percent of the adjustment to oil prices result from monetary policy, while Carlstrom and Fuerst (2006) using alternate assumptions deny a strong impact. Kilian and Lewis (2011) do also find no evidence that monetary policy responses to oil price shocks had significant macroeconomic effects. In this context, Bodenstein, Guerrieri, and Kilian (2012) stress the fact that the source of the oil price shock is crucial to determine the optimal monetary policy response, Bodenstein and Guerrieri (2011), using an estimated DSGE model, see links in non-oil trade as vital for the transmission of shocks that affect oil prices and Bodenstein, Guerrieri, and Gust (2013) argue that when policy rates reach their zero lower bound, the propagation of shocks

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reacts on market forces and a stochastic component that is independent from equilibrium on the oil market.

is changed which results in the persistence that alternative shocks induce to oil prices.

There are very few papers that, like our model, address oil price shocks in an environment with imperfect labor markets. One of those is Herrera, Karaki, and Rangaraju (2017) who use a factor augmented vector autoregressive (FAVAR) model to analyses job-market behavior after an oil price shock. They show that the pace of gross job reallocation is slowing. This effect is especially important in a monetary union, where the exchange rate as adjustment mechanism is absent. More flexible labor markets help to reduces imbalances as prices and wages can adjust faster. Unfortunate for EMU, the quality of labor market institutions varies across member countries (de Pace, 2013). While labor markets are more flexible among northern members, they are more rigid in the South (Bertola, 2017). For this reason, asymmetric labor markets may reduce the impact of oil price shocks in some countries, while the effect remains strong in others. In this paper, we want to explain under which circumstances oil price shocks increase or decrease imbalances in a currency union. We focus on labor markets, as they seem to be rigid in the European Union than in the United States (Edmans, Li, and Zhang, 2014) and less integrated than financial markets. Therefore, labor markets may be one force that prevents real adjustment to oil price shocks.

The remainder of this paper is organized as follows. The following section introduces the model; the third section describes the calibration of the model to a typical EMU member state; the fourth section presents reaction of the model to oil price and oil supply shocks under different monetary policy targets and labor market regimes. Finally, the fifth section concludes.

2. The model

We build a two-country, two-sector currency union model with search and matching frictions in which a representative household maximizes lifetime utility according to the rational expectations hypothesis. In each period, the household faces the decision of whether to buy tradables from the domestic or the foreign economy, to purchase non-tradables, to hold real money balances or to postpone consumption by buying bonds. Foreign and domestic tradable as well as non-tradable consumption goods sold by retailers are subject to staggered price setting (Calvo, 1983). Following Andolfatto (1996) and Merz (1995), we include the assumption of Uzawa-type preferences. This preference specification allows the model to be stationary, in the sense that the non-stochastic steady state is independent of initial conditions (Schmitt-Grohé and Uribe, 2003). Furthermore, the steady-state is always unique even in the presence of low elasticities of substitution between the tradable good bundles of the two countries (Bodenstein, 2011). There are two sectors of production in each country. Each sector is divided into two types of economic entities, firms which produce intermediate goods and retailers. The trade specification of the model resembles that of Obstfeld and Rogoff (2006) and, more specifically, Ferrero, Gertler, and Svensson, Lars E. O. (2008), with the exception that we impose staggered price setting on the level of the retailers (Bernanke, Gertler, and Gilchrist, 1999) rather than on the level of

the firms. Furthermore, we assume a search and matching labor market with endogenous separations rather than staggered wage setting.[2] Introducing search and matching labor markets with endogenous separations is, to all our knowledge, a novel approach in the DSGE literature on current account imbalances.

The preferences of households are expressed by a nested utility function combining, on the one hand, non-tradables and tradables using a Cobb-Douglas function and, on the other hand, tradables from the domestic and foreign economies using a CES specification. This setting is specified in a way which reflects the fact that households have a preference for domestically produced products. Additionally, the assumption of a home bias gives rise to a "transfer effect," as Obstfeld and Rogoff (2006) call it, according to which a country sees a deterioration in its terms of trade if national expenditures decline. We use a setting with tradable and non-tradable goods, as in a world with exhausted or nearly exhausted factors, the possibility to shift resources from non-tradable to tradable production is a necessary precondition for a country to increase exports.

In both sectors of the economy, we have nominal price rigidities. Given irrevocably fixed exchange rates due to our currency union setting, prices for tradable goods are identical in both countries. In a steady-state equilibrium, trade is always balanced. During adjustments following macroeconomic shocks, it might, nevertheless, be favorable for households in a given country to increase imports and run up debt. Financial markets are assumed to be imperfect in the sense that only the bond of the domestic country is internationally tradable.

In our model, labor is, at least in the short run, not mobile between the two countries. As a result, the imbalances that arise are more persistent than they would be in a model with factor mobility. We use this assumption since, compared to the US, intra-EMU labor mobility is still small (Krause, Rinne, and Zimmermann, 2014).

More specifically, the labor markets in our model are built on the search and matching model with endogenous job destruction developed by Mortensen and Pissarides (1994), in which a worker and a firm in each period have to decide whether to preserve or to terminate their relationship. Following Zanetti (2011), Krause and Lubik (2007) and Walsh (2005), we embed the labor market specification of the Mortensen-Pissarides model of den Haan, Wouter J., Ramey, and Watson (2000) in a New Keynesian setting.

In each period, unemployed workers search for a job and intermediate goods-producing firms want to fill their vacancies. The matching function describes the process of generating job matches by combining unemployed workers with open vacancies. In contrast to Krause and Uhlig (2012), where a new match can have an idiosyncratic productivity below the threshold level[3], we assume that the productivity of a new worker is always higher than the threshold to

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[2]Both deviations enable us to analyze labor market reforms as we include search and matching frictions and endogenous job-separations.

[3]The threshold productivity defines a specific idiosyncratic productivity, where a firm is indifferent between continuing or separating a match.

avoid instantaneous endogenous separations. When a match is generated, wage bargaining starts. After the firm and the worker have agreed on a specific wage training starts, enabling the match to become productive in the next period. At the beginning of each period, firms and workers are forced to separate with a given probability owing to disturbances exogenous to the model. If a match survives exogenous separations, the firm is still able to choose to post a vacancy or to keep the employee. As there are vacancy posting and firing costs for firms as well as search costs for workers, continuing a match might generate a surplus. This surplus occurs if firms and workers observe a productivity of the match that is above a threshold level at which the surplus is zero. Firms that have an open position post vacancies as long as the value of the vacancy is greater than zero. If the number of vacancies increases, however, the probability of finding a convenient match diminishes. This results in a reduction in the expected value of an open position. In equilibrium, free market entry ensures that the value of a vacancy is always zero.

To sum up, the model economy is characterized by nominal rigidities in the goods market and search and matching frictions in the labor markets. It consists of a representative household, a production sector comprised of representative intermediate goods-producing firms and a continuum of retail firms, indexed by i, with $i \in [0,1]$ in each country of the currency union, as well as a common central bank. Firms producing tadables can sell their goods in both countries and households can engage in international borrowing.

2.1. The representative household

Our economy is inhabited by a large number of infinitive living identical households consuming aggregates of domestic and imported monopolistic goods (Dixit and Stiglitz, 1977). Owing to labor market search frictions any household is either employed or unemployed. In general, labor is supplied inelastically. As a second source of income, households own shares in domestic firms and receive dividends D_t from them. We assume that households in the domestic economy and the foreign country have the same preferences and factor endowments, defined over a composite consumption good C_t and real money holdings M_t/P_t. As described by Merz (1995), we assume a perfect insurance system where households can insure themselves against variations in income. This assumption removes heterogeneity among households within a given country and enables us to consider the optimization problem of a representative household maximizing expected lifetime utility. During each period $t = 0, 1, 2, \ldots$, the expected lifetime utility function is given by

$$E \sum_{t=0}^{\infty} \beta_t \left[\ln C_t + \kappa_m \ln \left(\frac{M_t}{P_t} \right) \right], \tag{1}$$

where $\beta_t = \frac{e^{\varsigma_t}}{1+\psi(\ln C_t - \vartheta)}\beta_{t-1}$ for $t \geq 0$, $\beta_0 = 1$ represents the endogenous discount factor, with the parameter ψ that is assumed to be small and the shock term ς_t, and κ_m that denotes a scaling parameter for utility from real money holdings with $\kappa_m > 0$. The consumption index C_t is defined as

$$C_t \equiv \frac{CO_t^{\chi} Ol_t^{1-\chi}}{\iota(1-\iota)}. \tag{2}$$

with CO_t as non-oil tradable and non-tradable composite and Ol_t as oil related products. Non-oil goods are defined as goods that use oil not as the major input and whose prices are not linked to the oil price, like it is with natural gas.

$$CO_t \equiv \frac{C_{Tt}^{\iota} C_{Nt}^{1-\iota}}{\iota(1-\iota)}. \tag{3}$$

Tradable goods $C_{T,t}$ can be obtained from the domestic $C_{H,t}$ or from the foreign economy $C_{F,t}$ while non-tradables $C_{N,t}$ are produced at home, only. Following Ferrero, Gertler, and Svensson, Lars E. O. (2008), we employ a Cobb-Douglas[4] specification with ι as the proportion of total expenditure devoted to tradable goods.

$$C_{T,t} = \left[\alpha^{\frac{1}{\gamma}} C_{H,t} + (1-\alpha)^{\frac{1}{\gamma}} C_{F,t}^{\frac{\gamma-1}{\gamma}} \right]^{\frac{\gamma}{\gamma-1}} \tag{4}$$

In this specification, γ measures the elasticity of substitution between home and foreign goods and α is the share parameter of the CES-function. Household demand is derived by minimizing costs for the specific goods bundles.

$$C_{H,t} = \alpha \left(\frac{P_{T,t}}{P_{H,t}} \right)^{\gamma} C_{T,t} \quad C_{F,t} = (1-\alpha) \left(\frac{P_{T,t}}{P_{F,t}} \right)^{\gamma} C_{T,t} \tag{5}$$

$$C_{N,t} = (1-\iota) \frac{P_t}{P_{N,t}} CO_t \quad C_{T,t} = \iota \frac{P_t}{P_{T,t}} CO_t, \quad P_{G,j,t} = \left(\frac{P_{j,t}}{\chi} \right)^{\chi} \left(\frac{P_{O,t}}{(1-\chi)} \right)^{(1-\chi)}$$

where $P_{G,t}$ denotes the price of a bundle of oil and the composite of tradable and non-tradable goods, while P_t stands for the price of a bundle of tradable and non-tradable goods, $P_{T,t}$ is the price index for domestic tradable and foreign tradable and $P_{N,t}$ for non-tradable goods. A household chooses consumption, nominal money and bond holdings subject to a budget constraint of the form

$$P_{G,t} C_t + B_t / R_t + M_t = B_{t-1} + P_{G,t} Y_t + D_t + \varrho_t + M_{t-1}, \tag{6}$$

for $t = 0, 1, 2...$. At the beginning of period t, the household receives a lump-sum transfer ϱ_t from the central bank and dividends D_t from the representative intermediate-goods-producing firm. Total income amounts to Y_t. The household enters period t with bonds B_{t-1} and M_{t-1} units of money. Furthermore, the

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[4]We assume a unit elasticity between non-traded and traded goods which is typical but not undisputed in the literature. Based on the simulations of Obstfeld and Rogoff (2005) with an unit elasticity, a elasticity of two and one of 100, our prior is not to find a strong impact of the elasticity on our simulation results.

mature bonds are providing additional B_{t-1} units which are all sold at the beginning of the period and might be used to purchase B_t new bonds at the nominal cost B_t/R_t with R_t as the nominal interest rate between t and $t+1$. Solving the intertemporal optimization problem, we derive the following first-order conditions:

$$\Lambda_t = C_t^{-1} \tag{7}$$

$$E_t \beta_{t,t+1} = E_t \frac{\pi_{t+1}}{R_t} \tag{8}$$

$$\frac{\kappa_m}{m_t} = \Lambda_t - \beta_t E_t \frac{\Lambda_t}{\pi_{t+1}}, \tag{9}$$

where Λ_t is the shadow price and $\beta_{t,t+1} = \beta_t \Lambda_{t+1}/\Lambda_t$ is the stochastic discount factor. Real money holdings are defined as $m_t = M_t/P_{G,t}$. Combining the first-order conditions with respect to C_t and B_t, equation (7) and equation (9), yields the standard consumption Euler equation:

$$\beta_t E_t \left(\frac{C_{t+1}}{C_t} \right)^{-1} = E_t \frac{P_{G,t+1}}{R_t P_{G,t}}. \tag{10}$$

We distinguish three different statuses of employment of the representative household: let U_t, $W_{j,t}^N$ and $W_{j,t}(a_t)$ denote respectively the present discounted value of an unemployed, newly employed and continuously employed worker, with j being an index for the two sectors of each economy. In case of unemployment, the worker enjoys a real return b and expects to move into employment with probability $p_j(\theta_{j,t})$, becoming employed either in the tradable or in the non-tradable sector. Therefore, the present discounted income stream of an unemployed worker is

$$U_{j,t} = b + E_t \beta_{t,t+1} \left[p_j(\theta_{j,t}) W_{j,t+1}^N + (1 - p_j(\theta_{j,t})) U_{j,t+1} \right]. \tag{11}$$

Following Pissarides (2000) , the flow value of being unemployed, $b = h + \rho_w w$, consists of the value of home production or leisure h and unemployment benefits $\rho_w w$, where ρ_w represents the replacement ratio with $0 < \rho_w < 1$ and w the steady-state average wage. The second part of Equation (10) describes the expected capital gain from a change of state. As an equilibrium condition, the value of unemployment has to be identical in the both sectors ($U_t = U_{H,t} = U_{N,t}$).

The worker's value from holding a job with idiosyncratic match productivity $a_{j,t}$, that is assumed to be log-normal distributed with the cumulative distribution function $F(\cdot)$, is given by

$$W_{j,t}(a_{j,t}) = w_{j,t}(a_{j,t}) \tag{12}$$
$$+ E_t \beta_{t,t+1} \left[(1 - \rho^x) \int_{\mathring{a}_{j,t+1}}^{\infty} W_{j,t+1}(a_{j,t+1}) dF(a_{j,t+1}) + \rho_{j,t+1} U_{j,t+1} \right].$$

Equation (12) tells us that an employed worker is paid a sector-specific wage $w_{j,t}(a_{j,t})$, and that if he or she survives exogenous and endogenous job destruction, which happens with a total probability of ρ_{t+1}, the match will start to produce goods.

The present-discounted value of a new match is

$$W_{j,t}^N = w_{j,t}^N \tag{13}$$
$$+ E_t\beta_{t,t+1}\left[(1-\rho^x)\int_{\mathring{a}_{j,t+1}}^{\infty} W_{j,t+1}(a_{j,t+1})dF(a_{j,t+1}) + \rho_{j,t+1}U_{j,t+1}\right].$$

Please note, that equation (13) differs from equation (12) in the wages of new workers, only. The wages of new workers, $w_{j,t}^N$, will be different from those of continuing workers, $w_{j,t}(a_{j,t})$ owing to the presence of firing costs that a firm has to bear if it decides to fire a worker. As in the first period no endogenous job destruction takes place, firing costs in this period do not influence the wages of new workers.

2.2. Retail firms

We assume a continuum of monopolistic competitive retailers on the unit interval indexed by i that purchases goods from intermediate goods-producing firms. Each retailer first transforms the intermediate good $YG_{i,t}$ into a differentiated retail good using a linear production technology. During each period $t = 0, 1, 2, \ldots$ a retailer j of sector $j = H, F, N$ sells $Y_{j,t}(i)$ units of the retail goods at the nominal price $P_{j,t}(i)$. Let $Y_{j,t}$ denote the composite of individual retails goods which is described by the CES aggregator of Dixit and Stiglitz (1977):

$$Y_{i,t}^{\alpha} = \left[\int_0^1 Y_t(i)^{(\gamma-1)/\gamma}di\right]^{\gamma/(\gamma-1)}$$

$$Y_{i,t}^{\alpha}O_{i,t}^{1-\alpha} = YG_{,i,t}$$

where ϵ with $\epsilon > 1$ is the elasticity of substitution across the differentiated retail goods. Then, the demand curve facing each retailer i is given by

$$Y_{j,t}(i) = \left[\frac{P_{j,t}(i)}{P_{j,t}}\right]^{-\epsilon}\left[\frac{P_{j,t}}{P_{G,j,t}}\right]Y_{j,t}, \tag{14}$$

where $P_{j,t}$ is the aggregate price index of home-produced or foreign-produced tradable and non-tradable goods and $P_{G,t}$ is the price of the composite of non-oil tradable and oil product.

$$P_{j,t} = \left[\int_0^1 P_{j,t}(i)^{1-\epsilon}dj\right]^{1/(1-\epsilon)}, \tag{15}$$

for all $t = 0, 1, 2, \dots$. As in Calvo (1983), only a randomly and independently chosen fraction $1-\nu$ of the firms in the retail sector are allowed to set their prices optimally, whereas the remaining fraction ν sets their prices by charging the previous period's price adjusted by steady-state inflation. Hence, a retail firm i, which can choose its price in period t, chooses the price $\hat{P}_{j,t}(i)$ to maximize

$$
E_t \sum_{s=0}^{\infty} (\beta\nu)^j \beta_{t,t+s} \left[\left(\frac{\hat{P}_{j,t}(i)}{P_{j,t+s}} \right)^{-\epsilon} Y_{jt+s} \left(\frac{\hat{P}_{j,t}(i)}{P_{j,t+s}} - mc_{j,t+s} \right) \right], \quad (16)
$$

where $\beta_{t,t+s}$ is the stochastic discount factor used by the firms and $mc_{j,t}$ stands for the real marginal costs. The first-order condition for this problem is

$$
\hat{P}_{j,t}(i) = \frac{\epsilon}{(\epsilon-1)} \frac{\sum_{s=0}^{\infty} (\nu\beta)^j E_t(\Lambda_{j,t+s} P_{j,t+s}^{\gamma} Y_{j,t+s} mc_{j,t+s})}{\sum_{s=0}^{\infty} (\nu\beta)^j E_t(\Lambda_{j,t+s} P_{j,t+s}^{\gamma-1} Y_{j,t+s})}. \quad (17)
$$

2.3. The central bank

The central bank conducts monetary policy according to a modified[5] Taylor (1993) rule:

$$
\begin{aligned}
\ln(R_t/\bar{R}) = \quad & \rho_r \ln(R_{t-1}/\bar{R}) + \rho_y \left(\delta \ln(Y_t/\bar{Y}) + (1-\delta) \ln(Y_t^*/\bar{Y}^*) \right), \\
& + \rho_\pi \left(\delta \ln(\pi_{H,t}/\bar{\pi}_H) + (1-\delta) \ln(\pi_{F,t}^*/\bar{\pi}_F^*) \right) + mp_{r_t}
\end{aligned} \quad (18)
$$

where $\bar{R}$, $\bar{Y}$ and $\bar{\pi}_H, \bar{\pi}_F^*$ are the steady-state values of the gross nominal interest rate, output and core CPI gross inflation rate for domestically and foreign-produced goods, and $mp_{r_t} \overset{i.i.d.}{\sim} N(0, \sigma_{r_t}^2)$ is a shock to monetary policy. The coefficient of the degree of interest rate smoothing ρ_r and the reaction coefficients to inflation and output, ρ_π and ρ_y, are positive. The parameter δ denotes the relative steady-state size of the home country vice-versa the foreign country.

2.4. Trade

The real value of net exports is defined using the weighted difference between home production and tradable consumption $NX_t \equiv \frac{P_{H,t}Y_{H,t} - P_{Tt,t}C_{Tt,t}}{P_t}$. Using this definition, we specify total nominal bond holdings B_t according to

$$
\frac{B_t}{P_t} = \frac{R_{t-1}B_{t-1}}{P_t} + NX_t. \quad (19)
$$

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[5]The article of Gerlach and Schnabel (2000) discusses the properties of Taylor rules within a European Monetary Union. They end up at the conclusion that a Taylor rule should be similar to pre-EMU ones. In this paper, our modified Taylor rule for the EMU-area follows this assumption.

We apply the standard incomplete markets model[6] and assume that international financial markets clear $(B_t + B_t^* = 0)$, with B_t^* as nominal holdings of the domestic bond by foreign households, so that the net change of real bond holding reflects the current account $CA_t \equiv \frac{B_t - B_{t-1}}{P_t}$.

Given two sectors in each economy, it is convenient to define a set of relative prices. The relative price of non-tradables to tradables is defined as $X_t \equiv P_{N,t}/P_{T,t}$ and the terms of trade as $\top \equiv P_{F,t}/P_{H,t}$. Using these definitions and their foreign counterparts gives us the expression of the real exchange rate Q_t in terms of the relative price of non-tradables to tradables and the terms of trade

$$Q_t = \left[\frac{\alpha \top^{1-\gamma} + (1-\alpha)}{\alpha + (1-\alpha)\top_t^{1-\gamma}} \right]^{\frac{1}{1-\gamma}} \left(\frac{X_t^*}{X_t} \right)^{1-\iota}. \tag{20}$$

2.5. Domestic equilibrium conditions

In equilibrium, the value of an open vacancy is zero in both sectors. Making use of the vacancy posting condition (31), combined with equations (32) and (38), yields the job creation condition

$$\frac{c_j}{q_j(\theta_{j,t})} = (1-\eta)E_t\beta_{t,t+1}\left[mc_{j,t+1}A_{j,t+1}(a_{j,t+1}^N - \mathring{a}_{j,t+1}) - T_j \right]. \tag{21}$$

Equation (21) states that the expected hiring cost that a firm has to pay must be equal to the expected gain from a filled job. Jobs are destroyed by the firm when the realization of the worker's productivity is below the reservation productivity. The reservation productivity is defined as the value of a_{jt}, which makes the firm's surplus received from a job equal to zero,

$$J_{jt}(\mathring{a}_{j,t}) + T_j = 0. \tag{22}$$

The job destruction condition is derived using equations (33), (37) and (22) and is given by

$$\begin{aligned} mc_{j,t}A_{j,t}\mathring{a}_{j,t} - b_j - \frac{\eta}{(1-\eta)}c\theta_t + (1-\zeta_{jt})T_j &= 0 \\ +E_t\beta_{t,t+1}(1-\rho_j^x)mc_{j,t+1}A_{j,t+1}\int_{\mathring{a}_{j,t+1}}^{\infty}(a_{j,t+1} - \mathring{a}_{j,t+1})dF(a_{j,t+1}) \end{aligned}. \tag{23}$$

with $c_j\theta_{j,t}$ representing the average hiring costs of all firms in either of the two sectors of the economy.

As in Zanetti (2011), the equilibrium average real wage is a weighted average of continuing workers with weight $\omega_{j,t}^C = (1-\rho_{j,t})\frac{n_{j,t-1}}{n_{j,t}}$ while that for new workers is $1 - \omega_{jt}^C$. Therefore, the average real wage is

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[6]There is a wide discussion about the impact of imperfect financial market assumptions in open-economy models. For instance Devereux and Sutherland (2011) discuss the impact of this assumption on monetary policy, while Bodenstein (2011) compares different imperfect market assumptions for open economies.

$$w_{j,t} = \eta \left[mc_{j,t} A_{j,t} \overline{a}_{j,t} + c\theta_t + (\omega_{j,t}^c - \zeta_{j,t})T_j \right] + (1 - \eta_j)b, \tag{24}$$

where $\overline{a}_{j,t} = \omega_{j,t}^C H(\mathring{a}_{j,t}) + (1 - \omega_{j,t}^C)a_{j,t}^N$ is the average idiosyncratic productivity across jobs and $H(\mathring{a}_{j,t}) = E(a_{,j,t}|a_{,j,t} > \mathring{a}_{j,t})$ represents the average productivity for continuing workers. The aggregate output, net of vacancy costs, amounts to

$$y_{j,t} = n_{j,t} A_{j,t} \overline{a}_{j,t} - c_{j,t} v_{j,t}, \tag{25}$$

with $n_{j,t}$ as the number of workers employed in sector j. Non-tradable production must equal demand

$$Y_{N,t} = C_{N,t} \ Y_{N,t}^* = C_{N,t}^*,$$

as must tradable production

$$Y_{H,t} = C_{H,t} + C_{H,t}^*,$$

with $C_{H,t}^*$ as the demand for home tradable goods from abroad. Combining this relation with equation (19) reveals that the foreign trade balance in units of home consumption $Q_t N X_t^*$ must equal the negative home trade balance $N X_t$.

Now we make use of the market clearing condition for home production and include the demand functions for home-produced tradables, the definition of the real exchange rate and the definition of the terms of trade and the relative price of non-tradables to tradables, which yields

$$Y_{H,t} = \alpha \left[\alpha + (1 - \alpha)\top_t^{1-\gamma} \right]^{\frac{\gamma}{1-\gamma}} C_{T,t} + (1 - \alpha) \left[\alpha\top_t^{1-\gamma} + (1 - \alpha) \right]^{\frac{\gamma}{1-\gamma}} C_{T,t}^*. \tag{26}$$

For domestic and foreign non-tradables we get

$$Y_{N,t} = \frac{1 - \iota}{\iota} (X_t)^{-1} C_{T,t} \ Y_{N,t}^* = \frac{1 - \iota_F}{\iota_F} (X_t^*)^{-1} C_{T,t}^*.$$

Given that bond markets clear, we are able to get an expression for net exports in terms of non-tradable to tradable prices and the terms of trade

$$NX_t = (X_t)^{\iota-1} \left\{ \left[\alpha + (1 - \alpha)\top_t^{1-\gamma} \right]^{\frac{1}{1-\gamma}} Y_{H,t} - C_{T,t} \right\}.$$

Furthermore, the current account can be expressed as

$$CA_t = (R_{t-1} - 1)\frac{B_{t-1}}{P_t} + NX_t.$$

Finally, we can express tradable consumption in terms of aggregate consumption for the home and the foreign country

$$C_{T,t} = \iota (X_t)^{1-\iota} C_t \ C_{T,t}^* = \iota (X_t^*)^{1-\iota} C_t^*.$$

In the steady-state equilibrium, the household's bonds and money holdings are $B_t = B_{t+1} = 0$ and $\varrho_t = M_t - M_{t-1}$, which ensures that any seigniorage revenue is rebated to the households. Furthermore, international financial markets must clear, which implies that $B_t + B_t^* = 0$, where B_t^* represents the nominal bond holdings of domestic assets by foreign households.

3. Calibration

Household preferences are characterized by six parameters: the steady-state discount factor, the partial elasticity for tradables and non-tradables, the elasticity of substitution between home and foreign-produced tradables, the home bias and the two elasticities of substitution for varieties of a tradable or non-tradable good. The periods of the model are calibrated to quarters and we assume both countries and both sectors to be symmetrical. Parameters, therefore, are the same if not indicated otherwise. We set the steady-state discount factor to $\beta = .995$ which is in line with the most recent DSGE models of the Eurozone (Poutineau and Vermandel, 2015), and implies an annual steady-state interest rate of 2 percent. For relative risk aversion we choose the standard value of $\sigma = 2$ (Benchimol and Fourcans, 2012) while Smets and Wouters (2003) suggest a smaller value of 1 and Rabanal and Rubio-Ramirez (2005) estimate a posterior mean that implies a significantly higher risk aversion[7] of above 9.

In the literature, we find a variety of definitions distinguishing tradables from non-tradables. We follow Schmillen (2013) who extend a study by Jensen and Kletzer (2012) for the service sectors to assign tradability to NACE sectors. Given this definition, the size of the tradable sector for France is slightly higher than 53 percent of GDP; for Italy, the share is slightly higher than 57 percent and Germany has the highest tradable share at 62 percent. Some southern EMU countries like Greece, however, have much lower tradable shares. We set the tradable share to 55 percent, which in 2012 was the average for EMU countries and use this value to calculate the partial elasticities for the Cobb-Douglas function. We follow Obstfeld and Rogoff (2006) in setting the preference share parameter to $\alpha = 0.7$ and the elasticity of substitution between home and foreign tradables to $\gamma = 2.0$. The first value reflects the fact that Europeans and Americans attach a consumption weight of 70 percent to their own domestic products. The elasticity of substitution between home and foreign tradables is set according to Obstfeld and Rogoff (1995)[8].

We calibrate the labor market of the model to reproduce the structural characteristics of a typical EMU country. The unemployment rate is set to $u = 9.5$ percent, which is the long-term average among EMU countries. According to Hobijn and Sahin (2007), the quarterly separation rates are 6 percent for

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[7]We tested those values in a sensitivity analysis but the impact on current account imbalances and foreign debt was neglectable.

[8]Obstfeld and Rogoff (2000) and Obstfeld and Rogoff (2006) discuss the issue of an estimation bias using aggregate trade data which results in a lower than unity elasticity of substitution .

Spain and between 3 and 4 percent for France and Germany[9]. Given that the data reflects the period of the Great Moderation and that separations seem to have increased during the crisis, we set the total separation rate to $\rho = 0.05$, which is in the upper range of estimates. Unfortunately, the data does not contain information on the share of the endogenous and exogenous separation in the total separation rate, which, therefore, has to be calibrated using the job creation and job destruction function. The reservation productivity threshold of $\mathring{a} = 1.8$ is calculated at the steady-state intersection of the job destruction and job creation curve. We follow den Haan, Wouter J., Ramey, and Watson (2000) in assuming the idiosyncratic productivity to be log-normally distributed. As Germany is the biggest country in the Eurozone, we mimic the wage distribution of this country, which we have calculated using SOEP data. The mean of $F(.)$, therefore, is calibrated at $\mu_{ln} = 2.54$ and the value of its standard deviation equal to $\sigma_{ln} = 0.48$. We, furthermore, assume that the productivity of new matches is always in the $0.95th$ percentile of $F(.)$ and therefore always above the threshold productivity $a^n > \mathring{a}$, which implies that new matches never separate. Matching efficiency[10] differs to a great extent in the Eurozone. Countries like France, Spain, and Italy had a high matching efficiency in the past where estimates range between $\chi = 0.6$ and $\chi = 0.8$ (Ibourk, 2004; Destefanis and Fonseca, 2007; Ahamdanech-Zarco, Bishop, Grodner, and Liu, 2009). Germany is perceived to have a low efficiency, calibrated between $\chi = 0.2$ and $\chi = 0.3$ (Jung and Kuhn, 2014; Krause and Uhlig, 2012). Recently, efficiency has tended to increase in Germany (Fahr and Sunde, 2009; Hillmann, 2009) but shrunk in the other countries mentioned (Arpaia, Kiss, and Turrini, 2014). We, therefore, follow Lubik and Krause (2014) and set the matching efficiency[11] to $\chi = 0.5$, which is in line with the long-term unemployment level of the Eurozone.

The elasticity of a match w.r.t. unemployment is calibrated to $\xi = .7$, which reflects estimates by Burda and Wyplosz (1994) for Germany and France, Kohlbrecher, Merkl, and Nordmeier (2013) for Germany and Broersma (1997) for the Netherlands and is in line with the studies surveyed in Petrongolo and Pissarides (2001). As is standard in the literature, the Nash bargaining coefficient

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[9]The value for Germany is extremely close to $\rho = 0.03$, the separation rate calculated by Kohlbrecher, Merkl, and Nordmeier (2013) using German administrative data.

[10]The matching efficiency in the Eurozone is perceived to be lower than that of the United States (Jung and Kuhn, 2014). Lubik (2013) estimated the Beveridge curve for the US using data from 2000 to 2008. The point estimate for the matching efficiency is $m = 0.8$ which is significantly lower than the matching efficiency we set for the Eurozone. Most studies like Jung and Kuhn calibrate the US matching efficiency lower between 0.5 and 0.6.

[11]We also run the model with a significant lower matching efficiency of 0.23 following Jung and Kuhn (2014). The volatility of total vacancies and unemployment is too low in this specification, so that we returned to the standard specification. We could improve the buisness cylce statistics by setting the bargaining power according to Hagedorn and Manovskii (2008). If we, however, run the model with the standard matching efficiency and the Hagedon-Manovskii specification, the business cycle statistics better matched the data (Business cycle properties for this calibration are available in an online supplement). We did not use this specification as it was inconsistent with the long-term unemployment rate of EU-countries and the distribution of wages.

used in the wage-setting equation is set to $\eta = 0.5$, such that workers and firms have the same bargaining power[12]. The vacancy posting costs in the baseline scenario $c = 5.2$ and the unemployment benefits b are inferred from the steady-state job destruction and job creation conditions. The parameter measuring leisure is calibrated to $h = 0.3$ so that the income from not working (b and h) is worth 77 percent of w. Firing costs T are set to 67 percent, which is calculated as the EMU average using the World Development Indicators (WDI) database, while the replacement rate is 60 percent of the mean wage. This is in line with the study by van Vliet, Been, Caminada, and Goudswaard (2012) which calculates a replacement rate of between 50 and 60 percent for most EU-countries. The core countries of the Eurozone have values above 60 percent while Malta and members of the Eastern enlargement round have lower values (30 to 40 percent).

As is common in the literature, the parameter measuring the market power of retailer is set to $\varepsilon = 11$. This implies a markup over marginal costs of 10 percent and reflects empirical findings. The Calvo parameter that governs the frequency of price adjustments is following Taylor and Woodford (1999) set to $\nu = 0.75$ such that the average binding of prices is 4 quarters. As is common, we normalize steady-state inflation to unity. The Taylor rule is calibrated following Taylor and Woodford (1999), and implies a monetary policy response to inflation equal to $\rho_\pi = 1.5$, a response to a change in output of $\rho_y = .5$ and a degree of interest rate smoothing of $\rho_r = .32$.

Finally, we specify the shock processes. In line with most of the literature, we calibrate the productivity shock such that the baseline model replicates the standard deviation of output in the Eurozone, which on average is 1.64. The standard deviation of the shock in either of the two sectors consequently amounts to $\sigma_a = 0.0087$, while the shock persistence parameter is $\rho_a = 0.94$. From Crespo-Cuaresma and Fernandez-Amador (2013) it follows that the standard deviation of time preference[13] shocks should be roughly similar to that of supply shocks from 1990 onward, while supply shocks had twice the standard deviation of time preference shocks in the 1960s. We set the standard deviation of the time preference shock to $\sigma_a = 0.013$ and the shock persistence parameter to $\rho_a = 0.94$ reflecting the importance of time preference shocks[14] for the Eurozone (Wyplosz, 2013). We follow the findings of Uhlig (2005) that monetary policy shocks contribute to less than 10 percent of the volatility of output in setting the standard deviation of the monetary policy shock to $\sigma_a = 0.0016$ with a persistence of $\rho_a = 0.25$. The matching efficiency shocks are assumed to have a standard deviation of $\sigma_a = 0.0016$ and a persistence of $\rho_a = 0.25$. These values are in-line with those of estimated DSGE models of the Eurozone (Smets and Wouters, 2003; Ratto, Roeger, and Veld, 2009).

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[12]A low bargaining power of workers specification following Hagedorn and Manovskii (2008) can be found in the online supplement to this paper (Table 1)

[13]Time preference shocks affect the intertemporal marginal rate of substitution on consumption, they are also referred to as demand shocks.

[14]We also account for asymmetric time preference shocks but, in difference to Wyplosz, assume the same standard deviation of shocks.

4. Results

In this section, we show the impact of two shocks on the current account and the foreign debt of the foreign country, oil price shocks and oil supply shocks. Oil prices in our model have two components, an endogenous component adjusting prices to market conditions and a stochastic part that let the oil price deviate from its fundamental value. The reasons for this deviation can be manifold including expectations, imperfect financial markets, and third country effects. In the oil price shock scenario, the shock affects the stochastic component of the oil price while oil supply remains stable. There is, of course, a reaction of the fundamental value as sectors of the economy adjust, but this response is rather small. The second shock is a positive oil supply shock. With this shock, households and firms have more oil available that is needed for consumption purposes and the production of non-oil goods. We see a reaction of the fundamental component of the oil price but no response of the stochastic component. Compared to previous papers, the impact of oil price shocks and oil supply shocks on the current account is more persistent as we included imperfect labor markets. In the figures in appendix (7.4), it can be easily seen that labor market flexibility reduces imbalances within the currency union with both of the two shocks[15].

4.0.1. Increasing Oil prices

In Figures 1, 2 and 3, we have visualized the response of the model to a positive oil price shock of one standard deviation. On impact, output in both sectors decreases, while prices of non tradable goods decline (Figure 1). Households have to pay more for oil products so that they spend relatively less on non-oil products. The decrease in demand lowers prices of non-oil products even that oil input prices increase. As oil is more important in tradable production, costs of tradable commodities increase more than costs of non-tradables. This has the immediate effect that we have a downward pressure on interest on physical capital, labor demand and wages. A fall in the productivity of workers decreases the value of a match, the threshold idiosyncratic productivity increases (Figure 3) and workers who would otherwise have remain employed are now fired. Firms stop hiring unemployed workers, as the value of an open position falls. Vacancies, therefore, experience a sharp drop in the tradable and a lesser drop in the non-tradable sector. Endogenous separations also increase, as less productive workers were set off. In sum, tradable and non-tradable sectors produce less and reduce employment by posting fewer vacancies and releasing less-productive workers.

The decrease in vacancies and the increase in exogenous separations reduces employment and increases unemployment. Owing to price rigidities, not all firms are able to adjust prices in the first period so that the response of prices to the

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[15]Recently, the impact of the labor market for current account imbalances finds more attention. Baas and Belke (2014) discuss the impact of labor market reforms for the absorption of a variety of shocks. They find that countries that reformed labor markets and increased flexibility, in sum, reduced their imbalances.

shock is spread out over time. Therefore, we see a gradual increase in tradable prices relative to non-tradables, as tradable companies suffer more from higher input prices. Tradable prices get higher and consumer substitute non-tradable goods for tradables. As demand increases, firms in the non-tradable sector increase hiring and reduce endogenous separations. The non-tradable sector produces more goods and can overcompensate the negative impact of the oil price shock after a few quarters.

The increase in tradable prices also reduces foreign demand for domestic tradable goods. As foreign tradable goods, by assumption, are more scarce, they have a higher relative price compared to home tradables, that change relatively less to an oil price shock. Households in home and foreign now substitute home tradables for foreign tradables, which results in a depreciation of the real exchange rate of the home country. In foreign, production of tradable and non-tradables increases, firms hire more workers and fire less. However, this comes at a cost for the non-tradable sector that sees rising labor costs and reduces output shortly after the shock. The current account of the home country turns into deficit, and the foreign debt of the foreign country is diminished.

Figure 1 on page 28 and Figure 2 on page 29 about here

In our model, wages are bargained in the second stage of a two-stage process. In the first stage, workers and firms decide whether to match or not, in the second stage, the individual wages are negotiated according to, inter alia, the idiosyncratic productivity. The impact of the shock on average wages is not apparent. As total factor productivity decreases, there is a negative stimulus on the average wage. The average idiosyncratic productivity, however, increases with falling endogenous separations, serving as a positive stimulus. In the first periods after the shock, wages increase as job separations and average idiosyncratic productivity rise sharply, overcompensating for the decrease in total factor productivity. Shortly after that, less new workers are hired, which reduces average idiosyncratic productivity and, therefore, average wages (Figure 3).[16]

4.0.2. Oil price shocks and monetary policy

In this section, we discuss the possibilities of the central bank to reduce current account imbalances caused by oil price shocks. To describe the monetary policy of the central bank, we use a Taylor rule. In the economic literature, different price indices are used, CPI, core CPI and GDP deflator. While it is widely agreed that targeting the GDP deflator is an inferior monetary policy strategy in the wake of oil price shocks (Pierdzioch and Kamps, 2002), we use the former two. With regard to current account imbalances, targeting CPI

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[16]Please note that we assumed that the productivity of new workers is solidly above average in the first period to avoid immediate separations.

is the superior strategy as the current account deficit is smaller than in the case where the central bank targets core CPI. This, however, comes at a cost. Unemployment is higher and more persistent as in the core CPI case, while prices of non-oil goods fall stronger and prevent firms from hiring in the non-tradable sector. Employment in the tradable sector, however, is more stable.

If the central bank assigns different weights to the member countries of the currency union, this increases current account imbalances compared to core CPI. Labor markets, however, are more stable if the exporting country has a higher weight and unemployment increases less compared to the core CPI target. In any way, targeting CPI core inflation and assigning different weights to currency union members is superior to the CPI inflation target.

4.0.3. Increasing Oil supply

In the previous section, we showed that an oil price shock that does not affect supply worsens the current account of the country with a higher share of export goods. Now, we visualize the impact of an oil supply shock (figures 3 and 4). Oil is consumed by households and needed for the production of tradable and non-tradable goods. For non-tradable production, however, relatively less oil is used. In sum, increasing oil supply enhances production possibilities. As the demand of the tradable sector for oil is higher, it profits more than proportionally from an increase in supply. The increase in production, nevertheless, depends on the availability of workers. Both, tradable and non-tradable firms start hiring, but, as labor is more productive there, the tradable companies can pay higher wages. Again, we see an increase in average productivity that is accompanied by a decrease in idiosyncratic productivity. Rising labor demand reduces endogenous separations so that more workers with a low idiosyncratic productivity are in the market. Wages, therefore, could decline as idiosyncratic productivity is lower or they could increase, as average productivity is higher. In our example, wages increase, and households have higher earnings.

Figure 3 on page 27 and Figure 4 on page 30 about here

In sum, tradable firms attract more workers, so that employment in the non-tradable sector is reduced. Because of labor market rigidities, this process is time-consuming. In the first periods after an oil supply shock output of the non-tradable sector increases. However, a higher tradable labor demand makes non-tradable firms to hire less workers. Relative home tradable prices are now lower than foreign tradable or non-tradable good prices so that households demand more home tradable goods resulting in a current account surplus.

As more tradable goods are available, prices have to fall to let supply meet demand. Households then shift demand to home tradable goods and reduce consumption of non-tradables. The current account of the home country is in surplus and the foreign debt of the foreign country increases.

4.0.4. Oil supply shocks and monetary policy

With oil price shocks, a core CPI inflation target was the superior monetary policy strategy. With regard to oil supply shocks, a core CPI target is also superior to a CPI inflation target. The current account surplus of the home country is lower than with a CPI target scenario. Concerning weights, however, it would be beneficial to attribute a higher weight for the bigger exporter. This reduces current account imbalances, fluctuations in unemployment and vacancies. Regarding a stable production, however, a core CPI inflation target is beneficial. Tradable and non-tradable production react less in this setting even that fluctuations in prices of non-oil products are higher than with an asymmetric target.

5. Conclusion

Current account imbalances are at the core of the government debt crises in Europe and represent crucial issues in the international policy debate. In this paper, we analyzed the impact of oil price shocks and oil supply shocks on the current account and discussed monetary policy strategies to reduce imbalances. According to our model, the reduction of oil price since 2016 could widen current account imbalances in the Eurozone. By including search and matching labor markets, we show that the imbalances can be quite persistent, as the labor market reacts sluggishly to changes in relative prices. In such a setting, the central bank can target core CPI, a CPI index without prices of oil products, to balance current accounts. This, however, comes at the cost of higher unemployment. In the wake of oil price shocks targeting core CPI is the superior monetary strategy. With oil supply shocks, an asymmetric monetary policy target attaching more weight for the leading exporter seems to be superior regarding for reducing current account imbalances. Additionally, fluctuations in unemployment are lower and prices of non-oil goods more stable than in the symmetric core CPI case, as the central bank adopts a more contractionary monetary policy that reduces the boom triggered by additional oil supply. The costs of this strategy, nevertheless, are higher fluctuations in tradable and non-tradable production.

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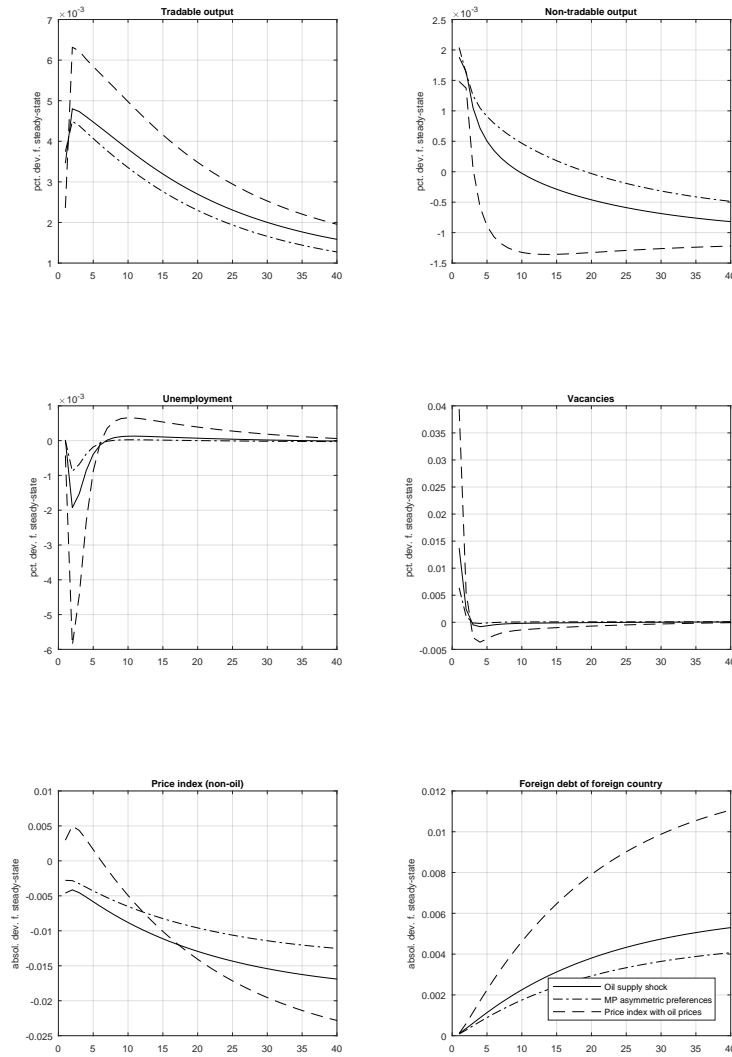
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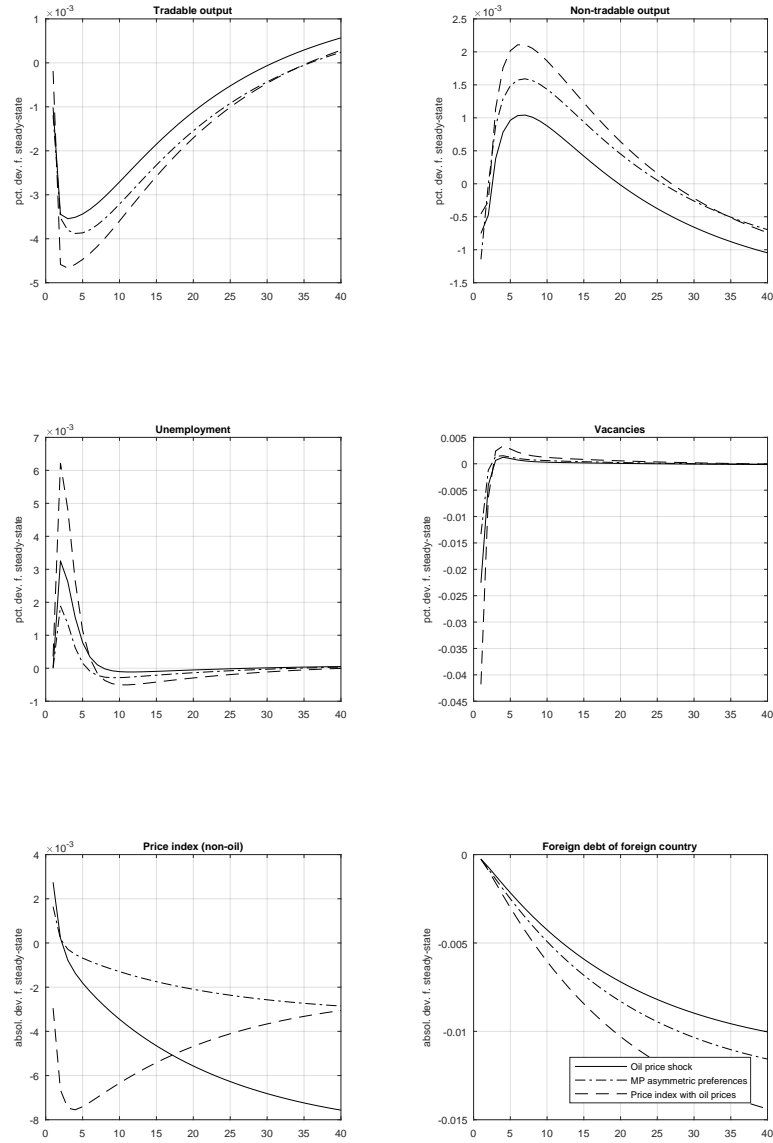
6. Tables and Graphs

Figure 3: Positive oil supply shock

Impulse response functions
Notes: Each panel shows the response of the model variables to an oil supply
shock of one standard deviation. The horizontal axes measure time, expressed
in quarters.

Figure 1: Positive oil price shock

Impulse response functions
Notes: Each panel shows the response of the model variables to an oil price
shock of one standard deviation. The horizontal axes measure time, expressed
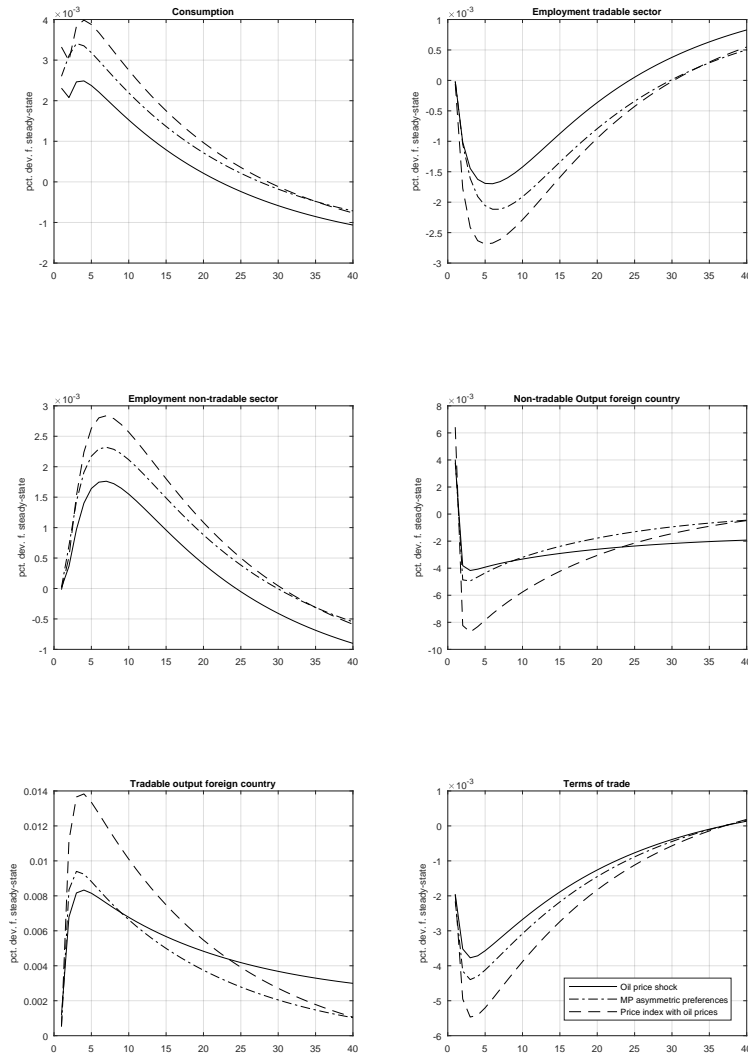in quarters.

Figure 2: Positive oil price shock

Impulse response functions
Notes: Each panel shows the response of the model variables to an oil price
shock of one standard deviation. The horizontal axes measure time, expressed
in quarters.

Figure 4: Positive oil supply shock

Impulse response functions
Notes: Each panel shows the response of the model variables to an oil supply
shock of one standard deviation. The horizontal axes measure time, expressed
in quarters.

7. Appendix (not for publication)

7.1. The labor market

During each period $t = 0, 1, 2, \dots$, an intermediate goods-producing firm
posts a vacancy or continues the match from the previous period. Each single
job has the status filled or vacant. Because of matching frictions, it is assumed
that the process of job search and hiring is time-consuming and costly for both
the worker and the firm. If a firm finds a suitable worker, both form a match.
The number of job matches depends on the matching function $m_{j,t}(u_{j,t}, v_{j,t})$,

where $v_{j,t}$ denotes the number of vacancies in both sectors of the economy, home-produced tradable and non-tradable goods $j = H, N$, and $u_{j,t}$ is the number of unemployed workers searching in sector j. We assume a Cobb-Douglas matching function, where ξ denotes the partial elasticities

$$m_{j,t}(u_{j,t}, v_{j,t}) = \chi u_{j,t}^{\xi} v_{j,t}^{1-\xi}, \tag{27}$$

$0 < \xi < 1$ and χ is a scale parameter reflecting the efficiency of the matching process. Defining labor market tightness as $\theta_{jt} = v_{j,t}/u_{j,t}$ and making use of the CRS property of $m_{j,t}$, we write the job-finding probability in sector j for an unemployed worker as

$$p(\theta_{j,t}) = m_{j,t}(u_{j,t}, v_{j,t})/u_{j,t} = \chi \theta_{j,t}^{1-\xi}, \tag{28}$$

and the probability that a searching firm in this sector will find a worker as

$$q(\theta_{j,t}) = m_{j,t}(u_{j,t}, v_{j,t})/v_{j,t} = \chi \theta_{j,t}^{-\xi}. \tag{29}$$

The tighter the labor market, the easier it is for unemployed workers to find a job. Equation (29) implies that the higher the number of vacancies v_{jt} for a given number of unemployed workers searching in this sector, $u_{j,t}$, the more difficult it is for firms to fill vacant positions.

At the beginning of any period t, job separations take place as a result of an exogenous negative shock with probability ρ_j^x. Firm and worker may decide to dissolve a match endogenously if the realization of the worker's idiosyncratic productivity of $a_{j,t}$ is below a certain threshold productivity $\mathring{a}_{j,t}$. The probability of endogenous job destruction is given by $\rho_{j,t}^n = P(a_{j,t} < \mathring{a}_{j,t}) = F(\mathring{a}_{j,t})$. The total job separation rate, therefore, is $\rho_{j,t} = \rho_j^x + (1 - \rho_j^x)\rho_{j,t}^n$. As in den Haan, Wouter J., Ramey, and Watson (2000), the idiosyncratic productivity $a_{j,t}$ is drawn from a log-normal distribution with mean μ_{ln} and standard deviation σ_{ln}.

Following Mortensen and Pissarides (1994), new matches have a productivity of $a_{j,t}^N$, which ensures that their productivity is always above the productivity threshold $\mathring{a}_{j,t}$, and that all jobs produce before being destroyed. New matches in t, $m_{j,t}$, become productive for the first time in $t+1$. Consequently, the employment in each sector evolves according to $n_{j,t} = (1 - \rho_{j,t})n_{j,t-1} + m_{j,t-1}(u_{j,t-1}, v_{j,t-1})$. As we normalize total employment to unity, the sum of unemployed persons becomes $u_t = (1 - n_{H,t} - n_{N,t})$.

The representative intermediate goods-producing firm

If an intermediate goods-producing firms posts a vacancy, it bears costs c_j. Labor is the only input in the production function. At the beginning of each period, old and new matches draw an idiosyncratic, job-specific productivity $a_{j,t}$. Production in each sector is subject to a productivity shock, common to all firms. If the realization of a worker's idiosyncratic productivity is above the reservation productivity $\mathring{a}_{j,t}$, the firms will produce output using labor. The total factor productivity $A_{j,t}$ follows an AR(1) process, $\ln(A_{j,t}) = \rho_{Aj} \ln(A_{j,t-1}) + \epsilon_{Aj}$,

where ρ_{Aj} is the serial correlation coefficient with $0 < \rho_{Aj} < 1$ and ϵ_{Aj} follows a white noise process with standard deviation σ_{Aj}.

We define the present discounted value of expected profits from a vacant job as follows:

$$V_{j,t} = -c_j + E_t\beta_{t,t+1}\left[q_j(\theta_{j,t})J^N_{j,t+1} + (1 - q_j(\theta_{j,t}))V_{j,t+1}\right]. \tag{30}$$

With a probability of $q_j(\theta_{j,t})$, the firms matches with a worker and the match yields a return of $J^N_{j,t+1}$. With a probability of $1 - q_j(\theta_{j,t})$, the job remains vacant with a return of $V_{j,t+1}$. As long as the value of a vacancy is greater than zero, a firm will post new vacancies. In equilibrium, free market entry drives the profit from opening a vacancy to zero, which implies $V_{j,t} = 0$ for any t. This yields the vacancy posting condition

$$\frac{c_j}{q_j(\theta_{j,t})} = E_t\beta_{t,t+1}J^N_{j,t+1}, \tag{31}$$

which states that the expected cost of hiring a worker, $c_j/q_j(\theta_{j,t})$, is equal to the expected profit generated by a new match.

The value of a newly hired worker enjoyed by a firm, therefore, is given by

$$J^N_{j,t} = \quad mc_{j,t}\frac{P_{j,t}}{P_t}A_{j,t}a^N_{j,t} - w^N_{j,t}$$
$$+E_t\beta_{t,t+1}(1 - \rho^x_j)\left[\int_{\mathring{a}_{j,t+1}}^{\infty} J_{j,t+1}(a_{j,t+1})dF_j(a_{j,t+1}) - F_j(\mathring{a}_{j,t+1})T_j\right], \tag{32}$$

where $mc_{j,t}$ denotes the sector-specific real marginal costs of providing one additional unit of output. We distinguish between endogenous and exogenous separations. With probability $1 - \rho^x_j$, the worker survives exogenous job destruction. For a surviving match, a realization of the idiosyncratic productivity below the critical threshold $\mathring{a}_{j,t+1}$ leads to endogenous separation and the firm incurs firing costs T_j.

Similarly, the present discount value of a continuing job with productivity $a_{j,t}$ to the employer is

$$J_{j,t}(a_{j,t}) = \quad mc_{j,t}\frac{P_{j,t}}{P_t}A_{j,t}a_{j,t} - w_{j,t}(a_{j,t}) \tag{33}$$
$$+E_t\beta_{t,t+1}(1 - \rho^x_j)$$
$$\cdot\left[\int_{\mathring{a}_{j,t+1}}^{\infty} J_{j,t+1}(a_{j,t+1})dF_j(a_{j,t+1}) - F_j(\mathring{a}_{j,t+1})T_j\right]$$

In equations (32) and (33) the term $mc_{j,t}\frac{P_{j,t}}{P_t}A_{j,t}a_{j,t} - w_{j,t}(a_{j,t})$ represents the net return of a match, and $J_{j,t+1} - F_j(\mathring{a}_{j,t+1})T_j$ represents the present discounted firm surplus, if the match is not destroyed.

In this model, an expression for the real marginal cost $mc_{j,t}$ can be derived by using equation (12) and the condition that a firm is indifferent between continuing a match and separating from the worker, $J_{j,t}(a^{\circ}_{j,t}) + T_j = 0$ (Mortensen and Pissarides, 2003). Combining these two equations and solving for $mc_{j,t}$, we obtain:

$$mc_{j,t} = \frac{P_t}{P_{j,t}A_{j,t}\mathring{a}_{j,t}}$$

$$\left(\begin{array}{c} w_{j,t}(\mathring{a}_{j,t}) - T_j \\ -E_t\beta_{t,t+1}(1-\rho^x)\left[\begin{array}{c} \int_{\mathring{a}_{j,t+1}}^{\infty} J_{j,t+1}(a_{j,t+1})dF_j(a_{j,t+1}) \\ -F_j(\mathring{a}_{j,t+1})T_j \end{array} \right] \end{array} \right) \qquad (34)$$

From equation (34), it can be seen that real marginal costs amount to the wage minus the the firing costs and the expected future return generated by the match, weighted by the marginal product of labor. As pointed out by Trigari (2009), the real marginal costs are, in the presence of search and matching frictions, not equal to the wage divided by the marginal product of labor. Instead, they also depend on the expected present-discounted payoff of preserving a match, which internalizes the firing costs.

Wage bargaining

In each period, firms and workers bargain over the real wage for that period, regardless of whether they form a continuing or a new match. The wage is set according to Nash bargaining. The worker and the firm share the joint surplus and the worker receives the fraction $\eta \in [0,1]$. Since the wage depends on the idiosyncratic productivity of the worker, the wage bargaining rules for continuing and new matches are given by

$$\eta(J_{j,t}(a_{j,t}) + T_j) = (1-\eta)(W_{j,t}(a_{j,t}) - U_t), \qquad (35)$$

and

$$\eta J_{j,t}^N(a_{j,t}) = (1-\eta)(W_{j,t}^N - U_t), \qquad (36)$$

respectively. The bargaining rule for continuing workers, represented by equation (35), internalizes firing costs T_j, whereas new workers are not subject to firing costs because in the period they are hired their idiosyncratic productivity a_{jt}^N is assumed to be above the critical threshold $\mathring{a}_{jt}$.

We can now derive the wage for continuing workers using the Bellman equations (10)-(13), (15)-(16) and the bargaining rules for continuing and new matches, equation (17) and (18)

$$w_{j,t}(a_{j,t}) = \eta \left[mc_{j,t}\frac{P_{j,t}}{P_t}A_{j,t}a_{j,t} + c_j\theta_{j,t} + (1-\zeta_{j,t})T_j \right] + (1-\eta)b. \qquad (37)$$

The agreed wage for new workers is equal to

$$w_{jt}^N = \eta \left[mc_{j,t}\frac{P_{j,t}}{P_t}A_{j,t}a_{j,t}^N + c_j\theta_{j,t} - \zeta_{j,t}T_j \right] + (1-\eta)b, \qquad (38)$$

where $\zeta_{j,t} = E_t\beta_{t,t+1}(1-\rho_j^x)$.

The wages that new and continuing workers receive consist of two elements. First, if firms have complete bargaining power, the bargained wage will equal

the benefits from unemployment b, which includes unemployment insurance payments and welfare captured by the replacement rate as well as the utility derived from not working. Second, if workers have complete market power, the wage will be the match revenue $mc_{j,t}\frac{P_{j,t}}{P_t}A_{j,t}a_{j,t}$, plus the saved hiring costs, $c_j\theta_{j,t}$, minus the present discounted firing costs, $\zeta_{j,t}T_j$, and plus the savings on firing costs[17], T_j, in the case of continuing workers. In cases where the bargaining power of firms and workers is between these two extremes, the bargaining power of workers η attaches weight to the two elements. It follows from equation (38) that the wage of new workers differs from those of continuing workers as they do not include firing costs related to endogenous job separations in the initial period.

7.2. The log-linearized model

We now derive the log-linear equations for the domestic economy. A symmetric set of equations specifies the economy of the foreign country. The log-linearized version of the model is derived through a first-order Taylor approximation, while variables with a tilde denote the log-deviations from a deterministic steady-state. From the household's utility maximization, we can derive a log-linearized Euler equation

$$\tilde{c}_t = E_t\left\{\tilde{c}_{t+1}\right\} - \left(\tilde{r}_t - E_t\left\{\tilde{\pi}_{t+1}\right\} - \hat{\beta}_t\right),$$

and money demand from equation (9)

$$\tilde{m}_{Ht} - \tilde{p}_t = \sigma_m\tilde{y}_t + \left(\frac{1 - \bar{\triangle}}{\bar{\triangle}}\right)\sigma_m\left(\hat{r}_t - \hat{r}_t^m\right),$$

where $\hat{\beta}_t$ denotes the log of the endogenous time-discount rate, $\tilde{\pi}_t \equiv \tilde{p}_t - \tilde{p}_{t-1}$ represents the log CPI inflation and the log differential in interest rates on assets and money is given by $\bar{\triangle} = 1 - \beta\left(1 - \bar{r}^m\right)$. The price of a consumption good bundle $\tilde{p}_t$ consists of prices for home-produced goods $\tilde{p}_{Ht}$ and goods produced in the rest of the currency union $\tilde{p}_{F,t}$. The log interest rate differential is given by $\hat{r}_t^m = \log\left(1 + \hat{r}_t^m/1 + \bar{r}^m\right)$, with $\bar{r}^m$ being the steady-state zero inflation interest rate.

The endogenous discount factor depends negatively on consumption according to

$$\hat{\beta}_t = \varsigma_t - \psi\beta\tilde{c}_t,$$

where ς_t denotes an exogenous shock to the discount factor that obeys an autoregressive process. We, nevertheless, assume that ψ is small so that the effect is negligible on medium-term dynamics.

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[17]Firing costs are assumed to affect endogenous separations, only. They do not occur for new workers in the first period, as the idiosyncratic productivity for those is per assumption above the threshold level.

The demand of home tradables depends on the non-tradable to tradable price relation and on the terms of trade

$$\tilde{y}_{H,t} = \alpha(1-\alpha)\gamma\tilde{\tau}_t\Phi_1 + (1-\eta)\left[\alpha\tilde{x}_t\bar{\tau}^{\gamma-1} + (1-\alpha)\tilde{x}_t^*\bar{\tau}\right] + \alpha\tilde{c}_t\bar{\tau}^{\gamma-1} + (1-\alpha)\tilde{c}_t^*\bar{\tau}.$$

with $\Phi_1 \equiv \frac{1+\bar{\tau}^2}{\alpha+(1-\alpha)\bar{\tau}^{(1-\gamma)}}$. To derive this equation, we used the tradables consumption to aggregate consumption relation and equation (26). We derive the demand for non-tradables using the market clearing condition and the relation of non-tradables to aggregate consumption, which also depends on the non-tradables to tradables price relation

$$\tilde{y}_{N,t} = -\gamma\tilde{x}_t + \tilde{c}_t.$$

We now relate the terms of trade and the non-tradable to tradable price relation to CPI inflation and home prices for both domestic as well as foreign-produced tradable goods

$$\tilde{\tau}_t = \tilde{\tau}_{t-1} + (\triangle\tilde{q}_t + \pi_{\tilde{F},t}^* - \tilde{\pi}_t) - (\tilde{\pi}_{H,t} - \tilde{\pi}_t),$$

$$\tilde{x}_t = \tilde{x}_{t-1} + \tilde{\pi}_{Nt} - \tilde{\pi}_{H,t} - \eta(1-\alpha)\triangle\tilde{\tau}_t.$$

The price of domestically produced goods, nevertheless, is subject to labor market imperfections. If we now log-linearize equation (17) around the steady-state, we can derive two New Keynesian Philips Curves

$$\tilde{\pi}_{H,t} = \beta E_t\tilde{\pi}_{H,t+1} + \frac{(1-\nu)(1-\nu\beta)}{\nu}\tilde{mc}_{T,t}, \qquad (39)$$

$$\tilde{\pi}_{N,t} = \beta E_t\tilde{\pi}_{N,t+1} + \frac{(1-\nu)(1-\nu\beta)}{\nu}\tilde{mc}_{N,t}.$$

where $\tilde{mc}_{j,t}$ is defined as the log-deviation of marginal costs from their steady-state value μ. Marginal costs $\tilde{mc}_{j,t}$ are derived using a log-linear first-order approximation of Equation (23). In general, CPI depends on home and foreign prices as well as the terms of trade

$$\tilde{\pi}_t = \mu\tilde{\pi}_{H,t} + (1-\mu)\tilde{\pi}_{N,t} + \mu(1-\alpha)\triangle\tilde{\tau}_t.$$

Net exports depend on the difference of time-varying discount factors, the terms of trade and expected future net exports

$$\tilde{nx}_t = \frac{\bar{P}_F\bar{C}_F}{(1-\alpha)\bar{C}}\left[(1-\alpha)\hat{\beta}_{R,t} - 2\alpha(1-\alpha)(\mu-1)E_t\triangle\tilde{\tau}_{t+1}\right] + E_t\tilde{nx}_{t+1}.$$

Net indebtedness evolves from previous trade imbalances and net exports in the current period

$$\tilde{b}_t = \frac{1}{\beta}\tilde{b}_{t-1} + \tilde{n}\tilde{x}_t.$$

Given the indebtedness of the economy, we can express the current account as

$$\tilde{ca}_t = \tilde{b}_t - \frac{1}{1+g}\tilde{b}_{t-1},$$

with ca_t denoting the current account normalized by steady-state growth.

From the labor market equilibrium, we get the log-linear average real wage per sector

$$\tilde{w}_{j,t} = \frac{1}{\bar{w}_j}\left[\begin{array}{c}\eta \bar{mc}_j\bar{A}_j\frac{\bar{P}_j}{\bar{P}}\bar{a}_j\left(\tilde{mc}_{j,t}+\tilde{p}_{j,t}-\tilde{p}_t+\tilde{A}_{j,t}+\tilde{a}_{j,t}\right)\\+c\bar{\theta}\tilde{\theta}_t+\tilde{T}_j\left((1-\tilde{\rho}_t)\left(\tilde{n}_t-\tilde{n}_{t-1}\right)-\tilde{\rho}_t\bar{\rho}_t-\beta(1-\rho^x)\sigma E_t\left(\tilde{y}_{j,t}-\tilde{y}_{j,t-1}\right)\right)\end{array}\right]$$

with the job creation condition

$$\tilde{\theta}_{j,t} = \frac{1}{\xi}\left[(1-\eta)\beta \bar{mc}_j(\bar{a}_j^N-\mathring{\bar{a}}_j)\left(\frac{\chi_j}{c_j\bar{\theta}_j^\xi}\right)E_t\Omega_1 + \sigma E_t\left(\tilde{y}_{j,t}-\tilde{y}_{j,t-1}\right)\right],\cdot$$

$$\Omega_1 = \left(\tilde{mc}_{jt+1}+p_{j,t}-p_t+\tilde{A}_{jt+1}-\frac{\bar{a}_i}{\bar{a}_j^N-\mathring{\bar{a}}_j}\mathring{a}_{jt+1}\right)$$

and the job destruction condition

$$\tilde{\theta}_{j,t} = \left(\frac{1-\eta}{\eta c\bar{\theta}}\right)\left[\bar{mc}_j\bar{A}_j\frac{\bar{P}_j}{\bar{P}}\Omega_2 + \beta(1-\rho^x)\tilde{T}_j\sigma E_t\left(\tilde{y}_{j,t}-\tilde{y}_{j,t-1}\right)\right],$$

$$\Omega_2 = \left\{\begin{array}{c}\mathring{\bar{a}}_j\left(\tilde{mc}_{j,t}+p_{j,t}-p_t+\tilde{A}_{j,t}+\mathring{a}_{j,t}\right)+\beta(1-\rho^x)\left(H(\mathring{\bar{a}}_j)-\mathring{\bar{a}}_j\right)\\E_t\left(\sigma E_t\left(\tilde{y}_{j,t}-\tilde{y}_{j,t-1}\right)+\tilde{mc}_{j,t+1}+\tilde{A}_{j,t+1}+\frac{\mathring{\bar{a}}_j}{H(\mathring{\bar{a}}_j)-\mathring{\bar{a}}_j}\mathring{a}_{j,t+1}\right)\end{array}\right\}$$

In our model, we assumed a currency union with a common monetary policy. In this case, the central bank targets inflation and output stability for the whole currency union

$$\tilde{r}_t = \rho_r\tilde{r}_{t-1} + \rho_y\left[\delta\tilde{y}_t^* + (1-\delta)\tilde{y}_t\right] + \rho_\pi\left(\delta\tilde{\pi}_t^* + (1-\delta)\tilde{\pi}_t\right) + \epsilon_{r_t}, \qquad (40)$$

where δ attaches weights to the importance of the economy in the monetary policy function and $\epsilon_{r_t} \overset{i.i.d.}{\sim} N(0,\sigma_{r_t}^2)$ is a shock to monetary policy. The degree of interest rate smoothing ρ_r and the reaction coefficients to inflation and output, ρ_π and ρ_y, are all positive.
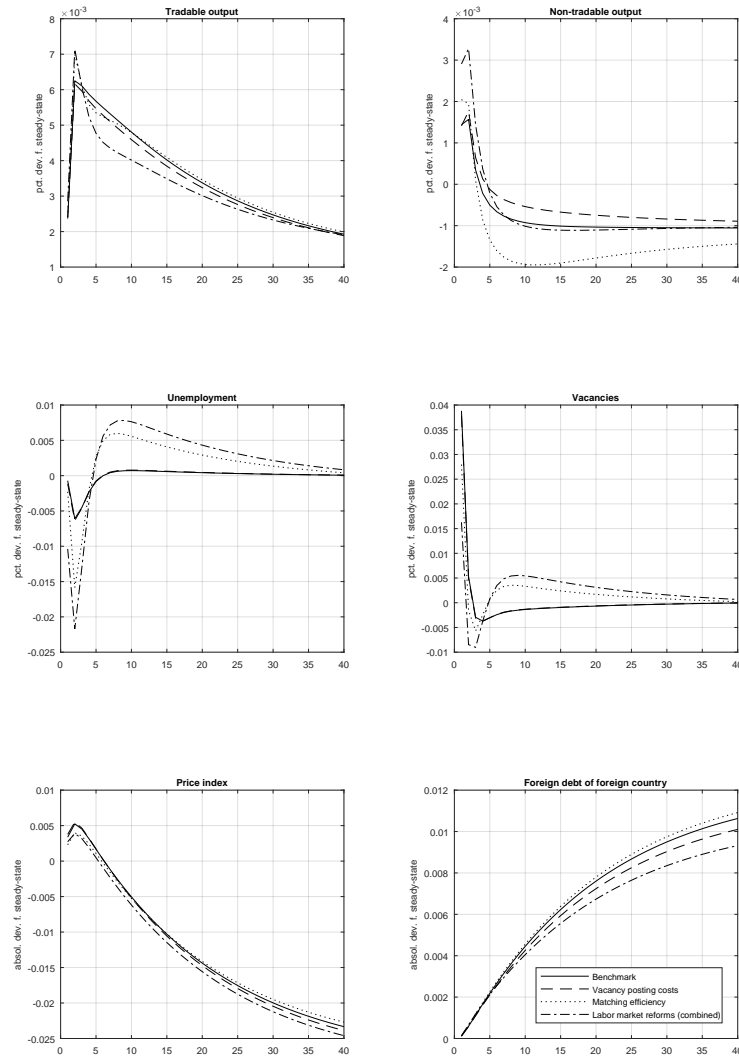
7.3. Tables supplement

Table 1: Business cycle properties, variety of shocks

Variable	Euro Area	Benchmark		Sensitivity
		Standard	H-M	
GDP	0.0164	0.0164	0.0164	0.0164
Vacancies	0.1079	0.0485	0.0416	0.0478
Unemployment	0.0712	0.0126	0.0617	0.0117
Employment		0.0013	0.0371	0.0014
Inflation	0.0069	0.0497	0.0029	0.0495
Production	0.0241	0.0365	0.0155	0.0364
Employment	0.0057	0.0276	0.0265	0.0281
Vacancies		0.2104	0.0348	0.2153
Job searchers		0.1642	0.0739	0.1716
Real wage	0.0135	0.0889	0.0032	0.0902
Labor market tightness	0.1573	0.0531	0.1018	0.0517
Production	0.0109	0.0319	0.0276	0.0318
Employment	0.0072	0.0277	0.0514	0.0281
Vacancies		0.1412	0.0524	0.1491
Job searcher		0.1834	0.0502	0.1888
Real wage	0.0101	0.6656	0.0054	0.6604
Labor market tightness	0.1573	0.0531	0.1018	0.0517
Output, real wages T	0.8622	0.1666	0.9684	0.1444
Output, real wages NT	0.4381	0.0969	0.8992	0.0841
Output, Inflation	0.5433	0.0128	0.3349	0.0026
Real wages T, Inflation	0.3226	0.9738	0.4709	0.9746
Real wages NT, Inflation	-0.4357	0.9777	0.6105	0.9774
Unemployment, vacancies	-0.5766	-0.2511	-0.9408	-0.2273

Notes: Observed and simulated business cycle properties for the Eurozone (EA-12).
The observed statistics are based on seasonally adjusted quarterly data from 2006:Q1
to 2012:Q2. Variables, except inflation, are transformed into logarithms. All the series
are HP filtered (frequency 1600), so that only the cyclical component remains. The
simulated business cycle statistics are based on 1000 simulations over 100 quarter
horizon and are HP filtered for comparison purposes. Simulated figures are averages
across simulations.
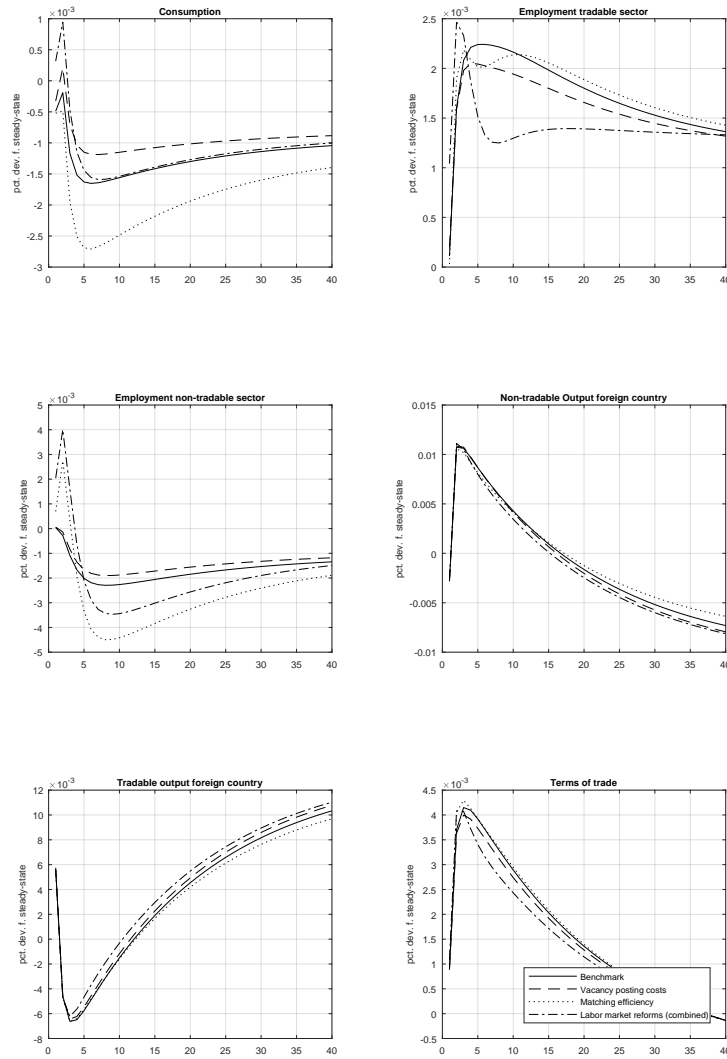
7.4. Figures supplement

Figure 5: Positive oil supply shock, labor market conditions

Impulse response functions to positive oil supply shock
Notes: Each panel shows the response of the model variables to an oil supply shock of one standard deviation. The horizontal axes measure time, expressed in quarters.

Figure 6: Positive oil supply shock, labor market conditions

Impulse response functions to a positive oil supply shock
Notes: Each panel shows the response of the model variables to an oil supply
shock of one standard deviation. The horizontal axes measure time, expressed
in quarters.