Labor Tax Reforms, Cross-Country Coordination, and the Monetary Policy Stance in the Euro Area: A Structural Model-Based Approach*

Pascal Jacquinot,[a] Matija Lozej,[b] and Massimiliano Pisani[c]

[a]European Central Bank
[b]Central Bank of Ireland
[c]Bank of Italy

We evaluate the effects of permanently reducing labor tax rates in the euro area (EA) by simulating a large-scale open-economy dynamic general equilibrium model. The model features the EA as a monetary union, split into two regions (home and the rest of the EA, or REA), the United States, and the rest of the world, region-specific labor markets with search and matching frictions, and public employment. Our results are as follows. First, a permanent reduction in labor tax rates in the home region would have stimulating effects on domestic economic activity and employment. Second, reducing labor tax rates simultaneously in both home and REA would

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have additional expansionary effects on the home region. Third, the short-run macroeconomic effectiveness of the EA-wide tax reduction is enhanced if the EA monetary policy is accommodating.

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"There is evidence that a significant share of unemployment is also structural."

Mario Draghi[1]

1. Introduction

Several reforms can be enacted to reduce the unemployment rate in the euro area (EA), equal to 9.7 percent in August 2017.[2] Among them is a permanent reduction in the labor tax. As emphasized by the European Commission, tax systems should become more growth friendly and supportive of job creation.[3] A decrease in labor taxes reduces labor costs to employers and increases the net take-home pay of employees, positively affecting both labor demand and labor supply. Shifting taxes away from labor can contribute to increasing employment and activity rates in the EA, by increasing incentives to hire, look for, and take up work. The exact effects will depend on the strength of the substitution effect between consumption and leisure and the assumption on how the reduction in labor taxation is financed.

In addition, short-run labor market dynamics can be significantly affected by the monetary policy stance and its interaction with labor market reforms, and in particular tax-based reforms. This can be particularly important for the EA, where the monetary policy stance is expansionary at the current juncture.

In this paper we contribute to the debate on those issues by evaluating the macroeconomic effects of a fiscal reform in the EA countries. The reform aims at permanently reducing taxes on labor, in line with the long-standing debate initiated by Prescott (2004). Specifically, we take into account (i) the coordination of the tax

[1] Draghi (2014).

[2] See Eurostat (2017).

[3] See European Commission (2015).

reductions across EA member states and (ii) the interaction between the fiscal measures and the EA monetary policy stance.

To that purpose, we simulate an augmented version of the EAGLE (Euro Area and Global Economy) model. The EAGLE is a multi-country dynamic general equilibrium model of the EA in the world economy. It is New Keynesian, as nominal prices of goods and services are sticky and, thus, monetary policy can have a non-trivial macroeconomic role. The EA is formalized as a monetary union of two regions that share the monetary policy rate and the nominal exchange rate against the United States (US) and a residual region labeled "rest of the world" (RW). Fiscal policy is conducted at a country level, as each region can use as policy instruments a rich set of spending and tax items.

There are two key novel features of the model, and they allow us to evaluate the impact of labor-market-based fiscal reforms on unemployment.

First, there is a country-specific labor market (labor services are non-tradable across countries) and there is unemployment because of search-and-matching frictions.

Second, we allow for public-sector employment and for the possibility of directed search between the private- and public-sector labor market, along the lines of Afonso and Gomes (2014). In fact, a proper assessment of the impact of the labor market reforms on private-sector employment should take into account that a common characteristic of the EA labor market is the important share of the public employment in total employment, which is, according to OECD (2015), around 20 percent in France; 15 percent in Spain, Italy, and Portugal; and 13 percent in Germany. Thus, this component is important to understand the labor market dynamics in the EA, given also that, during a crisis period, public and private labor markets tend to be more interrelated (when the unemployment rate is high, the number of applicants to the public sector is larger). In addition, the public sector typically has institutional features that are different from those in the private sector, both structurally and in terms of cyclical behavior (Lane 2003, Quadrini and Trigari 2007, Lamo, Pérez, and Schuknecht 2008, and Gomes 2015).

Finally, government as a large employer has additional instruments regarding public-sector employment that can supplement the changes in taxation.

In the model we allow the unemployed to choose the sector, private or public, in which they search for jobs. This is different from other large models featuring multiple sectors and frictional unemployment, where unemployed workers are typically passive (e.g., Costain and de Blas 2012, Stähler and Thomas 2012, or—a recent exception—Bandeira et al. 2016). There are three reasons for such a choice. First, there is evidence that unemployed workers do direct their search efforts towards sectors that they perceive to be better, as shown by, e.g., Afonso and Gomes (2014). Second, there is significant evidence that public- and private-sector wages co-move and that causality can go both ways (Lamo, Pérez, and Schuknecht 2008). Directed search opens a more powerful channel for such co-movements and allows the cause for the co-movement to stem from both private and public sector. Third, because we consider long-run changes, allowing workers to endogenously relocate to a different sector is a less restrictive assumption.

Other features of the model are rather standard.[4] In each region there are households and firms. Households consume, invest in physical capital, and supply labor. Both capital and labor are used by domestic firms, which produce intermediate goods and set their prices under monopolistic competition regime. There are two types of intermediate goods, tradable and non-tradable. All of them are combined to produce a final non-tradable good by firms acting under perfect competition. For the EA, the monetary policy rate is set according to a Taylor rule reacting in a gradual way to the EA-wide inflation rate and economic activity. For the US and the RW, the Taylor rules react to corresponding country-specific variables. The presence of countries outside the EA allows one to properly characterize the dynamics of the trade flows and international relative prices. In particular, and following the existing literature, the real exchange rate dynamics reflects the presence in the model of home bias, local currency pricing, non-tradable intermediate goods, and incomplete markets at the international level (one riskless bond is internationally traded). Fiscal policy is conducted at the regional level. Each regional fiscal authority can decide on fiscal measures by appropriately changing expenditure items, tax rates, and public

[4]For the documentation of the standard EAGLE model, see Gomes, Jacquinot, and Pisani (2010, 2012).

debt. The latter is stabilized according to a fiscal rule. In particular, regional governments set tax rates on labor. Finally, responses of main variables to shocks reflect the assumptions of habit in consumption, adjustment costs on investment changes and import changes, and price indexation. The model is calibrated to Germany, the rest of the EA (REA), the US, and the RW.

We initially simulate a permanent reduction in the labor tax rate paid by firms or households implemented by the German fiscal authority only. The tax rate reduction is gradually implemented over a two-year horizon and is calibrated to get a permanent reduction in labor tax revenues equal to 1 percent of the pre-shock German GDP. The fiscal rule in terms of lump-sum taxes is active throughout the experiment, implying that the reduction in tax revenues is financed by reducing lump-sum transfers by an equal amount, so that the measure does not increase public debt in the long run. The use of lump-sum transfers, which are not distortionary, allows us to measure the "clean" macroeconomic and labor market effect of lower labor taxes ("multipliers"). Moreover, this choice is consistent with the idea that financing lower labor tax rates should minimize distortions.

To disentangle the role of labor market frictions and public employment, we run the simulation initially in a version of the model without the public employment and, subsequently, in a version with public employment. We highlight the role of coordination among EA member states by simulating the simultaneous implementation of the tax reduction in both Germany and the REA. Finally, we assess the impact of the EA monetary policy stance on the short-run macroeconomic effectiveness of tax reductions by assuming that the EA monetary authority announces, in a fully credible way, that during the initial two years of the simulation the policy rate will be kept constant at its baseline level (instead of changing it according to the Taylor rule, which starts being active from the beginning of the third year). We label this measure as the "forward guidance" (FG) on monetary policy.

Our results, which are qualitatively similar across the two versions of the model (without and with public employment), are as follows. First, permanently reducing labor tax rates paid by home firms would have stimulating effects on domestic economic activity and employment, and would reduce the unemployment rate in the short run and in the long run. The same is true when tax rates paid by home households are reduced. Second, reducing the labor tax rates simultaneously in both home and the REA would have additional expansionary effects on the home region, because of the increase in the REA production and aggregate demand, which favors home households' purchasing power and home gross exports, respectively. Third, the short-run effectiveness of the EA-wide tax reduction is enhanced if the EA monetary policy is accommodating. When the monetary policy rate is kept constant at its baseline level, instead of being raised, the expansionary effects of the lower taxes are larger and more front-loaded, i.e., employment and other main macroeconomic variables would increase more and achieve their corresponding peak levels earlier.

Our paper is related to other contributions existing in the literature on the macroeconomic effects of labor market reforms in the EA. Coenen, McAdam, and Straub (2008) evaluate the impact of a labor tax reform in the EA. Their analysis shows that lowering tax distortions to levels prevailing in the US would result in an increase in hours worked and output by more than 10 percent. Fiori et al. (2012) and Gomes et al. (2013) simulate the impact of increasing competition in the EA labor market. The two contributions rely on the standard New Keynesian framework, based on nominal wage stickiness and monopolistic competition in labor supply. Different from them, we have a labor market with search frictions. Moreover, we explicitly consider that a substantial part of the workforce is employed by the public sector and that this workforce can, especially in the long run, decide to switch sectors. Stähler and Thomas (2012) do consider labor tax changes in a model with search frictions and a public sector, but in a model without hours choice and without directed search. While the model of Bandeira et al. (2016) has many similar features, they do not consider tax reforms.[5] Moreover, our model features the global economy and, thus, allows for international spillovers.

The paper is organized as follows. Section 2 reports the main features of the model and the calibration. Section 3 reports results. Section 4 concludes.

[5]We also do not assume that public-sector output enters private production functions.

2. The Model

2.1 Overview

In what follows we describe the labor market, as it is the novel feature of the model. Other features are standard and in line with the New Keynesian open-economy literature.

We introduce the frictional labor market in two stages. In the first stage, which we refer to as *the model without public employment*, we have one labor market that serves two private sectors, tradable and non-tradable. In the second stage, we add a public sector with its own labor market, but which is related to the private-sector labor market by the ability of unemployed workers to choose in which market to search. We call this *the model with public employment.*

The timing in both models is such that new matches become productive immediately and the breakup of employment relationships occurs in the beginning of the period. Because the model is quarterly, employment can react to shocks in the same quarter.[6] In the beginning of the period, a fixed proportion of employment relationships ends exogenously. The separated workers join the unemployed from the previous period in the searching process. Thereafter, aggregate shocks are realized, the number of matches is determined, wages are set, and production takes place. At the end of the period, the representative household receives labor income (wages and unemployment benefits) from workers, receives dividend income from firms, and pays taxes. The household as a whole then decides on consumption. This setup avoids the explicit consideration of heterogeneity and is based on Merz (1995) and Andolfatto (1996).

Posting vacancies is assumed to be costly, but is not a real resource cost.[7] Throughout the paper we assume that labor taxes are paid by households and by labor firms.[8] Unemployment benefits are distributed by the government and are assumed to be the same in all sectors.[9]

[6] Many models with labor market frictions assume a one-period delay, but typically these models are then calibrated to a monthly frequency.

[7] This is equivalent to assuming that the cost incurred by firms when posting vacancies is distributed as a lump sum to households.

[8] As labor firms sell labor services to final goods firms, a change in labor taxes paid by labor firms is passed on to marginal costs of intermediate goods firms.

[9] Note that, compared to the original version of the EAGLE, we assume the absence of non-Ricardian households.

2.2 The Labor Market

The model *without public employment* is characterized by a single labor market, which serves firms in both intermediate tradable and non-tradable sectors. Following the literature (e.g., Mortensen and Pissarides 1999; Christoffel, Kuester, and Linzert 2009), we assume that there is a continuum of labor firms, each employing one worker. Labor firms enter the market by posting a vacancy and, if matched with a worker, sell homogeneous labor services from hired workers to firms producing intermediate goods. They also pay labor taxes and bargain with households to determine the wage rate.[10]

2.2.1 Matching and Labor Market Flows

The matching process is modeled using a matching function, i.e.,

$$M_t^P = \phi_{mat}^P un_t^{P\ \mu_{mat}^P} vac_t^{P\ 1-\mu_{mat}^P}, \tag{1}$$

where M_t^P denotes the number of matches in each period, vac_t^P the number of vacancies, un_t^P the number of unemployed workers searching for a job, $\phi_{mat}^P > 0$ the efficiency of the matching process, and $0 < \mu_{mat}^P < 1$ the elasticity of the matching function with respect to employment.

The probability for a searching worker to find a job, $p_t^{P,W}$, is

$$p_t^{P,W} \equiv \frac{M_t^P}{un_t^P} = \phi_{mat}^P \left(\frac{vac_t^P}{un_t^P} \right)^{1-\mu_{mat}^P}. \tag{2}$$

Similarly, the probability for a firm to find a worker, $p_t^{P,F}$, is

$$p_t^{P,F} \equiv \frac{M_t^P}{vac_t^P} = \phi_{mat}^P \left(\frac{vac_t^P}{un_t^P} \right)^{-\mu_{mat}^P}. \tag{3}$$

Because of our assumption that separations occur at the beginning of the period and that newly matched workers become productive within the period, we have to distinguish between two aggregates of employed and unemployed workers.

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[10]These firms are similar to labor packers in Erceg, Henderson, and Levin (2000). Their role here is not to aggregate differentiated types of labor but to hire workers from unemployment.

The number of employed workers *after matching has been completed* is denoted by nde_t^P. These are workers who are in an employment relationship in the current period t. The number of employed workers *at the beginning of period* t is smaller and consists of workers who were employed in the previous period and have not been separated, $(1-\delta_x^P)nde_{t-1}^P$, where $0 < \delta_x^P < 1$ is the exogenous separation rate. Using the above definitions of probabilities, the law of motion for the number of employed workers can be written as

$$\begin{aligned} nde_t^P &= (1-\delta_x^P)nde_{t-1}^P + M_t^P \\ &= (1-\delta_x^P)nde_{t-1}^P + p_t^{P,F}\, vac_t^P \\ &= (1-\delta_x^P)nde_{t-1}^P + p_t^{P,W}\, un_t^P. \end{aligned} \tag{4}$$

Similarly, the number of unemployed workers, un_t, who search for work at the beginning of period t (i.e., the number of workers who enter the matching process) is equal to those who were unemployed at the end of the period $t-1$ after the $(t-1)$ matching has been completed, une_{t-1}, plus the newly separated workers, $\delta_x^P nde_{t-1}^P$:

$$un_t = une_{t-1} + \delta_x^P nde_{t-1}^P, \tag{5}$$

where

$$une_{t-1} = 1 - nde_{t-1}^P. \tag{6}$$

Consistently, the number une_t of unemployed at the end of period t (after period t matching has been completed) is

$$une_t = 1 - nde_t^P. \tag{7}$$

2.2.2 Value Functions

The value functions of job market participants (households and labor firms) are given by the current-period payoff and the continuation value, conditional on the probabilities of remaining in the current state or transitioning to another state.

Household. If a worker is employed, she works h_t^P hours, receives a real hourly wage w_t^P (expressed in domestic consumption units), and has to be compensated for the foregone leisure. In the case of a breakup in the beginning of the next period, she will be unemployed, conditional on not matching successfully in the next period. All unemployed workers search in the beginning of the next period and can either become employed with probability $p_{t+1}^{P,W}$ or remain unemployed. We follow den Haan, Ramey, and Watson (2000) and assume that the household as a whole makes the labor supply decision for its workers. The value of being employed, $E_{P,t}$, is

$$E_{P,t} = (1-\tau_t^{wh})w_t^P h_t^P - \frac{\chi}{\lambda_t}\frac{h_t^{P\ 1+\zeta}}{1+\zeta} + \beta\frac{\lambda_{t+1}}{\lambda_t}\left(\delta_x^P(1-p_{t+1}^{P,W})U_{P,t+1} + (1-\delta_x^P(1-p_{t+1}^{P,W}))E_{P,t+1}\right), \tag{8}$$

where $0 < \tau_t^{wh} < 1$ is the labor tax rate paid by the household, $1/\zeta$ is the Frisch labor supply elasticity, $\chi > 0$ is the weight of leisure in the utility function, $0 < \beta < 1$ is the time discount factor, λ_t is the marginal utility of household consumption, and $0 < \delta_x^P < 1$ is the exogenous probability of becoming unemployed.

The value of being employed is therefore determined by the after-tax real wage income, reduced for the disutility of foregone leisure (measured in consumption units), plus the continuation value, which depends on the future employment status and transition probabilities. Note that the continuation value is discounted by $\beta\lambda_{t+1}/\lambda_t$, which is the household's stochastic discount factor.

The value of being unemployed is

$$U_{P,t} = u_{ben,t} + \beta\frac{\lambda_{t+1}}{\lambda_t}\left((1-p_{t+1}^{P,W})U_{P,t+1} + p_{t+1}^{P,W}E_{P,t+1}\right), \tag{9}$$

where unemployed workers receive unemployment benefits paid by the government, $u_{ben,t} \geq 0$. The value of being unemployed depends on the level of unemployment benefits, but also on the future states and probabilities of transition to those states.

Unemployment benefits are assumed to be a fixed percentage $rrat > 0$ of the wage in the private sector,

$$u_{ben,t} = rrat\ w_t^P. \tag{10}$$

Labor Firm. Given our assumption of a continuum of labor firms with one worker, we define value functions for labor firms.

Labor firms sell labor services to intermediate goods firms at a price x_t. To obtain labor services, they hire workers by posting vacancies. Posting a vacancy involves a fixed cost, $\psi > 0$, which is paid in every period the vacancy is open. Once a worker is hired, she works h_t^P hours, which are transformed by a labor firm into labor services, $y_t^{P,h}$, according to the following technology:

$$y_t^{P,h} = h_t^{P\ \alpha_H},$$

where $\alpha_H > 0$. We follow the literature (e.g., Christoffel, Coenen, and Warne 2008) and assume α_H is below, but close to, 1.[11] For every hour worked, a labor firm pays its worker a wage w_t^P. The value for a labor firm of having a worker, $J_{P,t}$, is

$$J_{P,t} = x_t h_t^{P\ \alpha_H} - (1 + \tau_t^{wf}) w_t^P h_t^P + \beta \frac{\lambda_{t+1}}{\lambda_t} (1 - \delta_x) \left(J_{P,t+1} \right). \quad (11)$$

The value of having a worker is determined by per-period profits of the labor firm, which are the difference between the revenues from selling labor services and the costs of paying workers, which includes labor taxes paid by labor firms. If there is no breakup of the employment relationship, the firm keeps the value of having a worker in the next period.[12]

The value for a labor firm of having an open vacancy, $V_{P,t}$, is

$$V_{P,t} = -\psi + p_t^{P,F} J_{P,t} + \beta \frac{\lambda_{t+1}}{\lambda_t} \left((1 - p_{t+1}^{P,F}) V_{P,t+1} \right). \quad (12)$$

Every period, the firm has to pay a fixed cost $\psi > 0$ to search for a worker. If successful, which occurs with the probability $p_t^{P,F}$, it finds a worker and begins producing in the same period.[13] If the firm does not find a worker, it remains with a vacancy. Labor firms enter

[11] Assuming decreasing returns to scale to hours worked increases economic rents from matching at the individual labor firm level, in addition to fixed vacancy posting costs (see Christoffel and Kuester 2008).

[12] Note that due to our assumption that each labor firm hires one worker, total revenues (and total costs) of every labor firm are equal to marginal revenues (marginal costs) of having an additional worker.

[13] This is due to our assumption that newly formed matches become productive in the current period.

the labor market (post vacancies) as long as the value of having a vacancy exceeds zero. Because entry is free, the value of having a vacancy is driven to zero in equilibrium. Equation (12) can thus be simplified, resulting in the "free-entry condition"

$$\psi = p_t^{P,F} J_{P,t}, \tag{13}$$

which determines the number of vacancies in the model. Because the cost of having a vacancy open is fixed, and unemployment changes gradually, an increase in the value of having a worker $J_{P,t}$ induces firms to enter the labor market.

2.2.3 Wages and Hours Worked

The presence of labor market frictions implies that the wage is not equal to the marginal product of labor. Labor firms and households bargain over the surplus created by the match, taking into account their threat points (the value of having a vacancy, which is zero, and the value of being unemployed, respectively), bargaining powers, and labor taxes paid by each side in the bargaining.[14]

We assume that wages in the private sector are determined by means of Nash bargaining between labor firms and households that maximize the Nash surplus with respect to wages and hours worked. Such setting is often called efficient bargaining (Trigari 2009), as the surplus of the match between a labor firm and a worker is maximized with respect to the number of hours worked. The role of the wage is to split this surplus between the labor firm and the worker. The first-order condition with respect to wages is[15]

$$\eta(1 - \tau_t^{wh}) J_{P,t} = (1 - \eta)(1 + \tau_t^{wf}) \left(E_{P,t} - U_{P,t}\right), \tag{14}$$

where $0 < \eta < 1$ is the bargaining power of households. Equation (14) implicitly determines wages in the private sector. Note that labor taxes paid by firms τ_t^f influence the bargaining of households and firms. For instance, the larger is the share of the surplus that goes to the households; the bigger is the tax base for labor taxes paid by households and hence taxes paid to the government. If the

[14] See Mortensen and Pissarides (1999) for details.

[15] The derivations for wages and hours are provided in the appendix.

labor firm/worker pair decides to give a higher share to the worker, the pair as a whole loses the amount collected by the government. Agreeing on a lower wage implies that the total surplus that can be shared is larger (Afonso and Gomes 2014). In our setup, the effect is symmetric for household and firm taxes.[16] Changes in the tax rates therefore affect not only the asset values but also the shares of each side's surplus that the other side is able to appropriate.

Hours worked are determined as

$$\alpha_H x_t h_t^{P,\ \alpha_H - 1} = \frac{\chi h_t^{P\ \zeta}(1+\tau_t^{wf})}{\lambda_t(1-\tau_t^{wh})}, \tag{15}$$

where the marginal product for a labor firm of an additional hour of labor services sold to intermediate goods firms is equated to the disutility of the household having its workers work an additional hour (measured in consumption units). Note that the condition (15) depends on x_t (the price of labor services sold by the labor firms to intermediate goods firms) and, thus, only indirectly, via general equilibrium effects, on wages w_t. Moreover, it depends on labor taxes. An increase in the latter implies a reduction in the number of hours worked and, therefore, in the total surplus of the match between a worker and a firm.

2.3 Adding Public-Sector Employment

In the model with public employment, we introduce public-sector employment in addition to the employment in the two private sectors (tradable and non-tradable). We do this following the framework of Quadrini and Trigari (2007), Costain and de Blas (2012), Afonso and Gomes (2014), and Gomes (2015), and model a separate public sector, where public-sector employment is determined by government vacancy posting. Public-sector wages follow a wage rule that is linked to private-sector wages. In this sense, we improve the realism of the model without explicitly modeling wage bargaining in the public sector. Our public-sector wage rule guarantees that private- and public-sector wages are cointegrated, as in Lamo, Pérez, and

[16] Quadrini and Trigari (2007) and Afonso and Gomes (2014) consider only labor taxes paid by households.

Schuknecht (2008).[17] Because the public sector is different from private sectors in this respect (see Gregory and Borland 1999), we allow the unemployed to choose where to search. Note that this assumption can be viewed as being in between the models with frictionless labor markets (Finn 1998 or Ardagna 2007) and models with labor market frictions where unemployed workers are passive regarding their search decision (e.g., Stähler and Thomas 2012), as part of search frictions could be reduced by changes in unemployed workers' search direction.[18] We believe that such a setup is more realistic for the analysis of permanent shocks.

The structure of the model with public-sector employment is in terms of timing assumptions and in terms of the private-sector labor market identical to the model without public employment described in section 2.2. The most important difference is the addition of a new segment of the labor market for the public sector. Private and public labor market segments are linked by allowing unemployed workers to direct their search to a particular sector. This implies that in the beginning of every period, after the exogenous breakup but before matching takes place, unemployed workers can decide in which sector (public or private) they will search for a job.

2.3.1 Matching

The matching process is modeled as in the model without public employment, with the difference that there are two matching functions, one for the private sector and the other for the public sector. M_t^s is the number of matches in a sector s, where $s \in \{P, G\}$, with P denoting the private sector and G denoting the public sector. The number of vacancies in a sector s is vac_t^s, un_t^s is the number of unemployed searching in a sector, $\phi_{mat}^s > 0$ is now the sector-specific efficiency of the matching process, and $0 < \mu_{mat}^s < 1$ is the

[17] As Quadrini and Trigari (2007) note, adopting a rule may be viewed as an approximation, given that public-sector employment and wages are under some influence of the government and public-sector unions.

[18] We assume that transition from a job in the public sector to a job in the private sector (or vice versa) entails going through a search process, while this transition is frictionless in the private sector, unless a worker is separated from the firm. This can be viewed as an approximation of lower mobility between the private- and public-sector employees.

sector-specific elasticity of the matching function with respect to the number of searching workers. As the functional forms and the definitions of employed, unemployed, and searching workers are identical or similar to those in the model without public employment, we list them in the appendix.

2.3.2 Value Functions in the Private Sector

A worker who is employed in one of the sectors works h_t^s hours, receives an hourly wage w_t^s, and has to be compensated for the foregone leisure. In the case of a breakup in the beginning of the next period, she will be unemployed and receive the value of being unemployed, which is the value of having the opportunity to search in one of the sectors, $\widetilde{U}_t$. Note that this is not equal to the value of becoming unemployed in the model without public employment, because it includes the possibility to relocate to a different sector. Without the breakup, she will receive the continuation value of being employed. Unemployed workers receive unemployment benefits from the government, $u_{ben,t}$, which are identical across sectors. The value of being employed in the private sector, $E_{P,t}$, is

$$\begin{aligned} E_{P,t} &= (1-\tau_t^{wh})w_t^P h_t^P - \frac{\chi}{\lambda_t}\frac{h_t^{P\ 1+\zeta}}{1+\zeta} \\ &\quad + \beta\frac{\lambda_{t+1}}{\lambda_t}\left(\delta_x^P \widetilde{U}_{s,t+1} + (1-\delta_x^P)E_{P,t+1}\right), \end{aligned} \tag{16}$$

where $\widetilde{U}_{s,t+1}$ is the value of having an option to choose a sector s in the beginning of the next period, which includes the probability of finding a job in that sector. This value is defined below. The value of being unemployed in the private sector, $U_{P,t}$, is

$$U_{P,t} = u_{ben,t} + \beta\frac{\lambda_{t+1}}{\lambda_t}\widetilde{U}_{s,t+1}. \tag{17}$$

For the private-sector labor firm, the value of having a worker and the value of having a vacancy are identical to those in the model without public employment, equations (11) and (12), respectively. The free-entry condition is also the same as in equation (13).

2.3.3 Value Functions in the Public Sector

We do not define value functions of having a worker or a vacancy for a labor firm in the public sector explicitly.[19] These equations are not required, as we follow the literature (Quadrini and Trigari 2007, Afonso and Gomes 2014, Gomes 2015) and assume that public-sector wages follow a wage rule and vacancies in the public sector are the (exogenous) decision of the government. If the government decides on public-sector employment (or vacancies), there is no need to specify the free-entry condition in the public sector. Similarly, if wages in the public sector, w_t^G, follow a rule, there is no need for value functions that would enter wage determination (bargaining) in the public sector.[20]

The value of being employed in the public sector, $E_{G,t}$, is

$$E_{G,t} = (1-\tau_t^{wh})w_t^G h_t^G - \frac{\chi}{\lambda_t}\frac{h_t^{G\ 1+\zeta}}{1+\zeta} + \beta\frac{\lambda_{t+1}}{\lambda_t}\left(\delta_x^G \widetilde{U}_{s,t+1} + (1-\delta_x^G)E_{G,t+1}\right). \tag{18}$$

The value of being unemployed in the public sector, $U_{G,t}$ is

$$U_{G,t} = u_{ben,t} + \beta\frac{\lambda_{t+1}}{\lambda_t}\widetilde{U}_{s,t+1}. \tag{19}$$

Note that a change in labor taxes paid by households affects their take-home income, and not the public-sector wage, which is why taxes enter the value functions in exactly the same way as in the value functions for the private sector.

2.3.4 Directed Search

We model the connection between private- and public-sector (un)employment using a directed search approach. There are several

[19] If defined, such functions would be analogous to equations (11) and (12), with public-sector hours and wages replacing private-sector hours and wages, and labor firms' revenues in equation (11).

[20] We emphasize again that given the empirical evidence on cointegration of public- and private-sector wages, our wage rule is more realistic than simply assuming the government sets wages in the public sector. A completely micro-founded model would be explicit about the wage bargaining in the public sector.

reasons for this choice. In the directed search framework, searching workers can decide in which sector they wish to search. First, it implies that unemployed workers are free to move between public and private sectors. This is less restrictive than having them confined to one sector, and it also does not assume that unemployed workers do not vary their search according to the differences in the economic conditions in different sectors.[21] Moreover, this is in line with the evidence that workers do direct their search between private and public sectors both in the long run (Blank 1985 or Postel-Vinay and Turon 2007) and at business cycle frequencies (Gomes 2015). Second, because unemployed workers in the directed search framework are not passive, this reinforces the link between private and public sectors. Several authors have argued that such linkages are present and have important implications at business cycle frequencies (see, for instance, Lane 2003 and Lane and Perotti 2003).

We define the value for an unemployed worker of being in a sector s as

$$\widetilde{U}_{s,t} \equiv (1 - p_t^{s,W})U_{s,t} + p_t^{s,W} E_{s,t}. \tag{20}$$

Equation (20) states that at the beginning of period t (but after breakups), the value of searching in a sector s is a weighted average of the values of finding a job in that sector, or remaining unemployed, where the weights are the respective probabilities. Because searching workers are free to move between the private sector and public sector, they will reallocate as long as the value of searching in one sector is larger than the value of searching in the other sector. There will be no incentives to move between private and public sectors when the (marginal) gain from moving is zero, which will be the case when the value of being in either sector is equalized. Therefore, in equilibrium, the value of searching in the private sector has to be the same as the value of searching in the public sector.

Because matching takes place after workers reallocate, workers take into account that by switching sectors they can either get employed in that sector or be unemployed. This is why there is only one value of $\widetilde{U}_{s,t}$ in equilibrium, even though there are two sectors.

[21] The directed search assumption does not require that *all* unemployed workers shift their search from one sector to the other, but it is sufficient that workers *at the margin* do so (see Gomes 2015).

The directed search condition that determines how many workers search in each sector is therefore $\widetilde{U}_{P,t} = \widetilde{U}_{G,t}$, which implies

$$(1 - p_t^{G,W})U_{G,t} + p_t^{G,W} E_{G,t} = (1 - p_t^{P,W})U_{P,t} + p_t^{P,W} E_{P,t}. \quad (21)$$

Therefore, before matching in each sector, workers choose in which sector they will search based on the expected values of attaining a particular outcome in each sector. This is the directed search condition and is similar to that in, e.g., Afonso and Gomes (2014), with the difference that it includes the values of being employed. This is because in our model workers can match and become productive in the current period, whereas in Afonso and Gomes (2014) it takes one period before they match.[22]

The directed search condition in equation (21) can also be viewed as a sorting condition, as it determines the reallocation of searching workers across sectors through matching probabilities. Any change in the values of being (un)employed in a particular sector or changes in matching probabilities in one of the sectors will have an effect on the other sector. In particular, a change in relative wages between sectors will result in the reallocation of searching workers. The sorting condition therefore determines the spillovers between the private and the public sectors.

Finally, the number of workers searching in each sector has to equal the aggregate number of searching workers:

$$un_t = un_t^P + un_t^G. \quad (22)$$

2.3.5 Public-Sector Employment

The government sets public-sector employment by changing the number of vacancies according to the following law of motion:

$$vac_t^G = (1 - \rho_{vac})\overline{vac^G} + \rho_{vac} vac_{t-1}^G + \varepsilon_{t,vac}, \quad (23)$$

where $\overline{vac^G}$ is the steady-state level of public-sector vacancies. If the government wishes to increase public-sector employment, it has to

[22]Note that if the part of equation (20) for the private sector is used in equation (17), one obtains an identical expression for the value of being unemployed in the private sector as in equation (9) of the basic model.

change vacancies accordingly, either temporarily by changing $\varepsilon_{t,vac}$ or permanently by changing $\overline{vac^G}$. Note that changes in taxes do affect public-sector employment, even though they do not affect public-sector vacancies. Public-sector (and private-sector) employment is affected whenever tax or other changes trigger reallocation of workers among sectors, because given the number of vacancies in each sector, an inflow (outflow) of searching workers will increase (decrease) employment in the sector.

2.3.6 Public-Sector Wages and Hours

Public-sector wages, $w_{G,t}$, follow a wage norm. While it is possible to incorporate a different form of public-sector wage setting (e.g., Nash bargaining with different bargaining weights than in the private sector), we use as an approximation the wage norm that depends on the level of private-sector wages. In particular, we model public-sector wages as tied to private-sector wages.[23] In line with the aforementioned papers and with Afonso and Gomes (2014) and Gomes (2015), we assume public-sector wages have a premium, $pr_t > 1$, over private-sector wages in the steady state, $\overline{x}$:[24]

$$w_{G,t} = pr_t\,\overline{x} + pr_t(\rho_{wG}(w_t^P - \overline{x})), \tag{24}$$

where the last term, $pr_t(\rho_{wG}(w_t^P - \overline{x}))$, determines how fast public-sector wages adjust to private-sector wages. Unless otherwise stated, we assume that public-sector wages follow private-sector wages, i.e., $\rho_{wG} = 1$.

The differential between wages in the public and private sectors can therefore also be viewed as a change in the public-sector wage

[23]This is in line with Lamo, Pérez, and Schuknecht (2008), who find private- and public-sector wages cointegrated in OECD countries. The link between public- and private-sector wages is—for instance—also modeled in Quadrini and Trigari (2007) as a rule that determines public-sector wages as a function of private-sector wages.

[24]In addition to the direct empirical evidence for the existence of the public-sector wage premium reported in the papers cited and in Gregory and Borland (1999), there is also indirect evidence, reported in Gregory and Borland (1999) and discussed in Gomes (2015), that queues of workers for public-sector jobs are longer because of the existence of the public-sector wage premium. Assuming a premium for public-sector wages ($pr_t > 1$) in the model is consistent with the evidence that queues for public-sector jobs are longer.

premium. In the model, the change in this differential affects the search direction of searching workers and leads to the change in the matching probabilities for workers (length of the "queue" for a job in the sector) and labor firms.

Hours worked in the public sector are chosen optimally, taking the public-sector wage and tax rates as given. The decision is identical to that in the private sector (see equation (15)). The only difference is that now the government sets the public-sector hourly wage, so that in equation (15) the public-sector wage replaces labor firm revenues, and hours worked in the public sector replace hours worked in the private sector.[25] As in the model without public employment, labor taxes influence the choice of hours worked.[26]

The remaining modifications of the model involve changes to definitional equations and market clearing conditions, and are reported in the appendix.

2.4 Monetary Authority

In the case of the EA, there exists a single monetary authority that sets the (gross) nominal interest rate to target a weighted (by regional size) average of regional (home, H, and REA) annual consumer price inflation and real quarterly output growth:

$$\begin{aligned}\left(R_t^{EA}\right)^4 &= \phi_R^{EA}\left(R_{t-1}^{EA}\right)^4 + \left(1-\phi_R^{EA}\right)\\ &\quad\times\left[\left(\overline{R}^{EA}\right)^4 + \phi_\Pi^{EA}\left(\Pi_{C,t}^{EA,4} - \overline{\Pi}^{EA,4}\right)\right]\\ &\quad+\phi_{gY}^{EA}\left(Y_{gr,t}^{EA}-1\right)+\varepsilon_{R,t}^{EA}, \qquad (25)\end{aligned}$$

where $\overline{\Pi}^{EA,4}$ is the long-run annual inflation target and the annual inflation rate $\Pi_{C,t}^{EA,4}$ is defined as

$$\Pi_{C,t}^{EA,4} \equiv \left(\Pi_{C,t}^{H,4}\right)^{\frac{s^H}{s^H+s^{REA}}}\left(\Pi_{C,t}^{REA,4}\right)^{\frac{s^{REA}}{s^H+s^{REA}}}, \qquad (26)$$

[25]Note that only household members who are employed in the particular sector decide on the number of hours worked in that sector.

[26] The hours worked used in the utility of the household as a whole (irrelevant for the rest of the model) are a weighted average of the hours worked in each sector, $h_t = \frac{nde^P}{nde}h_t^P + \frac{nde^G}{nde}h_t^G$.

with

$$\Pi_{C,t}^{H,4} \equiv \frac{P_{C,t}^{H}}{P_{C,t-4}^{H}}, \ \ \Pi_{C,t}^{REA,4} \equiv \frac{P_{C,t}^{REA}}{P_{C,t-4}^{REA}}, \tag{27}$$

where $P_{C,t}^{H}$ and $P_{C,t}^{REA}$ are the home and REA consumer price deflators, respectively. The EA output growth rate $Y_{gr,t}^{EA}$ is defined as

$$Y_{gr,t}^{EA} \equiv \frac{Y_t^{EA}}{Y_{t-1}^{EA}} \equiv \frac{s^H Y_t^H + s^{REA} Y_t^{REA}}{s^H Y_{t-1}^H + s^{REA} Y_{t-1}^{REA}}, \tag{28}$$

where Y_t^H and Y_t^{REA} represent per capita total final real output in the H and REA regions, respectively. They are weighted by the corresponding regional sizes in the world economy (s^H and s^{REA}).

In some simulations we evaluate the role of the monetary policy stance for the macroeconomic effectiveness of the labor tax reduction, and assume that during the initial eight quarters the EA policy rate is kept constant at its baseline level, $R_t^{EA} = \overline{R}^{EA}$, and, starting from quarter 9, the rate is set according to the Taylor rule (25).

2.5 Calibration

We calibrate at the quarterly frequency the blocs to Germany (home country), REA, US, and RW. We set some parameters to match the great ratios. The remaining parameters are similar to those in the standard EAGLE model and thus in line with the calibration of models such as the GEM (Laxton and Pesenti 2003, Pesenti 2008) and the NAWM (Christoffel, Coenen, and Warne 2008).

Table 1 reports the matched great ratios. National accounts data for the EA regions and the US are taken from Eurostat. We set region sizes to match the corresponding shares of the world GDP (International Monetary Fund data). The sources of EA and of US net foreign asset position data are Eurostat and the Bureau of Economic Analysis, respectively.[27]

Table 2 reports preference and technology parameters. We set the discount factor of households to 0.9926 (implying a steady-state

[27] Given the import shares, net foreign asset position, and international interest rate, the steady-state trade balance and real exchange rate level endogenously adjust.

Table 1. Steady-State National Accounts (ratio to GDP, %)

	Home	REA	US	RW
Domestic Demand				
Private Consumption	59	60	63	64
Private Investment	20	20	20	20
Public Consumption	20	20	16	16
Trade				
Imports (Total)	28	24	11	15
Imports of Consumption Goods	18	20	7	9
Imports of Investment Goods	9	4	4	6
Net Foreign Assets (Ratio to Annual GDP)	40	−15	−63	40
Production				
Tradables	40	39	37	37
Non-tradables	60	61	63	63
Labor	52	52	56	66
Share of World GDP	6	16	31	47

Note: REA = rest of euro area; US = United States; RW = rest of world.

annualized real interest rate of about 3 percent). The habit persistence parameter, the intertemporal elasticity of substitution, and the Frisch elasticity are, respectively, set to 0.70, 1, and 0.50. We set the quarterly depreciation rate of capital to be consistent with a 10 percent annual depreciation rate.

On the production side, in the Cobb-Douglas production functions of tradable and non-tradable intermediate goods the bias towards capital is set to 0.30. As for the final goods baskets, the degree of substitutability between domestic and imported tradables is higher than that between tradables and non-tradables, consistent with the existing literature (elasticities equal to 2.5 and 0.5, respectively).[28] The biases towards the tradable bundle in the consumption and investment baskets are equal, respectively, to 0.45 and 0.75 in

[28]Note that the short-run elasticity for imported goods is lower because of adjustment costs on imports. The numbers are consistent with Bayoumi, Laxton, and Pesenti (2004).

Table 2. Households, Entrepreneurs, and Firms Behavior

	Home	REA	US	RW
Households				
Discount Factor (β)	$1.03^{-1/4}$	$1.03^{-1/4}$	$1.03^{-1/4}$	$1.03^{-1/4}$
Intertemporal Elasticity of Substitution (σ^{-1})	1.00	1.00	1.00	1.00
Inverse of the Frisch Elasticity of Labor Supply (ζ)	2.00	2.00	2.00	2.00
Habit Persistence (κ)	0.70	0.70	0.70	0.70
Capital Depreciation Rate (δ^K)	0.025	0.025	0.025	0.025
Intermediate Good Firms (Trad. and Non-trad. Sectors)				
Substitution between Labor and Capital	1.00	1.00	1.00	1.00
Bias towards Capital—Tradables (α_T)	0.30	0.30	0.30	0.30
Bias towards Capital—Non-tradables (α_N)	0.30	0.30	0.30	0.30
Production—Labor Services (α_H)	0.99	0.99	0.99	0.99
Final Consumption Good Firms				
Substitution between Domestic and Imported Traditional Goods (μ_{TC})	2.50	2.50	2.50	2.50
Bias towards Domestic Tradables Goods (ν_{TC})	0.28	0.22	0.65	0.59
Substitution between Tradables and Non-tradables (μ_C)	0.50	0.50	0.50	0.50
Bias towards Tradable Goods (ν_C)	0.45	0.45	0.35	0.35
Substitution between Consumption Good Imports (μ_{IMC})	2.50	2.50	2.50	2.50
Final Investment Good Firms				
Substitution between Domestic and Imported Trad. Goods (μ_{TI})	2.50	2.50	2.50	2.50
Bias towards Domestic Tradables Goods (ν_{TI})	0.40	0.76	0.71	0.56
Substitution between Tradables and Non-tradables (μ_I)	0.50	0.50	0.50	0.50
Bias towards Tradable Goods (ν_I)	0.75	0.75	0.75	0.75
Substitution between Investment Good Imports (μ_{IMI})	2.50	2.50	2.50	2.50

Note: REA = rest of euro area; US = United States; RW = rest of world.

each region of the EA and, respectively, to 0.35 and 0.75 in the US and RW. The weight of domestic tradable goods in the consumption and investment tradable baskets is different among countries, and is set to be consistent with multilateral import-to-GDP ratios.

Table 3. Price Markups (implied elasticities of substitution)

	Tradables (θ_T)	Non-tradables (θ_N)
Home	1.20 (6.0)	1.50 (3.0)
REA	1.20 (6.0)	1.50 (3.0)
US	1.20 (6.0)	1.28 (4.6)
RW	1.20 (6.0)	1.28 (4.6)

Note: REA = rest of euro area; US = United States; RW = rest of world.

Markups in the EA non-tradables sector (a proxy for the services sector) are higher than the corresponding values in the US and RW (see table 3). In all regions the markup in the tradables sector (a proxy for the manufacturing sector) has the same value.[29]

Table 4 reports nominal and real rigidities. We set Calvo price parameters in the domestic tradables and non-tradables sector to 0.92 (12.5 quarters) in the EA, consistent with the estimates by Smets and Wouters (2003) and Christoffel, Coenen, and Warne (2008). The corresponding nominal rigidities outside the EA are equal to 0.75, implying an average frequency of adjustment equal to four quarters, in line with Faruqee et al. (2007). Calvo parameters in the export sector are equal to 0.75 in all the regions. The indexation parameters on prices are equal to 0.50, to get a sufficiently hump-shaped response of prices. For real rigidities, we set adjustment costs on investment changes to 6 in the EA and to 4 in the case of the US and RW, and adjustment costs on consumption and investment imports to 2 and 1, respectively.

We set the weights of bilateral imports in the bundles to match the trade matrix reported in table 5.[30]

Table 6 reports parameters in the monetary rules and fiscal rules. The interest rate reacts to its lagged value (inertial component of

[29]The chosen values are consistent with estimates from Martins, Scarpetta, and Pilat (1996), suggesting that the degree of competition in the non-tradable sector is lower than in the tradable sector. Also, these values are in line with other similar studies, such as Bayoumi, Laxton, and Pesenti (2004), Faruqee et al. (2007), and Everaert and Schule (2008).

[30]The trade matrix is calibrated using Eurostat and International Monetary Fund trade statistics.

Table 4. Real and Nominal Rigidities

	Home	REA	US	RW
Adjustment Costs				
Imports of Consumption Goods (γ_{IM^C})	2.00	2.00	2.00	2.00
Imports of Investment Goods (γ_{IM^I})	1.00	1.00	1.00	1.00
Capital Utilization (γ_{u2})	2000	2000	2000	2000
Investment (γ_I)	6.00	6.00	4.00	4.00
Intermediation Cost Function—USD Bond (γ_{B^*})	0.01	0.01	—	0.01
Intermediation Cost Function—Euro Bond ($\gamma_{B^{EA}}$)	—	0.01	—	—
Calvo Parameters				
Prices—Domestic Tradables (ξ_H) and Non-tradables (ξ_N)	0.92	0.92	0.75	0.75
Prices—Exports (ξ_X)	0.75	0.75	0.75	0.75
Degree of Indexation				
Prices—Domestic Tradables (χ_H) and Non-tradables (χ_N)	0.50	0.50	0.50	0.50
Prices—Exports (χ_X)	0.50	0.50	0.50	0.50

Note: REA = rest of euro area; US = United States; RW = rest of world.

the monetary policy), annual inflation, and quarterly output growth. In the monetary union, monetary policy reacts to the EA-wide variables. For fiscal rules, *lump-sum* taxes stabilize public debt. Steady-state ratios of government debt over output are equal to 2.40 in all the regions (0.6 in annual terms). Tax rates are set to be consistent with empirical evidence (see Coenen, McAdam, and Straub 2008).

The labor market in the baseline model without the public sector is calibrated as follows (see table 7). We set the matching probability for workers and for firms, p^W and p^F, respectively, to 0.7. Hours per worker are standardized to 1 in the steady state (so that the amount of labor services in the steady state is equal to the level of employment), while the unemployment rate is set to 8 percent in home and the REA, and to 6 percent in the US and the RW. The estimates of matching probabilities are based on den Haan, Ramey, and Watson (2000), and unemployment rates are close to those reported in the literature (e.g., Stähler and Thomas 2012). We calibrate vacancy

Table 5. International Linkages (trade matrix, share of domestic GDP, %)

	Home	REA	US	RW
Consumption Good Imports				
Substitution between Consumption Good Imports (μ_{IMC})	2.50	2.50	2.50	2.50
Total Consumption Good Imports	18.4	20.1	7.3	8.7
From Partner				
Home	—	3.1	0.3	1.1
REA	8.9	—	0.8	3.6
US	1.1	0.5	—	4.0
RW	8.4	16.5	6.2	—
Investment Good Imports				
Substitution between Investment Good Imports (μ_{IMI})	2.50	2.50	2.50	2.50
Total Investment Good Imports	9.2	3.6	4.2	6.4
From Partner				
Home	—	2.2	0.2	0.7
REA	4.4	—	0.4	2.3
US	0.6	0.6	—	3.4
RW	4.2	0.8	3.6	—

Note: REA = rest of euro area; US = United States; RW = rest of world.

posting costs, matching function efficiency, breakup rate, and the disutility of hours worked to match the above values of endogenous variables.

We set the matching elasticity to 0.5, which is in the middle of the range reported by Petrongolo and Pissarides (2001). The bargaining power of workers is set to 0.5, which is also in line with the literature.[31] Unemployment benefits are set as a proportion of the steady-state wage, where the proportion is the replacement ratio. Replacement ratios are broadly in line with the OECD estimates and are set to be higher for blocs in the EA, at 0.5, and lower in the US and the RW, at 0.2. The labor supply elasticity is set to 0.5 (implying

[31]Moreover, the choice of the bargaining power equal to the matching elasticity satisfies the Hosios condition in flexible-price models.

Table 6. Monetary and Fiscal Policy

	Home	REA	US	RW
Monetary Authority				
Inflation Target ($\overline{\Pi}^4$)	1.02	1.02	1.02	1.02
Interest Rate Inertia (ϕ_R)	0.87	0.87	0.87	0.87
Interest Rate Sensitivity to Inflation Gap (ϕ_Π)	1.70	1.70	1.70	1.70
Interest Rate Sensitivity to Output Growth (ϕ_Y)	0.10	0.10	0.10	0.10
Fiscal Authority				
Government Debt-to-Output Ratio ($\overline{B_Y}$)	2.40	2.40	2.40	2.40
Sensitivity of Lump-Sum Taxes to Debt-to-Output Ratio (ϕ_{BY})	0.10	0.10	0.10	0.10
Consumption Tax Rate (τ_C)	0.183	0.183	0.077	0.077
Dividend Tax Rate (τ_D)	0.00	0.00	0.00	0.00
Capital Income Tax Rate (τ_K)	0.189	0.192	0.164	0.160
Labor Income Tax Rate (τ_N)	0.122	0.122	0.154	0.154
Rate of Social Security Contribution by Firms (τ^{wf})	0.219	0.219	0.071	0.071
Rate of Social Security Contribution by Households (τ^{wh})	0.118	0.118	0.071	0.071

Note: REA = rest of euro area; US = United States; RW = rest of world.

its inverse, $\zeta = 2$) and follows Gomes, Jacquinot, and Pisani (2012). Tax rates correspond to effective tax rates in each of the blocs and are also taken from Gomes, Jacquinot, and Pisani (2012).

The calibration of the model with public-sector employment is based on the principles outlined in Gomes (2010, 2015), Stähler and Thomas (2012), and Afonso and Gomes (2014). Because the model with public employment has two matching functions, there are now two sets of matching probabilities and two sets of matching function efficiencies, elasticities, and breakup rates (one in each sector) that have to be calibrated to be consistent with the following findings in the literature. First, the matching probability for a worker in the public sector is lower than the matching probability for a worker in the private sector. Second, the breakup rate in the public sector is

Table 7. Labor Market in the Basic Model

	Home	REA	US	RW
Matching Prob., Workers (p^W)	0.70	0.70	0.70	0.70
Matching Prob., Firms (p^F)	0.70	0.70	0.70	0.70
Matching Efficiency (ϕ_{mat})	0.70	0.70	0.70	0.70
Vacancy Posting Cost (ψ)	0.1190	0.1170	0.5490	0.5449
Breakup Rate (δ_x)	0.0574	0.0574	0.0428	0.0428
Disutility of Labor (χ)	2.2178	2.1772	2.6929	2.6372
Unemployment Benefits ($uben$)	0.5009	0.4924	0.2356	0.2338
Matching Elasticity (μ_{mat})	0.50	0.50	0.50	0.50
Bargaining Power (η)	0.50	0.50	0.50	0.50
Replacement Ratio ($rrat$)	0.50	0.50	0.20	0.20
Unemployment (un)	0.08	0.08	0.06	0.06

Note: REA = rest of euro area; US = United States; RW = rest of world.

lower than in the private sector. Third, the matching function elasticity with respect to unemployment in the public sector is lower than in the private sector, which reflects the fact that in the public sector variations in vacancies play a more important role in hiring. The calibration is detailed in table 8.

We calibrate the labor market setup of the private sector along the same lines as in the model without public employment, except where the addition of the public sector requires modifications. Specifically, we choose vacancy posting costs (assumed to be the same in both sectors), both matching efficiencies, breakup rates, and the disutility of hours to target the matching probability for workers in the private sector, $p^{P,W} = 0.7$; the matching probability for firms in the private sector, $p^{P,F} = 0.7$; and the matching probability for firms in the public sector, $p^{G,F} = 0.7$. Hours per worker are standardized to 1 in the steady state, and unemployment rates in home and the REA are set to 8 percent, while they are set to 6 percent in the US and in the RW. We calibrate the quarterly separation rate in the public sector to $\delta_x^G = 0.01$, which is close to Afonso and Gomes (2014), and use the separation rate in the private sector to match the aggregate unemployment levels. The obtained values for the private-sector separation rate δ_x^P are between 4 percent and 5 percent, which is in line with the literature (e.g., Afonso and Gomes

Table 8. Calibration of the Full Model with Public Sector

Parameter	Home	REA	US	RW
Matching Prob., Workers (p^W)	0.70	0.70	0.70	0.70
Matching Prob., Firms (p^F)	0.70	0.70	0.70	0.70
Matching Efficiency, Private (ϕ^P_{mat})	0.70	0.70	0.70	0.70
Matching Efficiency, Public (ϕ^G_{mat})	0.4408	0.4413	0.5247	0.4899
Vacancy Posting Cost (ψ)	0.1193	0.1206	0.5519	0.5468
Breakup Rate, Private (δ^P_x)	0.0517	0.0487	0.0432	0.0400
Breakup Rate, Public (δ^P_x)	0.01	0.01	0.01	0.01
Disutility of Labor (χ)	2.2463	2.2453	2.7767	2.7171
Job-Finding Prob. in Public Sector ($p^{P,W}$)	0.0688	0.0693	0.1656	0.1160
Unemployment Benefits ($uben$)	0.4998	0.5036	0.2369	0.2341
Matching Elasticity, Private (μ^P_{mat})	0.50	0.50	0.50	0.50
Matching Elasticity, Public (μ^G_{mat})	0.20	0.20	0.20	0.20
Replacement Ratio ($rrat$)	0.50	0.50	0.20	0.20
Public-Sector Wage Premium (pr)	3.00%	3.00%	3.00%	5.00%
Public-Sector Wage Bill $\left(\frac{(1+\tau^{wf})\overline{w_G}\,\overline{nde^G}}{P_Y Y}\right)$	8.10%	12.00%	11.20%	10.00%
Public-Sector Employment	12.78%	18.48%	17.00%	15.00%
Unemployment (un)	0.08	0.08	0.06	0.06

2014 use 4 percent) and is always above the separation rate in the public sector.[32]

The number of public-sector vacancies is set to target the share of public-sector employment in total employment. We take this to be 12.78 percent in home and 18.48 percent in the REA, following Gadatsch, Stähler, and Weigert (2015). For the US, we use the estimate from Quadrini and Trigari (2007), which is 17 percent. The value for the RW is set to 15 percent, based on OECD and ILO data on public employment.[33] The probability that a worker finds a job in the public sector is the residual of this calibration procedure, and

[32]Stähler and Thomas (2012) assume separation rates of 6 percent for the private sector and 3 percent for the public sector. The calibration of Quadrini and Trigari (2007), who use the same separation rate of 10 percent in both sectors, is at the upper bound of the values reported in the literature.

[33]While this choice is somewhat arbitrary, it tends to reflect that Japan and most countries in Latin America and Africa have very small public-sector employment (typically below 10 percent), while most of the post-communist countries and China tend to have large (but decreasing) public-sector employments, typically above 20 percent.

the outcomes are in line with those implied in Afonso and Gomes (2015).[34]

We set the public-sector wage premium in home and in the REA to 3 percent, following the estimates in Gadatsch, Stähler, and Weigert (2015). For the US, we also use 3 percent, which is slightly lower than in Quadrini and Trigari (2007). To set the public-sector wage premium in the RW, we follow Gomes (2015), who reports that the plausible estimates of public-sector wage premium are in the range between 0 and 10 percent. We choose the midpoint of this range.[35] Government spending on public-sector wages is part of government consumption in national accounts. Thus, we adjust government spending on non-wage consumption accordingly.[36]

In all other respects, we align the calibration of the model with the public employment with that of the model without public employment. That is, we set unemployment rates, hours worked, replacement ratios, and tax rates to be the same as in the model without public employment. The same applies to country sizes, great ratios, taxes, and trade linkages.

To further validate the model, we simulate a standard monetary policy shock in the basic version.[37] Figures 1 and 2 report the effects of an initial 1 percentage point drop in the EA monetary policy rate. The reduction is persistent because of the parameter for inertia in the Taylor rule. The effects are symmetric across the EA regions. GDP, consumption, investment, and inflation increase (see figure 1). Exports initially decrease, because the prices of the EA

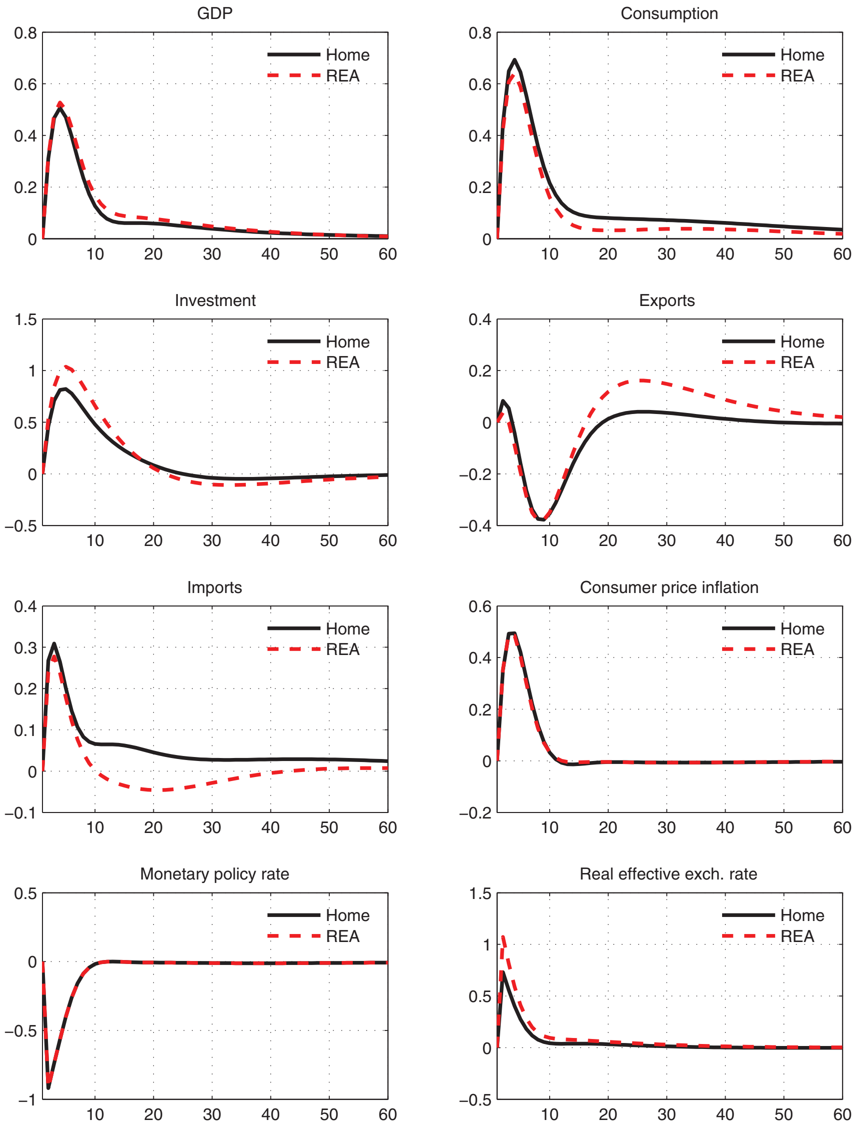
[34] See table 3 in their paper.

[35] Note that workers in both sectors in the model are identical. The corresponding public-sector wage premium in the data should be the premium which is obtained by controlling for worker heterogeneity (most importantly, skill level). Quadrini and Trigari (2007) use 3.75 percent and Afonso and Gomes (2014) use 4 percent.

[36] This implies that to avoid double-counting, government consumption G has to be adjusted for the government wage bill. Our calibration of public-sector sizes and wage premiums implies that the government wage bill is approximately 10–11 percent of GDP, which is consistent with the values reported by Gadatsch, Stähler, and Weigert (2015) for Germany and the EA, and the values reported by the World Bank (Dahal et al. 2011). Total government consumption is identical to the values used in Gomes, Jacquinot, and Pisani (2012).

[37] The responses to the monetary policy shock in the full model are almost identical and we do not report them here.

Figure 1. Decrease in the Monetary Policy Rate: Main Macroeconomic Variables



Notes: Horizontal axis: quarters. Inflation and interest rate are in annualized percentage-point deviations from the initial steady state. The remaining variables are in percent deviations.

goods increase, following the higher EA aggregate demand. Moreover, the pass-through of the nominal exchange rate (which depreciates) into exports and imports prices is gradual. Thus, it takes time for the EA exported goods to increase above the baseline level, following the depreciation. Imports increase, following the increase in EA aggregate demand. Quantitatively, responses are in line with those obtained for a monetary policy shock, when simulating the NAWM and the standard version of the EAGLE.

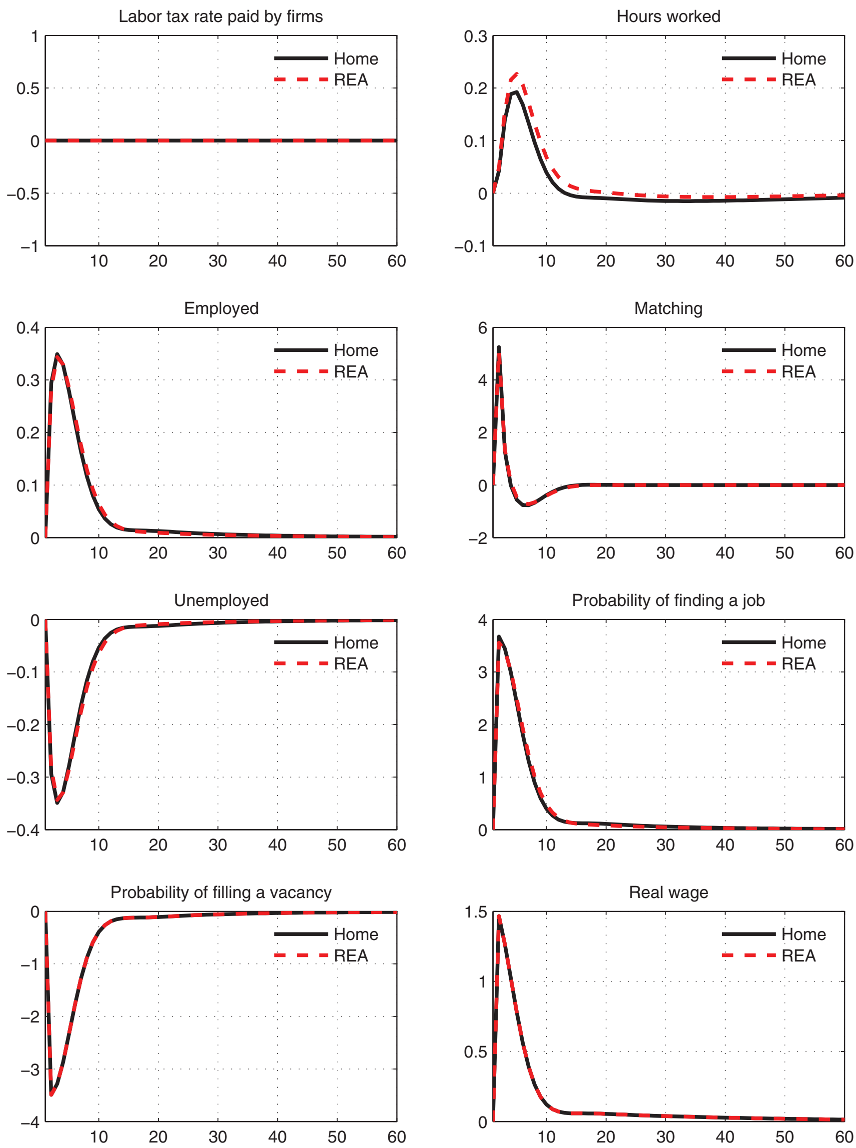
Figure 2 reports labor market variables. Their dynamics is consistent with the increase in the EA economic activity. The price of labor services increases, because firms demand more labor to augment production and satisfy the higher aggregate demand. Higher price of labor services leads to higher profits of labor firms, because wages do not adjust sufficiently. The value of having a worker for a labor firm increases, which leads to a larger number of vacancies posted. The probability of finding a job increases and that of filling a vacancy decreases. The number of new matches increases. Consistently, employment and unemployment increases and decreases, respectively. Higher job-finding probability for workers implies that the values of employment and unemployment increase. Because the value of unemployment is a threat point in wage bargaining (it is workers' outside option and it is now more valuable), they can achieve higher wages in the bargaining process. Hours worked increase because the effect of higher real wages prevails over the decrease in the marginal utility of consumption. Effective labor, equal to the product of the number of employed and the number of hours worked, increases.

3. Results

To assess the impact of reducing labor taxes on the main labor market and macroeconomic variables, we initially simulate the "basic" model, i.e., without public-sector employment. Thereafter, we simulate the "full" model, i.e., with public-sector employment.

We consider several scenarios in which the labor taxes are permanently reduced. In the first scenario, the labor tax rate paid by home firms is reduced. In the second, the labor tax rate paid by home households is reduced. In the third and fourth, the labor tax rates paid by firms and households are simultaneously reduced in

Figure 2. Decrease in the Monetary Policy Rate: Labor Market Variables



Notes: Horizontal axis: quarters. Tax rate, probabilities, employment, and unemployment rates are in percentage-point deviations from the initial steady state. The remaining variables are in percent deviations.

both home and REA regions. For the latter two scenarios, we consider two alternative monetary policy stances: the standard Taylor rule and the forward guidance (FG), in which the monetary authority credibly announces to keep the monetary policy rate constant at its baseline level during the initial eight quarters (the Taylor rule becomes active in quarter 9). In every scenario, the tax rate reduction is such that the corresponding tax revenues decrease by 1 percent of pre-shock (steady-state) nominal GDP. The new lower tax rate is achieved by around two years after the beginning of the simulations.

All simulations are run under the assumption of perfect foresight, so that households and firms perfectly anticipate the future path of the variables, and decisions made by the fiscal and monetary authorities are fully credible.

3.1 Unilateral Home Tax Decrease

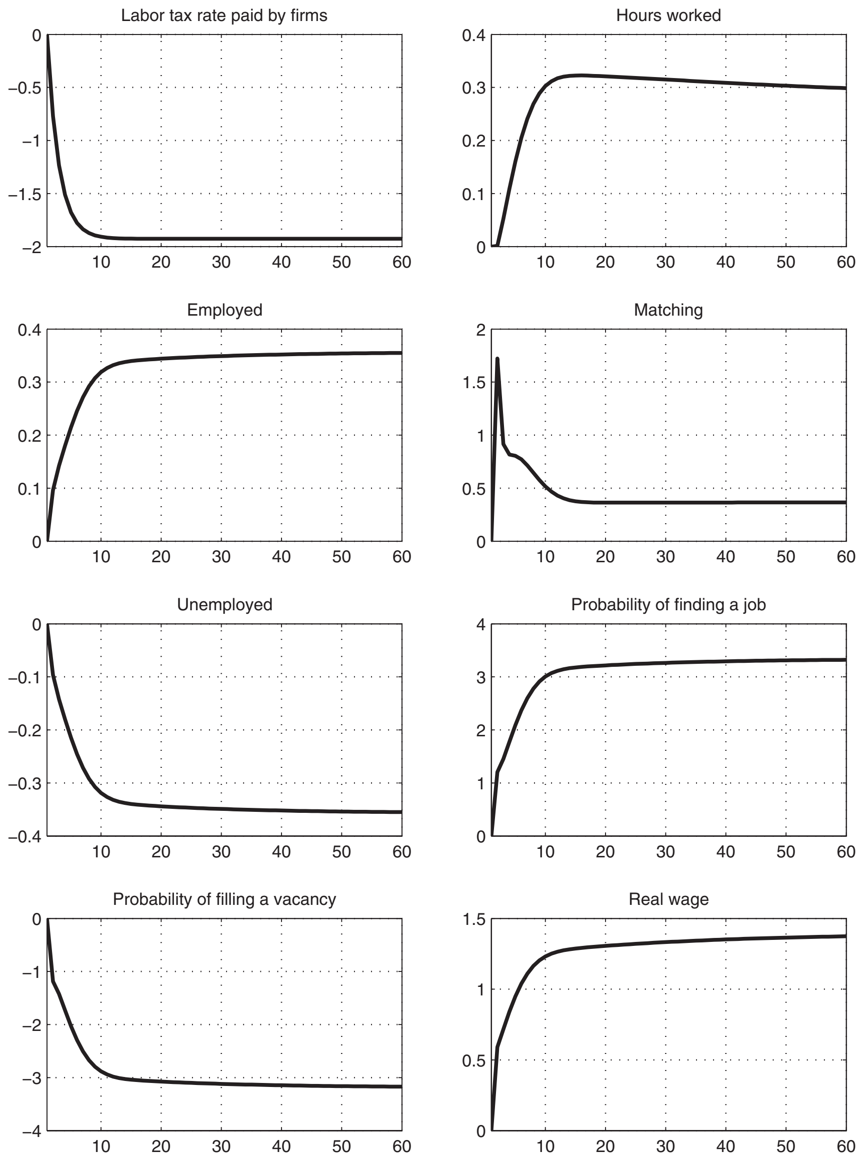
In what follows we first report results obtained when reducing labor taxes paid by home firms and then results when reducing labor taxes paid by home households. The EA monetary policy is set according to the Taylor rule (equation (25)).

3.1.1 Decrease in the Labor Tax Rate Paid by Home Firms

Figure 3 reports the effects on labor market variables of reducing the labor tax rate paid by home firms.[38] The tax rate is reduced by almost 2 percentage points (trough level). The reduction of labor taxes paid by firms reduces the gross wage bill of firms and hence increases the value of having a worker. Workers are able to obtain part of the increase in firms' surplus in the bargaining process, which results in a real wage increase. Nevertheless, the wage increase is not sufficient to undo the increase in the value of having a worker for firms, which leads to an increase in labor demand through vacancy posting. The number of matches increases as well and, consistently, the probability of finding a job and that of filling a vacancy increases and decreases, respectively. Employment increases (and the unemployment rate decreases) by roughly 0.3 percentage points after

[38] Recall that labor taxes are paid by labor firms; see equation (11).

Figure 3. Decrease in the Labor Tax Rate Paid by Home Firms: Labor Market Variables



Notes: Horizontal axis: quarters. Tax rate, probabilities, employment, and unemployment rates are in percentage-point deviations from the initial steady state. The remaining variables are in percent deviations.

two years and 0.4 percentage points in the medium run and in the long run, respectively. Hours worked increase because higher wages induce both a positive substitution effect and a negative wealth effect. The former dominates the latter.

Figure 4 shows the main macroeconomic effects. Home GDP increases by 0.5 percent after two years and by about 0.7 percent in the long run (see also table 9, column labeled "Constant Benefits"). Both consumption and investment increase. Consumption increases because of households' larger permanent income, associated with the increase in employment, hours, and production. Investment increases because firms augment physical capital to accompany the rising employment. Both home exports and imports rise. Exports benefit from the deterioration in the home real exchange rate, due to the expansion in home supply. Imports are favored by larger home aggregate demand. Home consumer price inflation slightly decreases in the short run, because the reduction in labor taxes paid by firms reduces after-tax labor costs in the short run despite the wage increase. The REA economic activity and inflation, not reported, increase, because of higher exports towards the home region. The spillover effects are relatively small.[39] The EA monetary policy rate slightly increases.

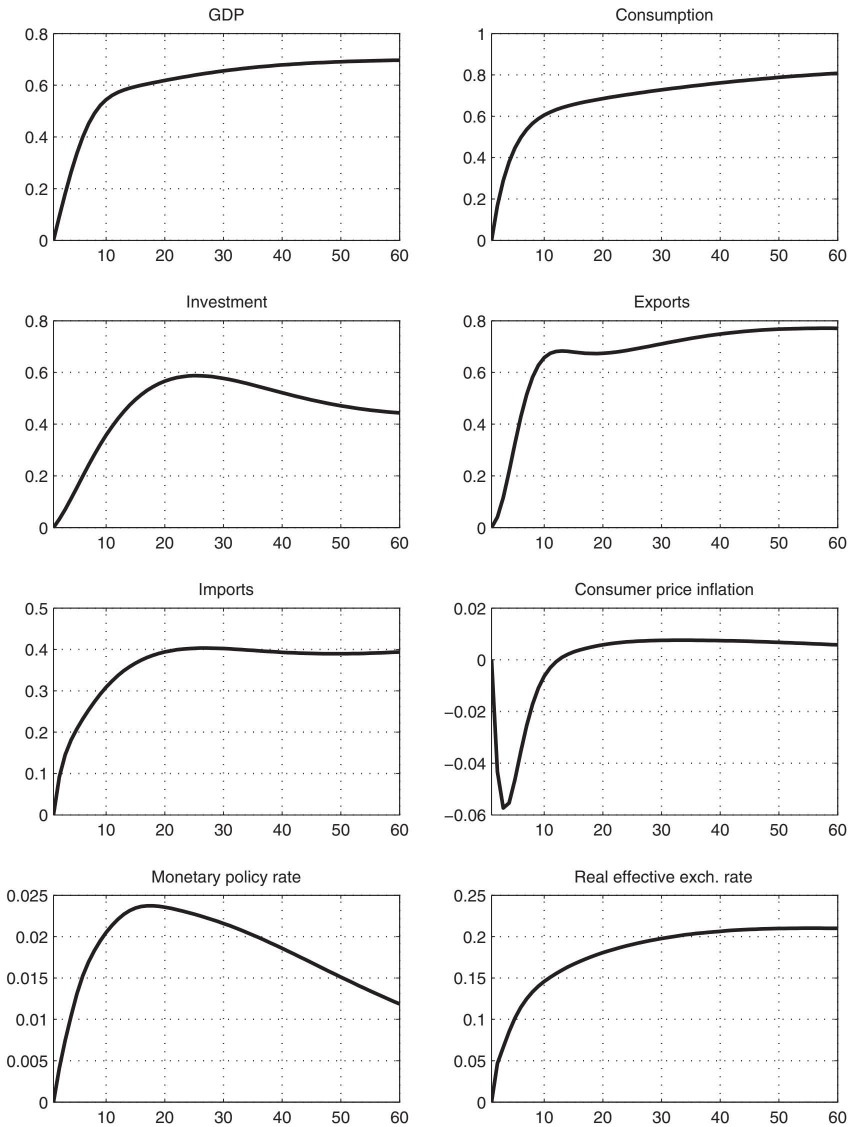
Overall, the reduction in the labor tax rate paid by home firms has non-negligible expansionary effects on both employment and economic activity. These effects characterize not only the new long-run equilibrium but also the transition (equilibrium) dynamics.

3.1.2 Decrease in the Labor Tax Rate Paid by Home Households

Figure 5 reports the effects of gradually and permanently reducing the labor tax rate paid by home households. The tax rate decrease is equal to almost 2 percentage points (trough level). Qualitatively, results are similarly expansionary as those obtained when reducing labor taxes paid by firms. Hours worked, employment, matches, and the probability of finding a job increase, while the probability of filling a vacancy decreases. The only qualitative difference is the response of the real wage. Unlike in the previous scenario, in which it increases, now the real wage decreases for the following reason.

[39]To save space, we do not report them. They are available upon request.

Figure 4. Decrease in the Labor Tax Rate Paid by Home Firms: Macroeconomic Variables



Notes: Horizontal axis: quarters. Inflation and interest rate are in annualized percentage-point deviations from the initial steady state. The remaining variables are in percent deviations.

Table 9. Long-Run Responses, Reduction of Labor Taxes Paid by Firms

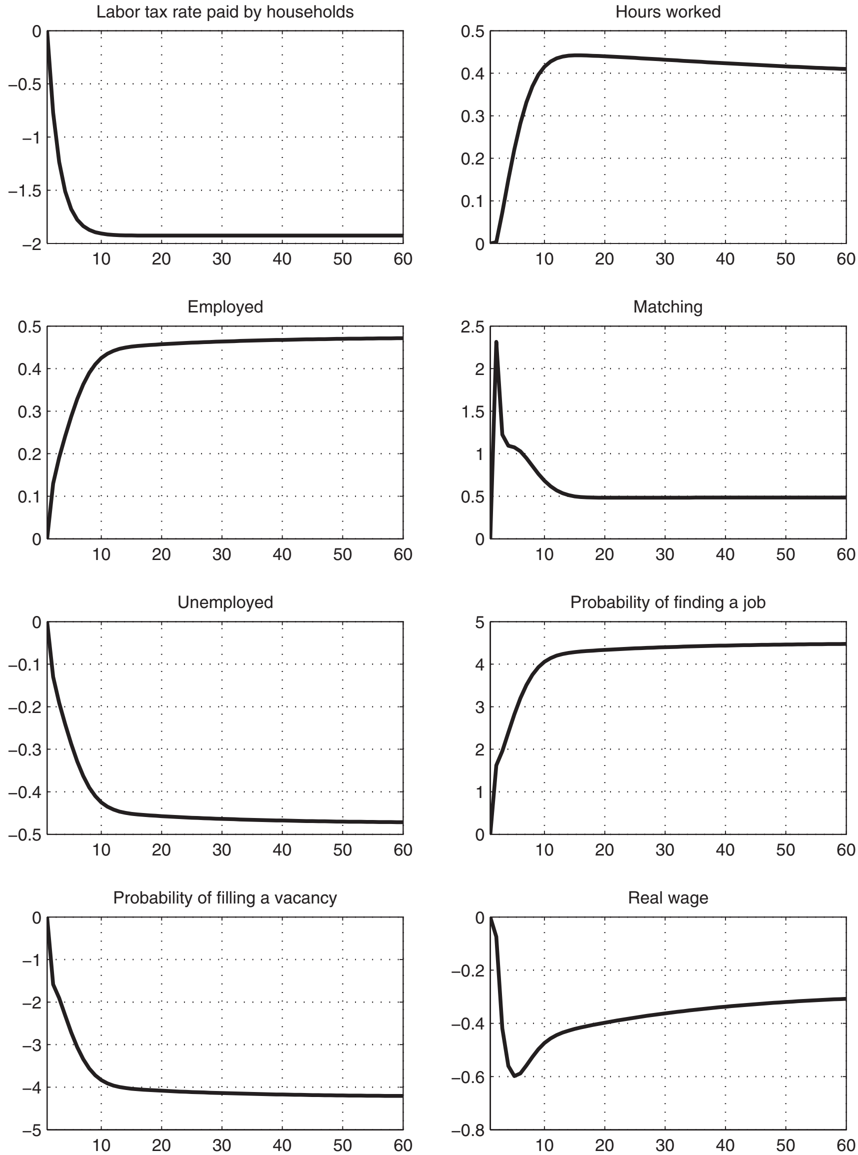
Variable	Flexible Benefits	Constant Benefits
Output	0.54	0.71
Consumption	0.67	0.87
Investment	0.33	0.44
Export	0.57	0.74
Import	0.34	0.45
Wages	1.47	1.40
Employment Rate (pp)	0.11	0.36
Matches	0.11	0.36
Hours Worked	0.40	0.28

Notes: All are percent deviations from the initial steady state, except employment rates, which are in percentage points of labor force. Hours are hours per worker.

The reduction in taxes paid by households increases the after-tax wage income of households and therefore their asset values of being employed and unemployed. The value of being employed increases by more, and part of this surplus of households is shared with firms during wage negotiations, causing a decrease in (pre-tax) real wages. Moreover, because households have an incentive to increase their labor supply given the lower taxation, hours worked increase by more than in the previous scenario. The reduction in real wages induces firms to increase employment by more than in the previous scenario. Hours worked now increase by 0.4 percent (0.3 percent in the previous simulation), and employment increases by almost 0.5 percent (0.35 percent in the previous simulation), while the unemployment rate falls by almost 0.5 percentage points (0.4 percentage points in the previous simulation).

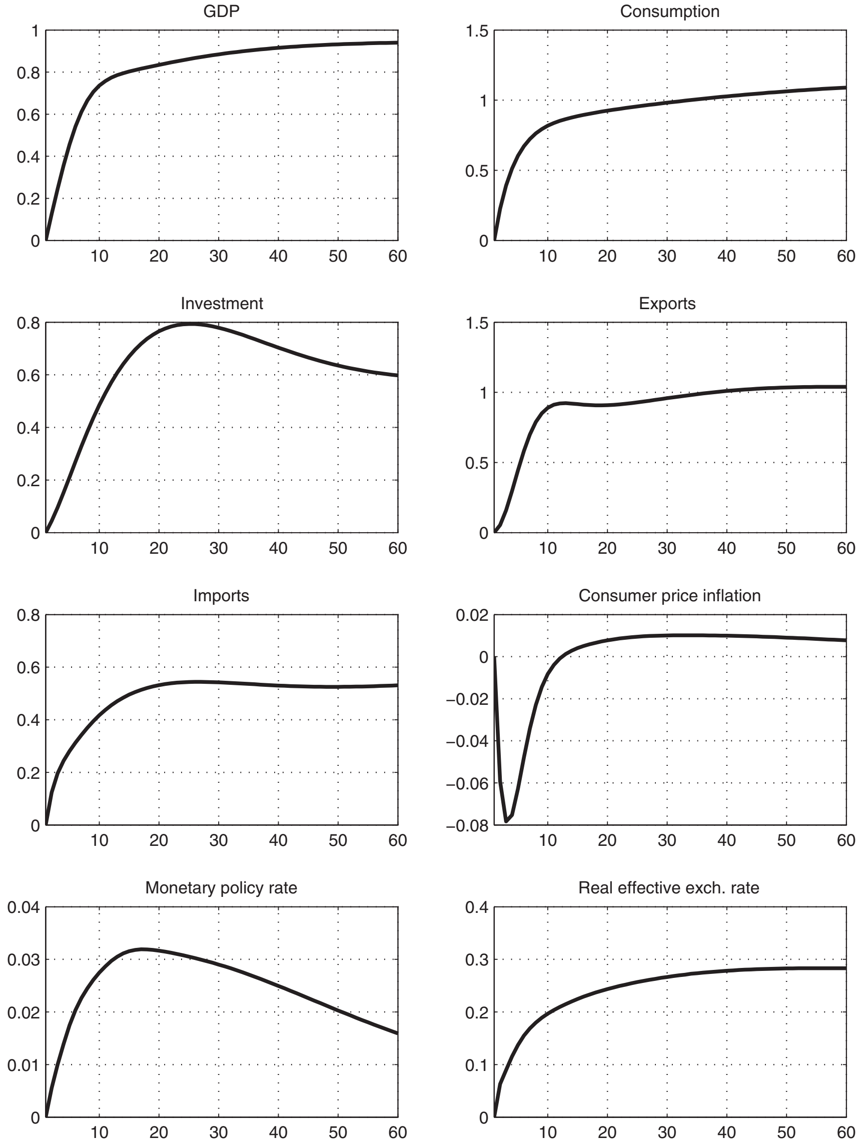
Figure 6 shows the effects on the main macroeconomic variables. They are expansionary. The effects on GDP and its components are larger than those obtained when reducing labor tax rates paid by firms, consistent with the responses of hours worked and employment. Home GDP increases by around 0.7 percent after two years, and by almost 1 percent in the long run (see table 10, column labeled "Constant Benefits"). These results are within the range of values reported in Kilponen et al. (2015) and are larger than

Figure 5. Decrease in the Labor Tax Rate Paid by Home Households: Labor Market Variables



Notes: Horizontal axis: quarters. Tax rate, probabilities, employment, and unemployment rates are in percentage-point deviations from the initial steady state. The remaining variables are in percent deviations.

Figure 6. Decrease in the Labor Tax Rate Paid by Home Households: Macroeconomic Variables



Notes: Horizontal axis: quarters. Inflation and interest rate are in annualized percentage-point deviations from the initial steady state. The remaining variables are in percent deviations.

Table 10. Long-Run Responses, Reduction of Labor Taxes Paid by Households

Variable	Flexible Benefits	Constant Benefits
Output	0.98	0.96
Consumption	1.21	1.18
Investment	0.60	0.59
Export	1.03	1.00
Import	0.62	0.60
Wages	–0.29	–0.27
Employment Rate (pp)	0.53	0.49
Matches	0.53	0.49
Hours Worked	0.37	0.39

Notes: All are percent deviations from the initial steady state, except employment rates, which are in percentage points of labor force. Hours are hours per worker.

the results reported there for Germany. Finally, lower wages reduce marginal costs of firms and temporarily cause a small decrease in inflation.[40]

3.2 EA-wide Decrease in Tax Rates and the Monetary Policy Stance

We report the effects of a simultaneous reduction in home and REA labor taxes paid by firms and, alternatively, households. Initially, we assume that the EA monetary policy sets the policy rate according to the Taylor rule (equation (25)). Subsequently, we simulate the two tax reductions under the assumption that the EA monetary authority keeps the policy rate constant at its baseline level during the first eight quarters. From quarter 9 onwards, the policy rate resumes following the Taylor rule.

[40] Note that inflation decreases in the short run for different reasons than in the previous simulation. After the reduction in labor taxes paid by firms, inflation declines because marginal costs of firms after taxes are lower (not because wages decline). When labor taxes paid by households are reduced, marginal costs of firms decline because wages paid by firms (before the household wage tax) decline (but note that after-tax take-home wages are still higher for households).

3.2.1 Standard Monetary Policy

Decrease in the Labor Tax Rate Paid by EA Firms. Figures 7 and 8 report results when the labor tax rate paid by firms is simultaneously reduced in both home and REA regions. The responses of the labor market variables, shown in figure 7, are similar among the two regions. The tax rate reduction favors employment and hours worked in the short run and in the long run. Similarly, aggregate economic activity, shown in figure 8, is stimulated in both regions, in the short run and in the long run.

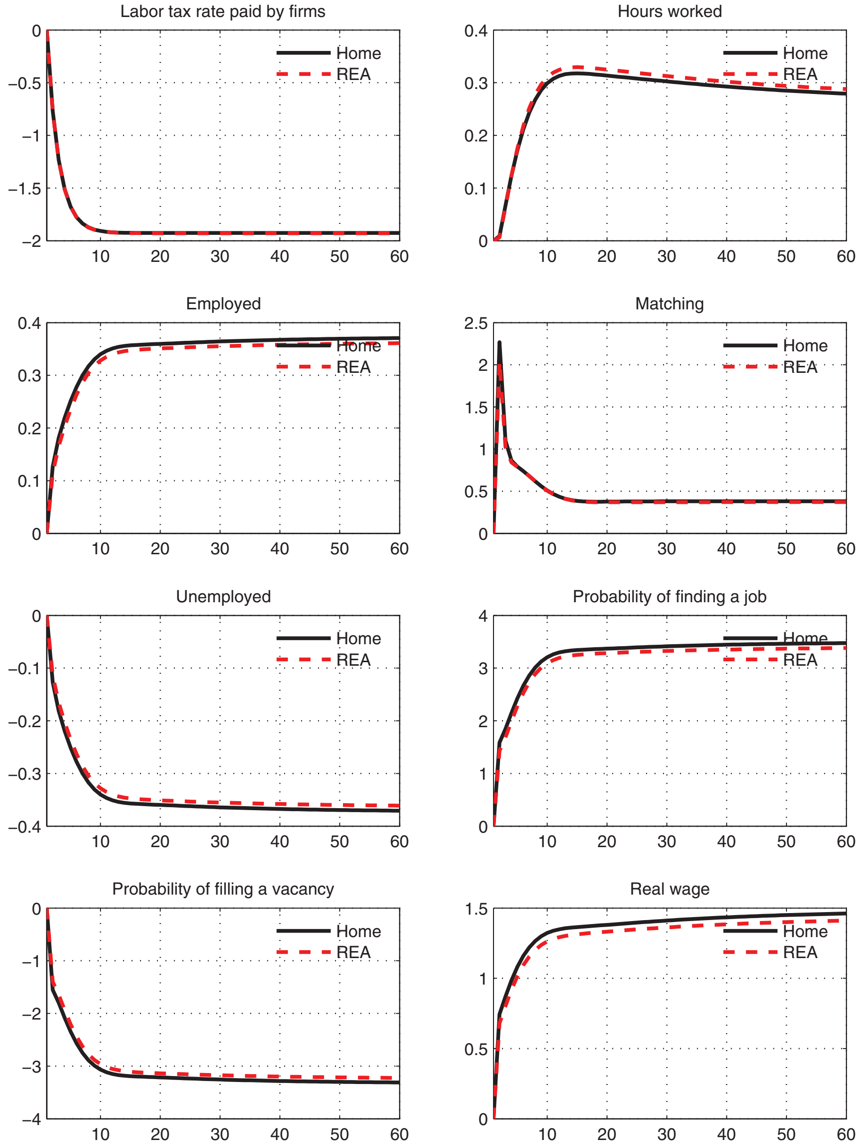
Relative to the case of home tax reduction, the short-run effects on home GDP are larger (compare with figures 3 and 4). Home households' purchasing power benefits from the lower deterioration of relative prices against the REA, as also the REA supply side expands and home is integrated with the REA through trade. This is why home aggregate demand for consumption and investment increases relatively more. The larger increase in home aggregate demand is matched by a larger increase in home employment and physical capital, and by higher imports. Home exports increase to a larger extent as well, because of the increase in REA aggregate demand. Effects on inflation are rather contained.[41]

Effects on the main REA macroeconomic variables are similar to those of the home region. In particular, REA inflation increases, favored by the increase in aggregate demand. The monetary policy rate is raised in a rather mild but persistent way, to stabilize the economy.

Decrease in the Labor Tax Rate Paid by EA Households. Figures 9 and 10 report results when the labor tax rate paid by households is simultaneously reduced in both home and REA regions. The responses of the labor market variables and the aggregate economic activity are similar among the two regions. The tax rate reduction favors employment, and hours worked increase in the short run and in the long run. Output, consumption, investment, and trade increase.

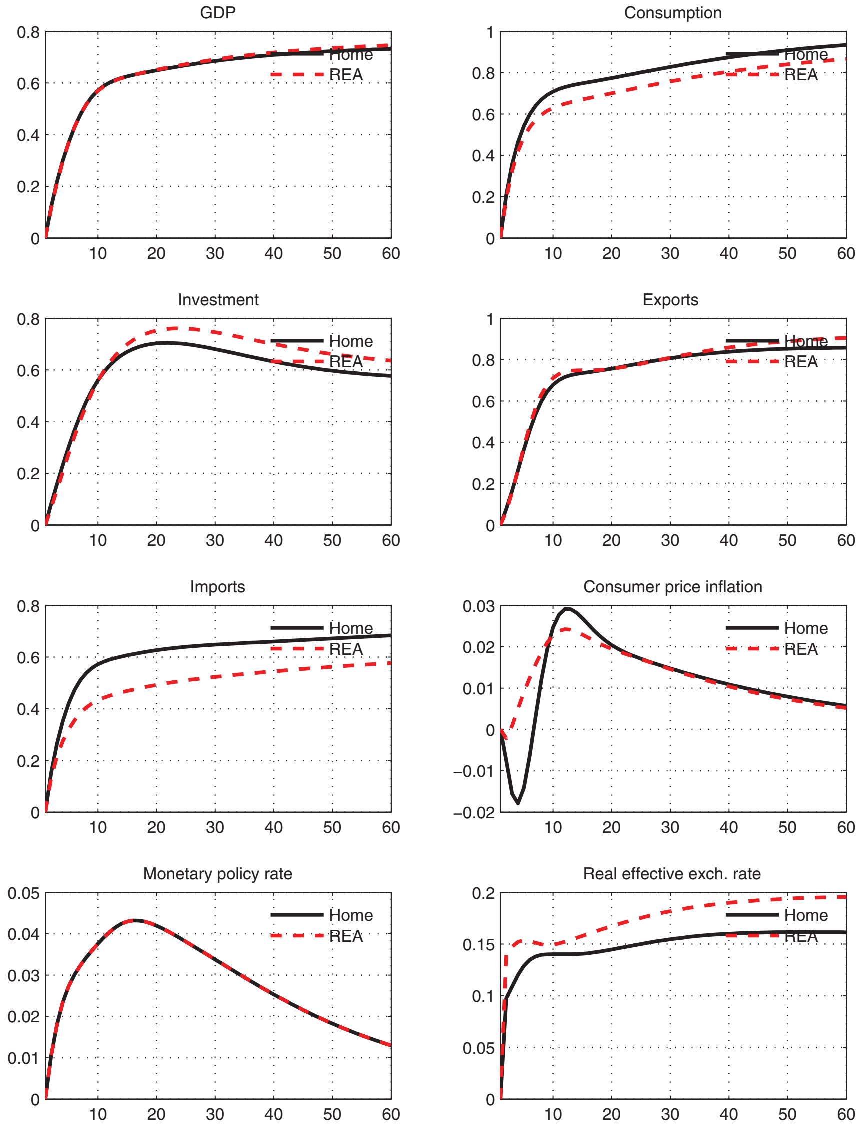
[41] Importantly, the larger increase in aggregate demand reduces the decrease in home inflation on impact and favors its larger increase in the short run. The less deflationary path is favored also by the "imported" inflation, associated with the larger effective depreciation of the euro in nominal and real terms (the depreciation allows to absorb the increase in EA production).

Figure 7. Decrease in the Labor Tax Rate Paid by EA Firms: Labor Market Variables



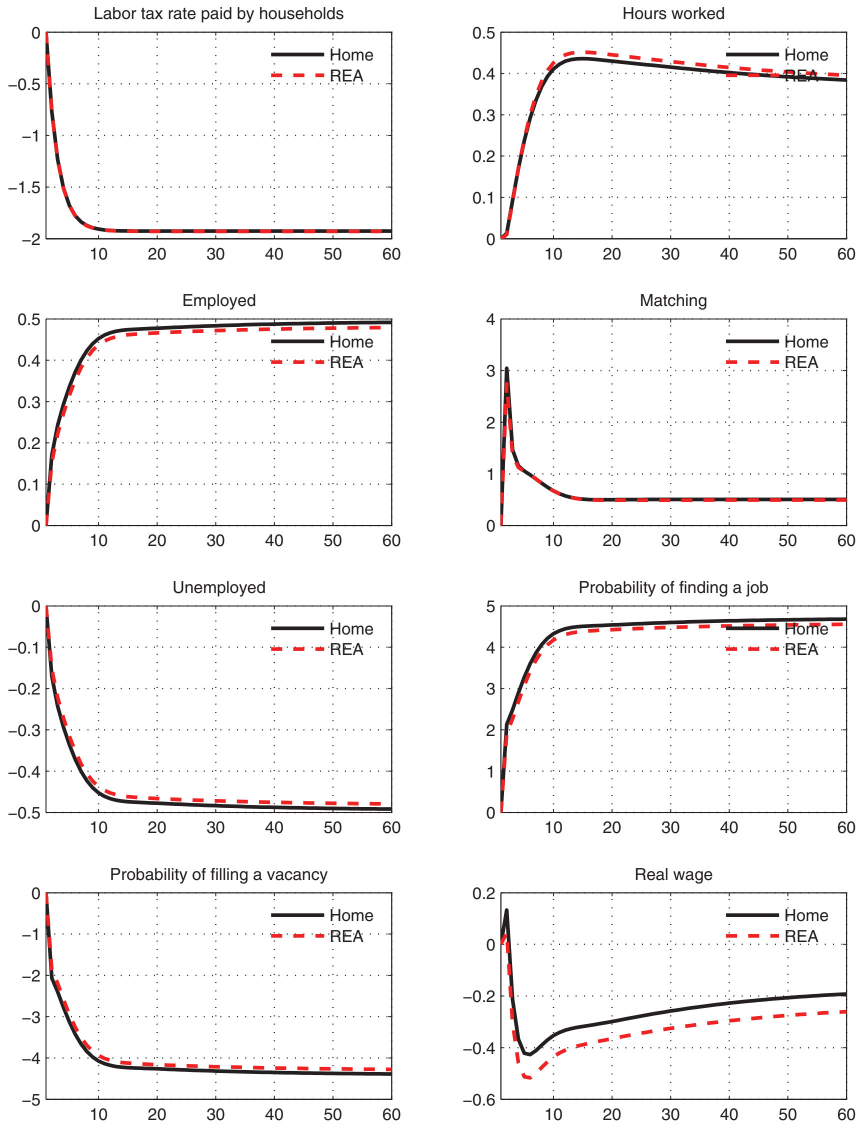
Notes: Horizontal axis: quarters. Tax rate, probabilities, employment, and unemployment rates are in percentage-point deviations from the initial steady state. The remaining variables in percent deviations.

Figure 8. Decrease in the Labor Tax Rate Paid by EA Firms: Macroeconomic Variables



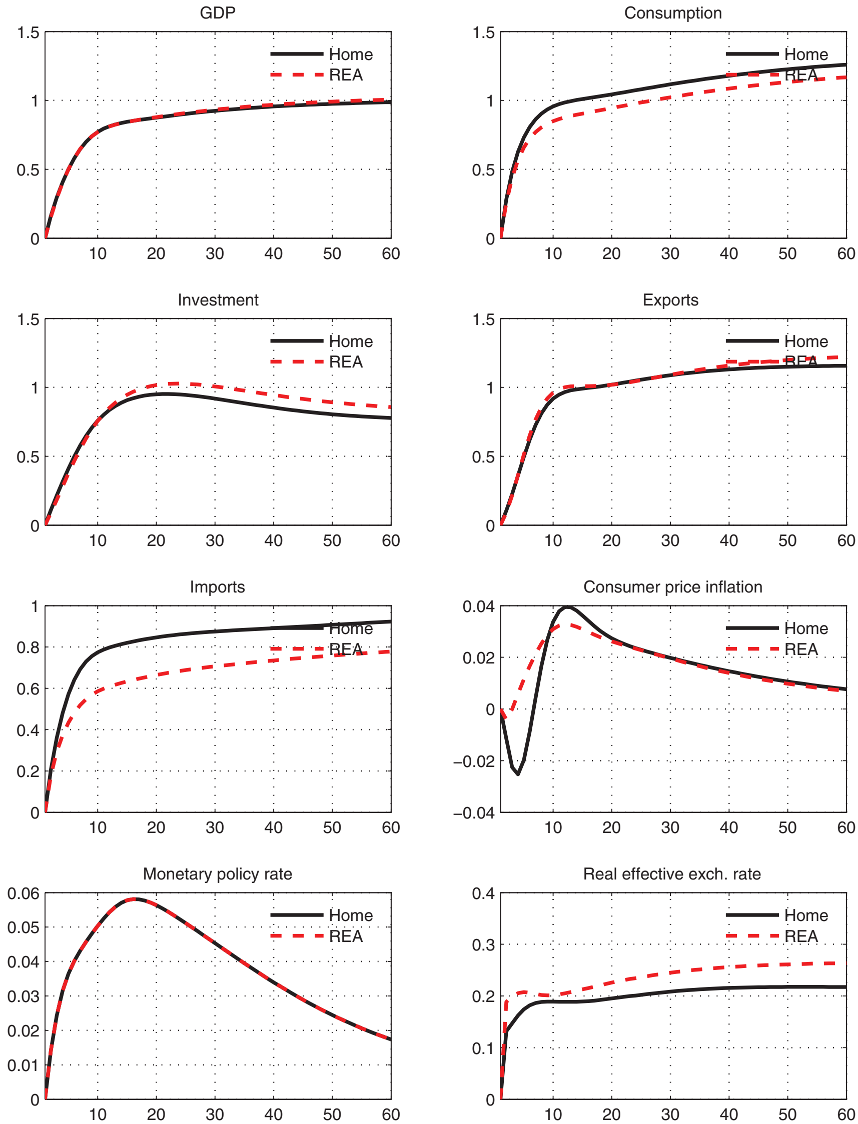
Notes: Horizontal axis: quarters. Inflation and interest rate are in annualized percentage-point deviations from the initial steady state. The remaining variables are in percent deviations.

Figure 9. Decrease in the Labor Tax Rate Paid by EA Households: Labor Market Variables



Notes: Horizontal axis: quarters. Tax rate, probabilities, employment, and unemployment rates are in percentage-point deviations from the initial steady state. The remaining variables are in percent deviations.

Figure 10. Decrease in the Labor Tax Rate Paid by EA Households: Macroeconomic Variables



Notes: Horizontal axis: quarters. Inflation and interest rate are in annualized percentage-point deviations from the initial steady state. The remaining variables are in percent deviations.

Relative to the case of the unilateral home tax decrease, the short-run increase in home employment and GDP is larger (compare with figures 5 and 6). The mechanism is similar to that of the reduction in labor taxes paid by home firms. Under the EA-wide reduction in labor taxes paid by households, home aggregate demand increases by more than under the unilateral home tax reduction because of the improvement in the purchasing power, favored by the lower deterioration in relative prices against the REA. The larger home demand is satisfied partially by increasing production (employment and capital accumulation increase to a larger extent) and partially by a larger increase in home imports.

The impact on the home inflation rate is quite limited, because the increase in aggregate demand is satisfied by an almost equal increase in aggregate supply.[42]

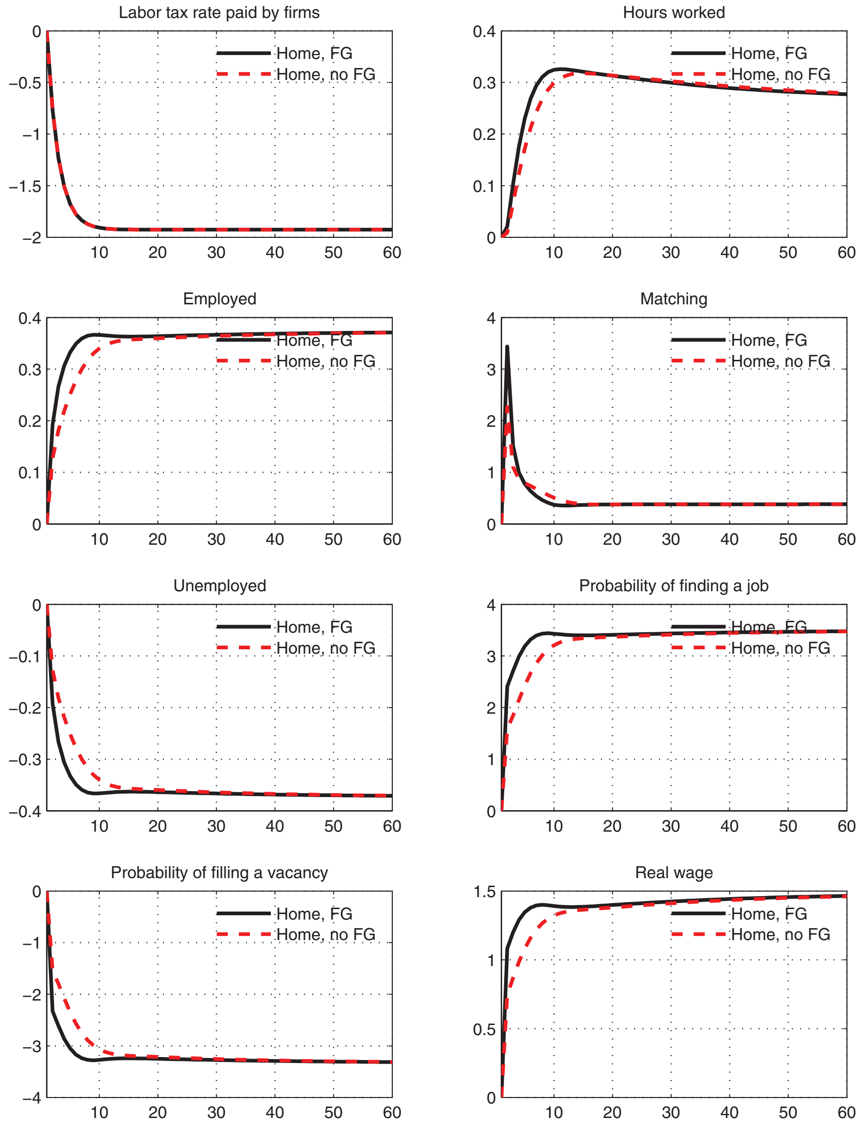
3.2.2 Coordinating Fiscal and Monetary Policy Measures

We now assume that the EA monetary authority announces to keep the policy rate constant at its baseline level during the initial eight quarters and to set it according to the Taylor rule from quarter 9 onwards. We label this announcement as forward guidance (FG).

Figures 11 an 12 report the home responses when labor taxes paid by EA firms are reduced (results for the REA are similar and, to save space, we do not report them). The black continuous line shows the responses under the FG assumption, and the red dashed line under the Taylor rule assumption (figures appear in color in the online version, available at http://www.ijcb.org). The responses are more front-loaded and larger under the FG than under the Taylor rule. Thus, the FG has stronger short- and medium-run expansionary effects. Households and firms anticipate that, under the FG, the nominal interest rate will be much lower in the initial periods than in the medium and long run. Thus, they have an incentive to immediately increase consumption and investment, given the stimulus

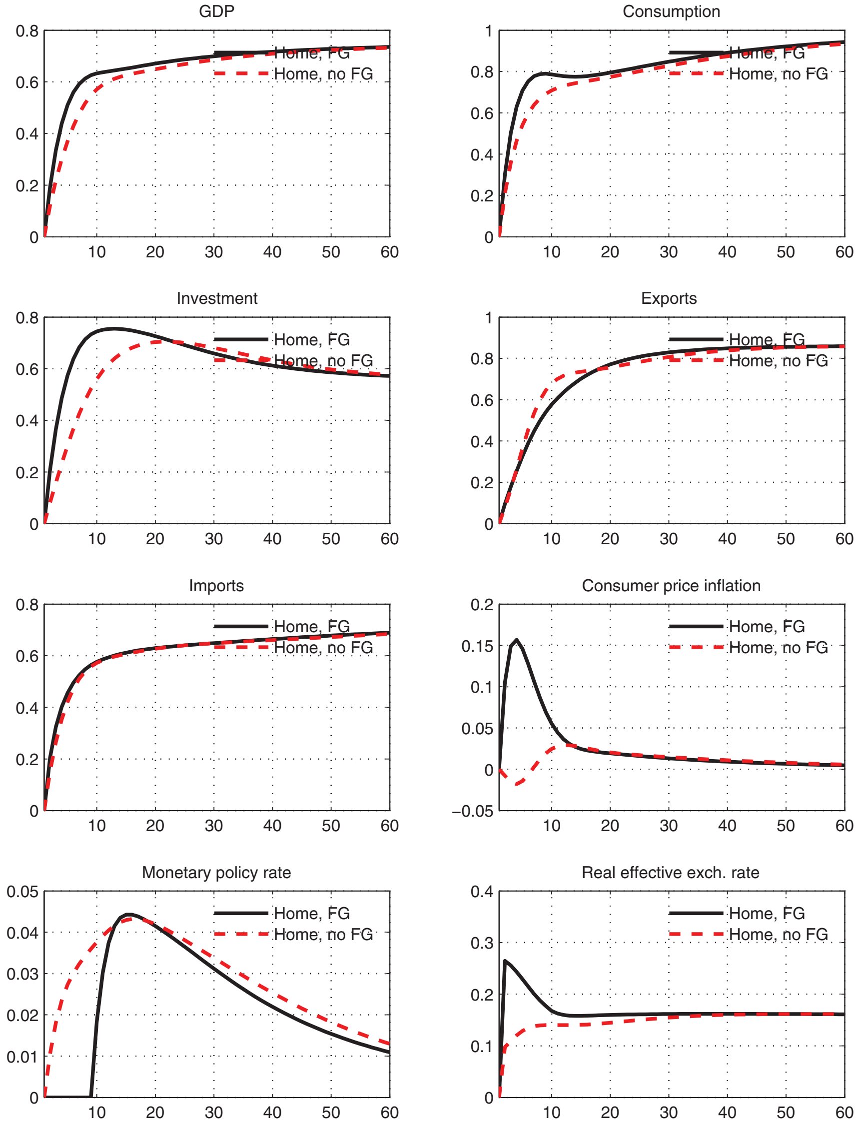
[42]Home inflation rises relatively more in the case of coordination than in the case of unilateral home tax reduction. In the REA, inflation increases, stimulated by the increase in aggregate demand. The larger depreciation of the euro in effective terms further contributes to the increase in home and REA inflation. The EA policy rate, which reacts to output increase and the inflation rate, slightly and persistently increases.

Figure 11. Decrease in the Labor Tax Rate Paid by EA Firms, Forward Guidance: Labor Market Variables



Notes: Horizontal axis: quarters. Tax rate, probabilities, employment, and unemployment rates are in percentage-point deviations from the initial steady state. The remaining variables are in percent deviations.

Figure 12. Decrease in the Labor Tax Rate Paid by EA Firms, Forward Guidance: Macroeconomic Variables



Notes: Horizontal axis: quarters. Inflation and interest rate are in annualized percentage-point deviations from the initial steady state. The remaining variables are in percent deviations.

provided by the tax reduction. The relatively large increase in inflation and the constant nominal interest rate reduce the expected real interest rate. This reduction further magnifies the incentive to increase aggregate demand in the short run. Consumption, investment, and inflation increase relatively more under the FG than under the Taylor-rule assumption. Given that the EA interest rate does not increase under the FG, the EA nominal (and real) exchange rate depreciates to a larger extent. The depreciation contributes to the increase in home inflation because of the increase in the price of home imports from the US and the RW. It also contributes to limit the increase in home imports and works in favor of exports by improving the price competitiveness. Imports benefit from the larger increase in aggregate demand, while exports are penalized by the larger increase in prices, associated with the larger increase in aggregate demand. The net effect of these mechanisms is that, under the FG, both imports and exports increase similarly as under the Taylor rule.

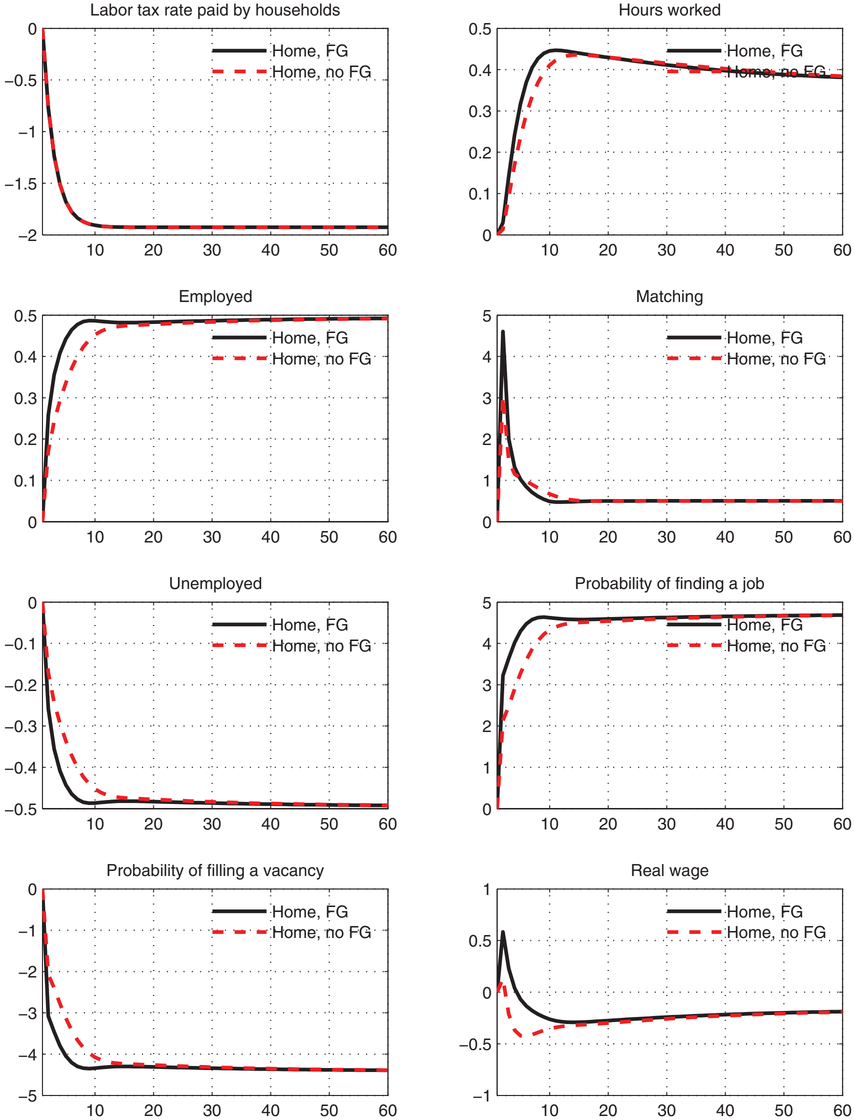
A similar picture emerges when labor taxes paid by EA households are reduced. The results for home are reported in figures 13 and 14. The FG again amplifies the expansionary effects of the tax-based stimulus through the same mechanism. The lower real interest rate stimulates aggregate demand, leading to short-run responses of labor market and macroeconomic variables being larger under the FG than under the standard Taylor rule.

Overall, we find that the monetary policy stance is very important for the short-run effectiveness of the tax reductions. The more accommodative the monetary policy is, the more stimulating are the tax reductions. Moreover, they are also not deflationary.

3.3 Tax Reductions and Public-Sector Employment

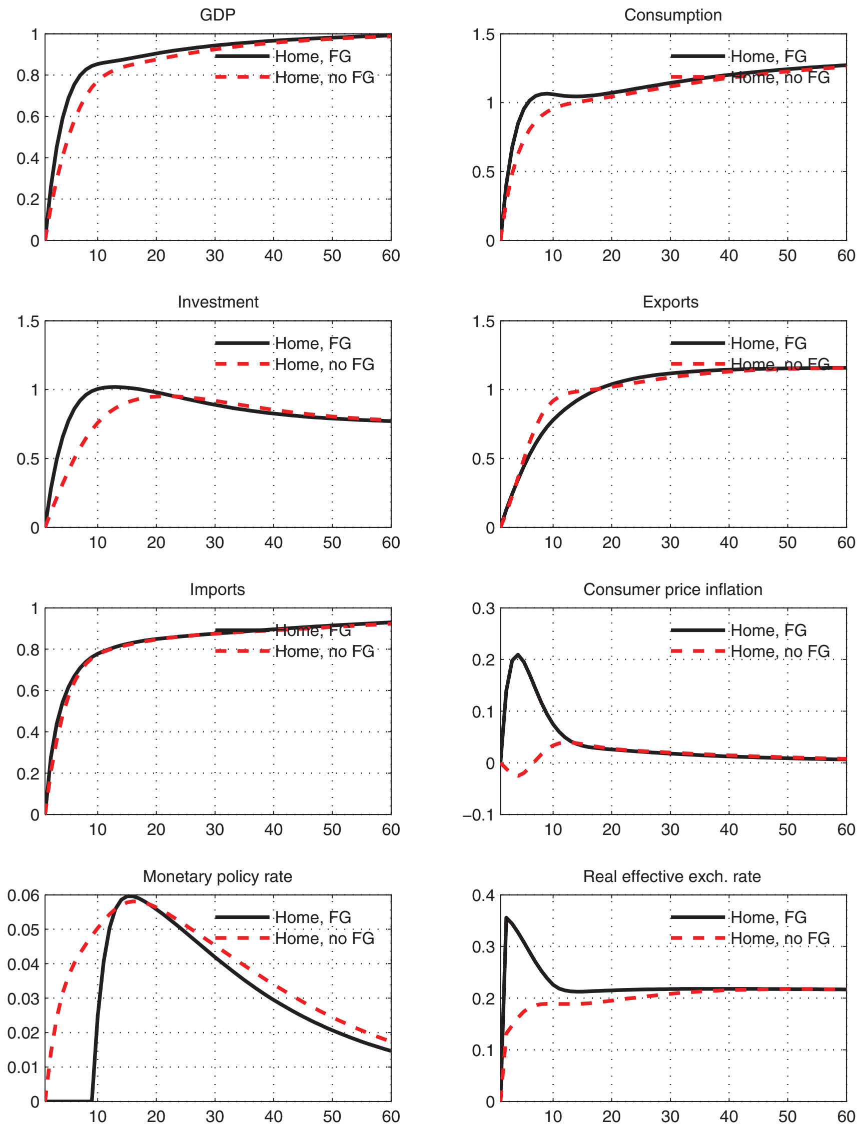
In this section we compare the results obtained by simulating the model without public employment with those obtained by simulating the model with public-sector employment. Recall that there are three key differences among the two models. First, workers can move across the two sectors. Second, the public-sector labor market is characterized by lower matching efficiency, which reflects the longer queuing for public-sector vacancies reported in the literature, and by lower elasticity of the matching function with respect to

Figure 13. Decrease in the Labor Tax Rate Paid by EA Households, Forward Guidance: Labor Market Variables



Notes: Horizontal axis: quarters. Tax rate, probabilities, employment, and unemployment rates are in percentage-point deviations from the initial steady state. The remaining variables are in percent deviations.

Figure 14. Decrease in the Labor Tax Rate Paid by EA Households, Forward Guidance: Macroeconomic Variables



Notes: Horizontal axis: quarters. Inflation and interest rate are in annualized percentage-point deviations from the initial steady state. The remaining variables are in percent deviations.

unemployment in the public sector.[43] The latter, together with reallocation of workers across sectors, can play an important role in explaining the differences among the models. Third, as discussed in section 2, public-sector employment and vacancies are determined by the government, and public-sector wages follow a wage norm.

In this section, we report results where public-sector wages follow private-sector wages and where public-sector vacancies remain unchanged. Unemployment benefits also remain unchanged. We analyze the results when this is not the case in the next section. To save space, we only report unilateral tax changes in the home region when the EA monetary policy rate is set according to the Taylor rule.[44]

3.3.1 Decrease in the Labor Taxes Paid by Home Firms

Figures 15 and 16 report the results of the model with public employment (the full model) compared to the results of the model without public employment (the basic model).

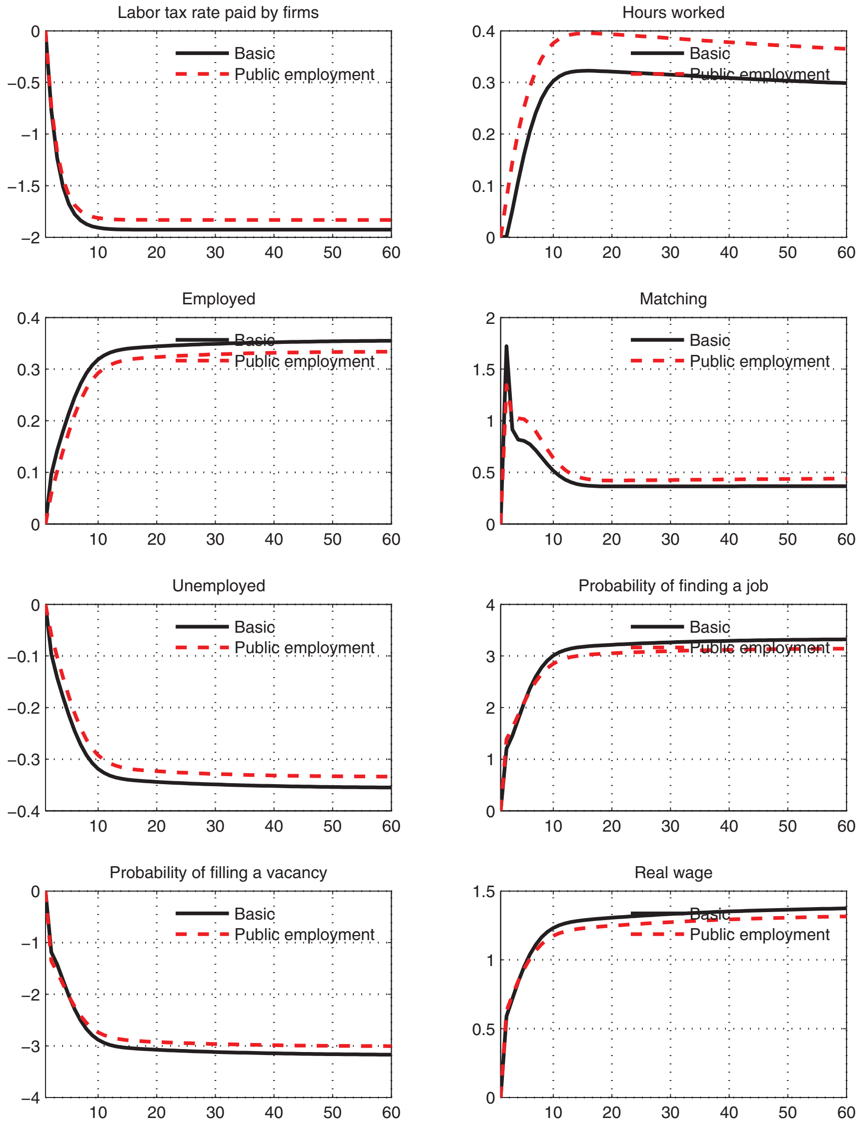
The transmission mechanism of lower labor taxes paid by home firms is similar to the one in the model without public employment. Given our assumptions that public-sector wages follow private-sector wages and that public-sector vacancies remain fixed, the results do not greatly differ across the two versions of the models.

The decrease in labor taxes paid by firms reduces their gross wage bill, and this reduction is partially shared in the bargaining process with workers, resulting in higher wages but, at the same time, lower marginal costs of firms. The latter lead to an increase in demand for labor in the private sector, which leads to higher employment in the private sector and lower unemployment overall. At the extensive margin (number of workers), some unemployed workers direct their search towards the private sector because of the relative increase in the matching probability for workers. This reallocation, however, is

[43]See Gomes (2015) and references therein. Lower matching efficiency is the result of longer queues for workers in the public sector, which are analogous to lower probabilities of finding a job. Lower matching elasticity with respect to unemployment in the public sector makes the role of public-sector vacancies bigger in determining employment in the public sector.

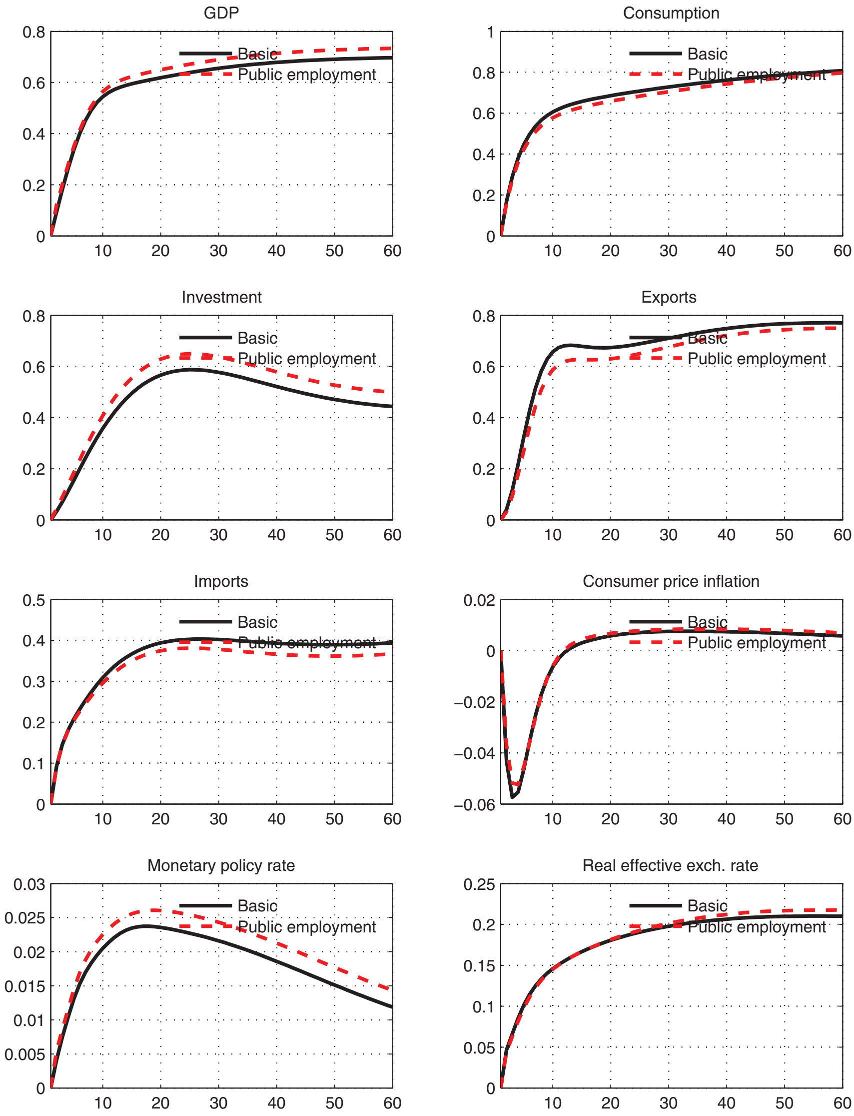
[44]The results for the EA-wide tax changes are qualitatively similar to those of the model without public employment, while quantitatively they tend to be somewhat more expansionary. Results for the EA-wide tax changes are available upon request.

Figure 15. Decrease in the Labor Tax Rate Paid by Home Firms, Full Model: Labor Market Variables



Notes: Horizontal axis: quarters. Inflation and interest rate are in percentage-point deviations from the initial steady state. The remaining variables are in percent deviations.

Figure 16. Decrease in the Labor Tax Rate Paid by Home Firms, Full Model: Macroeconomic Variables



Notes: Horizontal axis: quarters. Tax rate, probabilities, employment, and unemployment rates are in percentage-point deviations from the initial steady state. The remaining variables are in percent deviations.

relatively weak and does not have material effects on macroeconomic aggregates.

Note that in the model without public employment labor, firms sell labor services to intermediate goods firms at the price x_t, which decreases after the tax reduction. This in turn dampens the increase in demand for hours worked from labor firms. While this is still true for the private sector in the model with public employment, it is not true for the public sector. There, the price at which the labor firms sell labor services to the government is linked to private-sector wages. Because the latter increase, hours worked in the public sector increase, which leads to a stronger increase in average hours worked.[45]

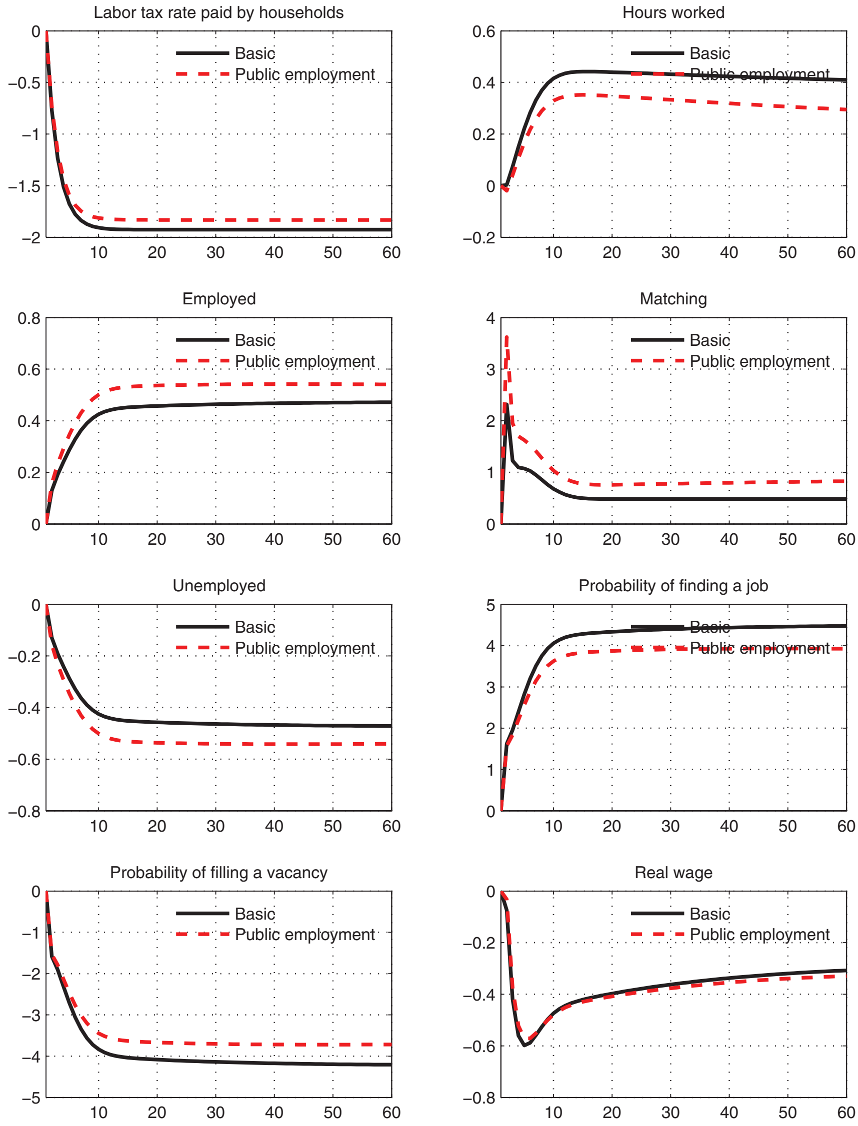
3.3.2 Decrease in the Labor Taxes Paid by Home Households

Figures 17 and 18 report the labor market and macroeconomic responses to the decrease in labor taxes paid by households. Responses of the model with public employment are shown together with those of the model without public employment. The reduction in labor taxes paid by households in the model with public employment triggers a transmission mechanism similar to that in the model without public employment. The reasons are that the wage norm and the public-sector vacancies remain unchanged. Overall, the effects on the macroeconomic aggregates are not greatly different from those in the model without public employment.

The main difference compared to the reduction in labor taxes paid by firms is that when labor taxes paid by households are reduced, negotiated wages *decrease*. However, the take-home wages, relevant for household decisions, increase. Wage decrease has stimulative effects on labor demand by firms, which post more vacancies, and leads to an increase in the probability of finding a job. This increase is lower than in the model without public employment, because there is some reallocation of workers from the public to the private sector.

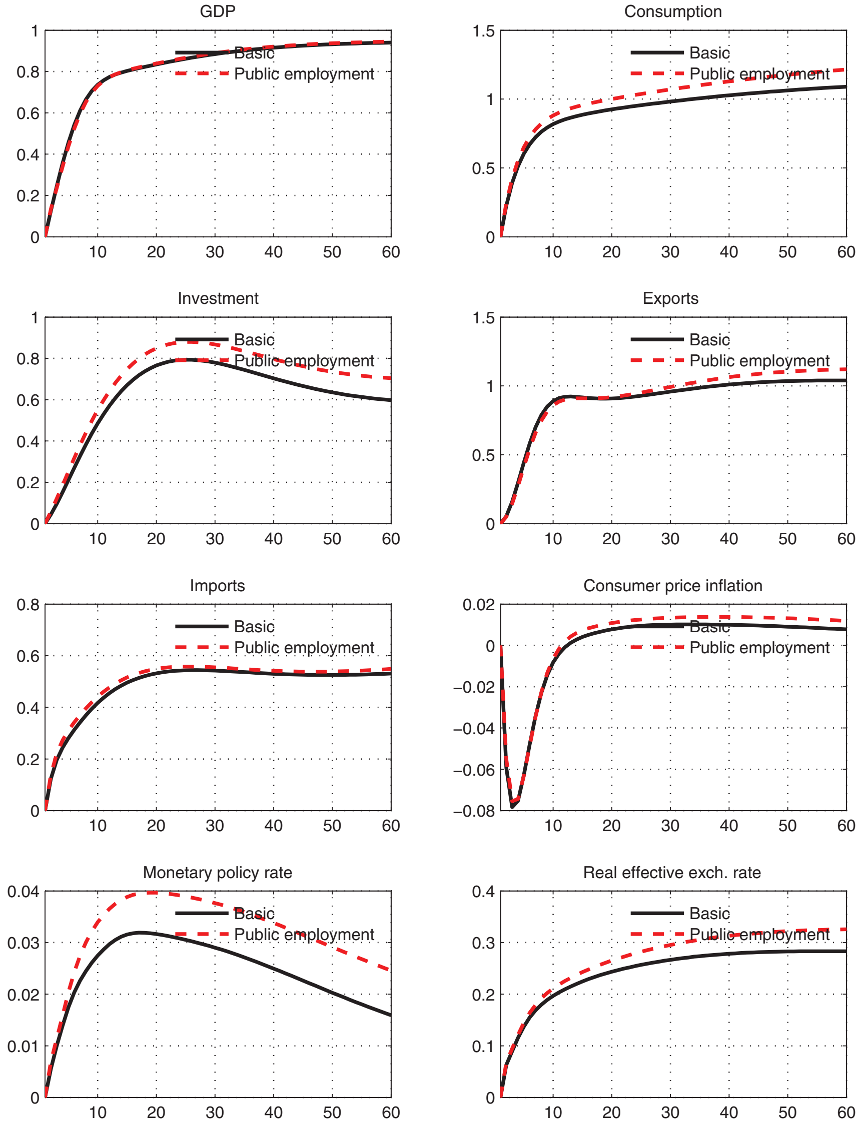
[45] If public-sector wages were linked to x_t instead of w_t, hours per worker would change identically in the public and in the private sector in the full model, due to our wage norm that public-sector wages follow private-sector wages ($\rho_{wG} = 1$ in equation (24)) and all other quantities that determine hours worked change identically in each sector (see equation (15) and footnote 26).

Figure 17. Decrease in the Labor Tax Rate Paid by Home Households, Full Model: Labor Market Variables



Notes: Horizontal axis: quarters. Inflation and interest rate are in percentage-point deviations from the initial steady state. The remaining variables are in percent deviations.

Figure 18. Decrease in the Labor Tax Rate Paid by Home Households, Full Model: Macroeconomic Variables



Notes: Horizontal axis: quarters. Tax rate, probabilities, employment, and unemployment rates are in percentage-point deviations from the initial steady state. The remaining variables are in percent deviations.

3.3.3 Sensitivity Analysis: Public-Sector Wages, Vacancies, and Unemployment Benefits

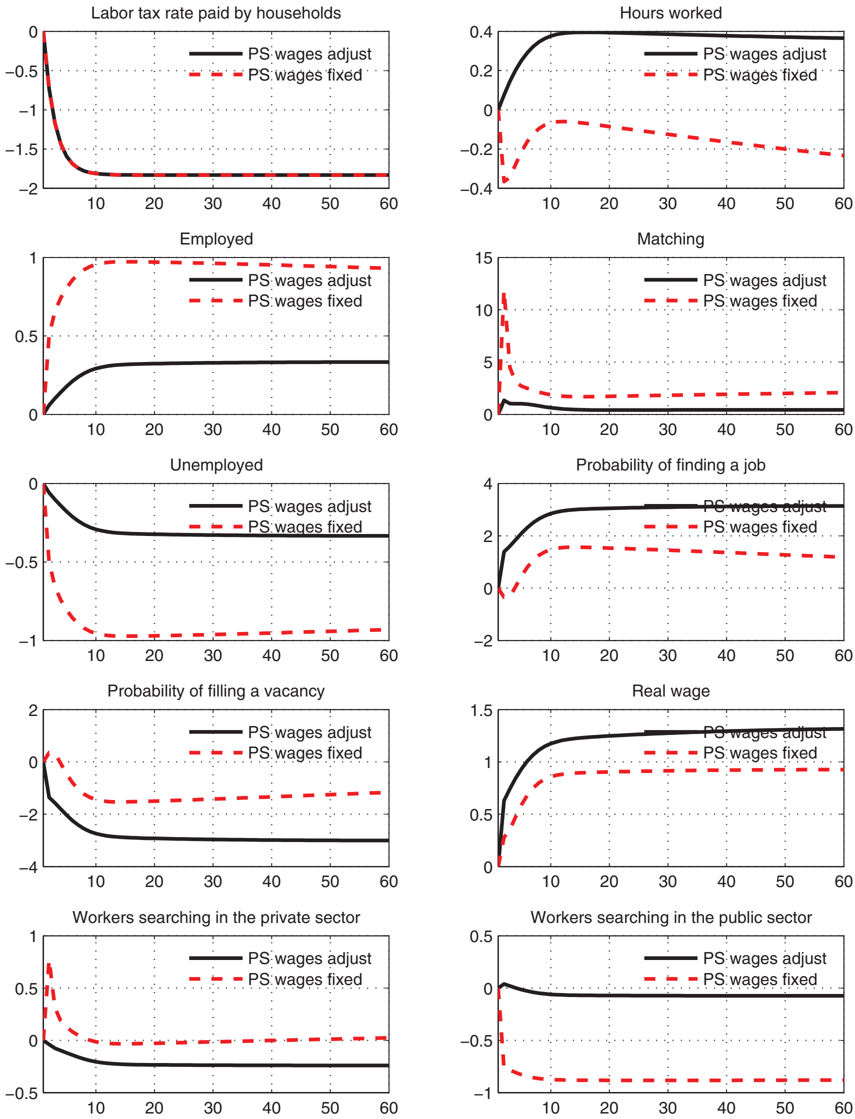
In the simulations presented above we assumed that public-sector wages follow a wage norm and that government policies regarding public-sector vacancies and unemployment benefits remain unchanged after the tax reduction. Whether this is realistic or not at business cycle frequencies is an open issue. Quadrini and Trigari (2007), for instance, find procyclical private-sector wages and only somewhat procyclical public-sector wages for the United States. They report similar findings for public-sector employment, with strongly countercyclical share of public-sector employment. Lamo, Pérez, and Schuknecht (2008) find that private- and public-sector wages in most OECD countries co-move, but that causality can go both ways. They even find some cases where public-sector wages are leading private-sector wages. In the long run, however, they find that private- and public-sector wages are cointegrated, i.e., they move together, which supports our modeling choice of the wage norm. In this section we investigate the effects of assumptions regarding public-sector wages, vacancies (employment), and unemployment benefits that are different from the assumptions in the main text. We make those assumptions exclusively to further illustrate the transmission mechanism of the model.

At the one extreme, we consider the case where public-sector wages, vacancies, and unemployment benefits all adjust to the level consistent with the steady state after the tax reduction. We call this the "flexible" case. We consider three other cases where, alternatively, (i) public-sector wages, vacancies, and unemployment benefits are fixed, (ii) only public-sector vacancies are kept fixed, and (iii) only unemployment benefits are kept fixed. In all cases, we focus on home country only and the case where monetary policy always follows the Taylor rule.

3.3.4 Reduction in the Labor Tax Rate Paid by Home Firms

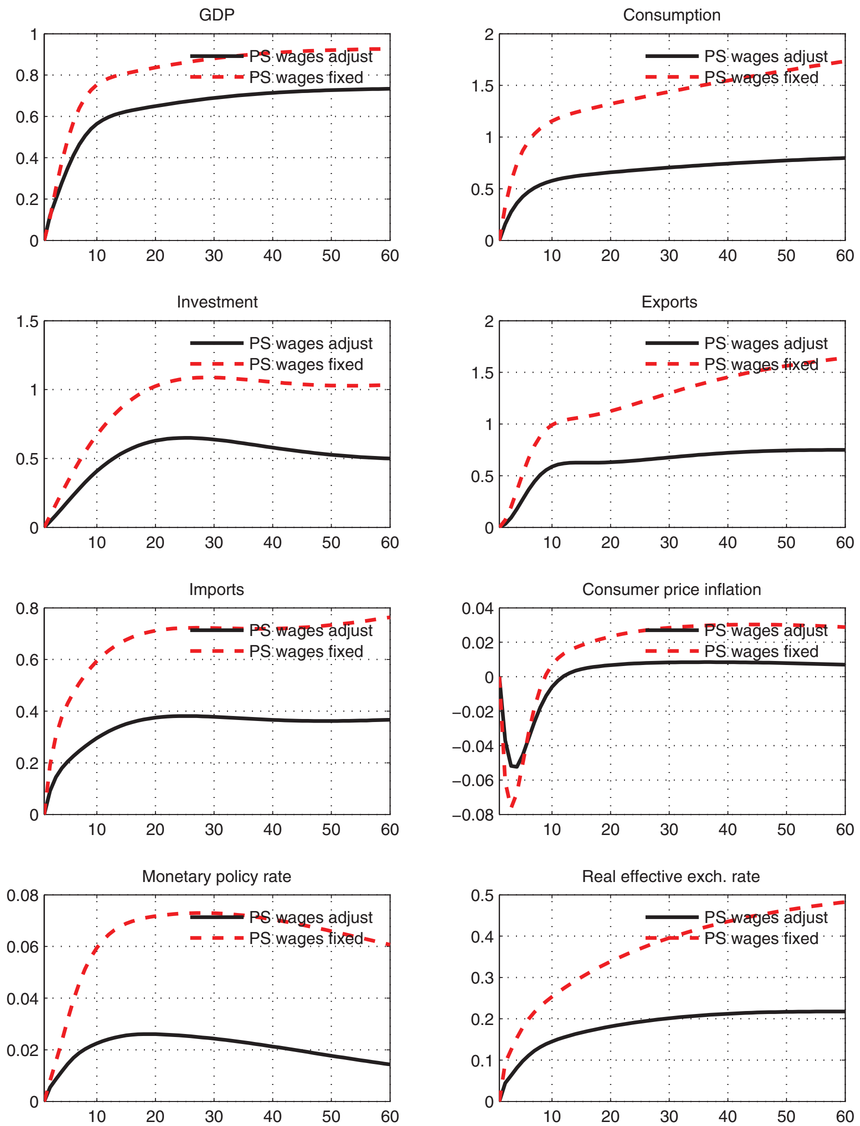
We first consider the case where public-sector wages, vacancies, and unemployment benefits remain fixed at initial levels after the reduction of labor taxes paid by firms. The results are shown in figures 19 and 20, and in the last column of table 11.

Figure 19. Decrease in the Labor Tax Rate Paid by Home Firms, Full Model: Labor Market Variables



Notes: Horizontal axis: quarters. Inflation and interest rate are in percentage-point deviations from the initial steady state. The remaining variables are in percent deviations.

Figure 20. Decrease in the Labor Tax Rate Paid by Home Firms, Full Model: Macroeconomic Variables



Notes: Horizontal axis: quarters. Tax rate, probabilities, employment, and unemployment rates are in percentage-point deviations from the initial steady state. The remaining variables are in percent deviations.

Table 11. Long-Run Responses, Reduction of Labor Taxes Paid by Firms

Variable	All Flexible	Vac. Fixed	Ben. Fixed	All Fixed
Output	0.57	0.57	0.75	0.97
Consumption	0.51	0.51	0.91	2.59
Investment	0.29	0.29	0.51	1.47
Export	0.42	0.41	0.74	2.14
Import	0.25	0.25	0.45	1.27
Private-Sector Wages	1.43	1.43	1.34	1.10
Public-Sector Wages	1.43	1.43	1.34	0
Employment Rate (pp)	0.05	0.05	0.33	0.83
Employment Rate in the Private Sector (pp)	–0.04	–0.05	0.40	2.34
Employment Rate in the Public Sector (pp)	0.09	0.10	–0.08	–1.51
Vacancies in Private Sector	1.65	1.65	4.94	3.26
Vacancies in Public Sector	–0.06	0	–0.06	0
Hours Worked	0.54	0.54	0.33	–0.56
Hours in Private Sector	0.46	0.46	0.23	–0.72
Hours in Public Sector	1.21	1.21	0.97	–0.52

Notes: All are percent deviations from the initial steady state, except employment rates, which are in percentage points of labor force. Hours are hours per worker.

Wages, vacancies (through matching probability), and unemployment benefits (through the outside option) are the most important variables that determine the value of employment in a particular sector, and through that also the value of searching in a particular sector. The reduction in labor taxes paid by firms leads to an increase in private-sector wages and vacancies. Unchanged wages and vacancies in the public sector imply that being employed in this sector has become less attractive. Both existing unemployed workers and workers who become separated direct their search towards the private sector. This causes the probability for a worker to find a job in the private sector to decrease in the short run and increase by much less in the long run compared to the case when public-sector wages and vacancies adjust.

In addition, unemployment benefits remain at the initial level, which corresponds to the initial (pre-tax-change) level of wages and is lower than the after-tax-change level of wages. This weakens the bargaining position of workers. Both effects result in a weaker bargaining position of workers in the private sector and lead to a lower increase in wages, which further stimulates demand for labor.

Both the number of searching workers in the private sector and the number of vacancies increase at the same time, which means that congestion effects are small. This is important, because typically the increase in vacancies is accompanied by the increase in labor market tightness, which results in congestion and leads to a smaller number of matches, given the number of searching workers.[46] The absence of congestion effects is one of the reasons why the number of new matches increases substantially. As a result, employment increases and unemployment decreases both in the short run and in the long run. In terms of total workforce, employment in the private sector increases by 2.3 percentage points in the long run and employment in the public sector decreases by 1.5 percentage points. Because of the reallocation, the net increase in employment (above the reallocation) is thus only 0.8 percentage points in the long run.

Macroeconomic variables are mainly driven by the labor market conditions. Aggregate production increases by more than when there is no reallocation and is met by demand, as consumption increases because both employment and wages increase (although the latter increases by less than when there is no reallocation).[47] Investment increases to supplement the increase in labor, which is stronger when there is reallocation.

[46] Congestion in the sector depends on the marginal productivity (elasticity) of the matching function. Suppose the number of vacancies is fixed. Then a large increase in the number of searching workers yields fewer new matches per worker than a small increase. In our case, because negotiated wages do not increase as much, the number of vacancies increases, which counters the congestion effects.

[47] Consumption also increases because, in the long run, government expenditure for public-sector wages is smaller due to lower public-sector employment when workers reallocate. Hours decrease when there is reallocation partly because of the stronger consumption increase, which causes a stronger wealth effect, and partly because of the lower wage increase in the private sector, which results in a stronger decrease in prices at which labor firms sell labor services to intermediate goods firms (x_t; see equation (15)).

We emphasize that the above result hinges on strong reallocation of workers. This is an artefact of two assumptions. First, wage bargaining in the public sector is switched off. Second, it is assumed that public-sector services have no benefits for the private sector. Thus, the reduction in public-sector employment has no direct effects on GDP beyond the reduction in the public-sector wage bill. If public services had benefits for the private sector (as in Bandeira et al. 2016), a reduction in public-sector employment would have negative effects. If we modeled wage bargaining in the public sector, the same reallocation of searching workers that dampens the wage increase in the private sector would *cause the wage increase in the public sector*. This would happen because workers in the public sector would become scarcer and their job-finding probability would increase. Wages in public and private sectors would tend to equalize.

Finally, there are efficiency concerns when there is reallocation that are not addressed (see also Albrecht, Robayo-Abril, and Vroman 2015). Workers most likely to reallocate from the public to the private sector would be the most productive ones, which implies that creating conditions where workers do not wish to stay in the public sector would disproportionally worsen the quality and quantity of public services. There is, for instance, evidence that recruitment and retention of highly skilled individuals is difficult in the public sector (Katz and Krueger 1991).

Efficiency of the matching process also plays an important role in the long run. Recall that we have calibrated the public-sector matching such that the queues for jobs in that sector are long (the matching probability for workers is low).[48] Reallocation is beneficial in the above case because it reduces congestion in the public sector (the matching probability for workers in the public sector increases by 4.8 percentage points in the long run), while not increasing congestion in the private sector because of the increase in vacancies (matching probability for workers increases by 0.3 pp). If we recalibrate the model so that the public-sector matching process is the same as in the private sector and keep public-sector wages fixed to induce reallocation, then the effects on long-run aggregate employment are

[48]The matching process in the private sector satisfies the Hosios condition, while the matching process in the public sector does not.

negative. The reason is that the increase in matching probabilities for workers in the public sector is small in this case (0.7 pp) while the matching probability for workers in the private sector falls (by 0.1 pp).[49]

The results of sensitivity exercises for the cases when only public-sector vacancies adjust and when only unemployment benefits adjust to the new level are shown in the middle columns of table 11. The sensitivity experiment with respect to public-sector vacancies has negligible effects (the difference between the first and the second column is only with respect to sectoral employment). The reason is that public-sector vacancies do not have to change much when public-sector wages follow the wage norm, and the reallocation due to the change in the number of public-sector vacancies is small. The results with respect to changes in unemployment benefits are larger, and the direction is predictable (see the third column of table 11). Because wages increase after the reduction in labor taxes paid by firms, unemployment benefits increase as well when replacement ratios are kept constant. This improves the outside option of workers, who can negotiate higher wages. If this effect is absent, then the outside option of workers is worth less and negotiated wages do not increase as much. This in turn stimulates vacancy posting and increases employment in general and in the private sector in particular. Note that the increase in output if unemployment benefits are kept fixed is responsible for about half of the output increase when all of the variables related to the public sector are kept fixed.[50]

[49]The model was recalibrated so that the matching probability for workers and firms in the private and in the public sector is the same (0.7), which implies that the productivity of the matching function is also the same in both sectors. Because the private-sector matching satisfies the Hosios condition, if public-sector wages follow private-sector wages, this condition is satisfied in the public sector as well. When we keep public-sector wages fixed, this induces reallocation and therefore departure from the allocation consistent with the Hosios condition in the long run. The results are available upon request.

[50]Higher unemployment benefits also tend to favor reallocation of searching workers towards the public sector. The intuition is that when unemployment benefits are higher, it is less costly to search in the public sector, where the probability of finding a job is lower. Formally, because $(1 - p_t^{G,W})$ in equation (21) is larger than $(1 - p_t^{P,W})$, the change in the value of being unemployed has a stronger effect on the value of being in the public sector.

Table 12. Long-Run Responses, Reduction of Labor Taxes Paid by Households

Variable	All Flexible	Vac. Fixed	Ben. Fixed	All Fixed
Output	1.00	0.97	0.97	0.91
Consumption	1.51	1.45	1.44	1.11
Investment	0.81	0.78	0.77	0.59
Export	1.23	1.17	1.16	0.90
Import	0.74	0.71	0.70	0.54
Private-Sector Wages	–0.31	–0.29	–0.29	–0.24
Public-Sector Wages	–0.31	–0.29	–0.29	0
Employment Rate (pp)	0.58	0.52	0.52	0.40
Employment Rate in the Private Sector (pp)	0.88	0.80	0.79	0.42
Employment Rate in the Public Sector (pp)	–0.31	–0.28	–0.27	–0.03
Vacancies in Private Sector	7.14	6.42	6.43	6.72
Vacancies in Public Sector	0.11	0	0.10	0
Hours Worked	0.18	0.22	0.22	0.40
Hours in Private Sector	0.15	0.19	0.19	0.38
Hours in Public Sector	0.12	0.16	0.17	0.47

Notes: All are percent deviations from the initial steady state, except employment rates, which are in percentage points of labor force. Hours are hours per worker.

3.3.5 Reduction in the Labor Tax Rate Paid by Home Households

Because the transmission mechanisms for a reduction in labor taxes paid by households are similar to those explained above, we focus here only on the main differences. The results from the sensitivity analysis are shown in table 12. The main difference is that when labor taxes paid by households are reduced, wages decrease, which stimulates labor demand, employment, and output. Unlike in the case when labor taxes paid by firms are reduced, this is more pronounced when public-sector variables are allowed to adjust to new levels. If they are kept fixed at the initial level (in particular, unemployment benefits and public-sector wages), this promotes the reallocation of searching workers from the private to the public sector.[51] Because of the lower matching probability for workers and low elasticity of the matching function with respect to searching workers in the public sector, this leads to faster congestion and to somewhat smaller positive effects in the long run. This is true when comparing the "fixed" case and the "flexible" case in table 12 (the last and the first column, respectively), as well as when comparing the "fixed" case in table 12 with the "fixed" case in table 11. Even though the reduction in labor taxes paid by households tends to be somewhat more expansive in terms of output than the reduction of labor taxes paid by firms, this is not the case for employment. This is again due to congestion effects. If vacancies, unemployment benefits, or public-sector wages are kept fixed after the reduction in labor taxes paid by households, reallocation of workers is towards the sector that becomes congested faster.

4. Conclusions

In the aftermath of the sovereign crisis many European countries have been advised to implement reforms to reduce the unemployment rate. One of the frequently proposed reforms is a permanent reduction in labor taxes, with the aim of supporting job creation and growth.

We address the implications of such tax reforms by simulating a microfounded structural model of the EA and the global economy, featuring search-and-matching frictions in the labor market. Moreover, we introduce public-sector employment to account for the fact that, in the EA in particular, a substantial proportion of employment is in the public sector. We add the possibility for the unemployed to decide in which sector they will search for work.

Our results suggest that the labor tax reduction is quite effective in stimulating employment and macroeconomic activity in the EA member states. The effectiveness is enhanced if the tax reduction is simultaneously implemented in all EA member states (cross-country coordination) and if the monetary policy stance is accommodating, because each country benefits from expansionary spillover effects due

[51] As reported in table 12, the more variables are kept fixed, the lower is the increase in the aggregate employment rate and the lower is the reallocation from the public to the private sector, as measured by employment rates in each sector.

to the increase in other countries' economic activity and aggregate demand and from the larger reduction in real interest rates.

This paper can be extended in several directions. First, the impact of "fiscal devaluation" on (un)employment could be assessed by financing lower labor taxes with higher consumption taxes, along the lines of Gomes, Jacquinot, and Pisani (2016). Second, the framework could be exploited to analyze the effects of different wage-bargaining schemes, e.g., alternating offer bargaining as in Hall and Milgrom (2008) and Christiano, Eichenbaum, and Trabandt (2016). Third, the paper does not consider that workers may have different skills or any other sources of heterogeneity. Moreover, it does not consider that labor tax schedules are typically progressive and that there can be distributional issues, depending on the propensity of households to consume. Finally, we do not take into account the interaction between fiscal and non-standard monetary policy measures, such as, for example, the purchases of long-term sovereign bonds by the monetary authority for monetary policy purposes. We leave these issues for future research.

Appendix. Derivation of Wage Bargaining in the Presence of Taxes

This appendix shows how wages and hours are determined with Nash bargaining in the presence of labor taxes. The key difference from the case without taxes is that the labor taxes paid by households and labor firms enter the bargaining problem and influence both the determination of wages and hours worked. We reproduce here the key equations before turning to the derivation of Nash bargaining.

The value of being employed is as follows:

$$E_{P,t} = (1-\tau_t^{wh})w_t^P h_t^P - \frac{\chi}{\lambda_t}\frac{h_t^{P\ 1+\zeta}}{1+\zeta} + \beta\frac{\lambda_{t+1}}{\lambda_t}\left(\delta_x^P \widetilde{U}_{t+1} + (1-\delta_x^P)E_{P,t+1}\right).$$

The value of being unemployed is as follows:

$$U_{P,t} = u_{ben,t} + \beta\frac{\lambda_{t+1}}{\lambda_t}\widetilde{U}_{t+1}.$$

The value of having a worker is as follows:

$$J_{P,t} = x_t h_t^{P\ \alpha_H} - (1+\tau_t^{wf}) w_t^P h_t^P + \beta \frac{\lambda_{t+1}}{\lambda_t}(1-\delta_x)\left(J_{P,t+1}\right).$$

Nash Bargaining

When a labor firm and a worker match, the wage and the number of hours worked are determined by maximizing the following Nash product (η is the bargaining power of a household):

$$\max_{w_t^P, h_t^P} (E_{P,t} - U_{P,t})^{\eta} J_{P,t}^{1-\eta}.$$

The first-order condition with respect to wages is

$$\eta(1-\tau_t^{wh}) J_{P,t} = (1-\eta)(1+\tau_t^{wf})\left(E_{P,t} - U_{P,t}\right).$$

Note that labor taxes influence the bargaining by modifying the share of the surplus that goes to the household and to the labor firm. The larger is the share of the surplus that goes to the household, the bigger is the tax base and hence taxes paid to the government, which is taken into account during wage bargaining. An analogous result holds for taxes paid by labor firms.

The first-order condition with respect to hours worked is

$$\begin{aligned} &\eta\left((1-\tau_t^{wh}) w_t - \frac{\chi}{\lambda_t} h_t^{P\ \zeta}\right) J_{P,t} \\ &\quad = (1-\eta)\left(E_{P,t} - U_{P,t}\right)\left((1+\tau_t^{wf}) w_t - \alpha_H x_t h_t^{P,\ \alpha_H - 1}\right), \end{aligned}$$

which, after using the first-order condition for wages and simplifying, reduces to

$$\alpha_H x_t h_t^{P,\ \alpha_H - 1} = \frac{\chi h_t^{P\ \zeta}(1+\tau_t^{wf})}{\lambda_t(1-\tau_t^{wh})}.$$

While the above condition does not depend on wages, it does depend on labor taxes.

Matching in the Model with the Public Sector

For every sector s, there is a separate matching function. Each matching function takes the following form:

$$M_t^s = \phi_{mat}^s un_t^{s\ \mu_{mat}^s} vac_t^{s\ 1-\mu_{mat}^s}. \tag{29}$$

The probabilities of a worker to find a job in each sector, $p^{s,W}$, and the probabilities of a firm to find the worker, $p^{s,F}$, in each sector are

$$p_t^{s,W} = \frac{M_t^s}{un_t^s} = \phi_{mat}^s \left(\frac{vac_t^s}{un_t^s}\right)^{1-\mu_{mat}^s}, \tag{30}$$

$$p_t^{s,F} = \frac{M_t^s}{vac_t^s} = \phi_{mat}^s \left(\frac{vac_t^s}{un_t^s}\right)^{-\mu_{mat}^s}. \tag{31}$$

In each sector s, the number of employed at the end of the period, nde^s, evolves according to the following law of motion:

$$nde_t^s = (1-\delta_x^s) nde_{t-1}^s + M_t^s \tag{32}$$

$$= (1-\delta_x^s) nde_{t-1}^s + p_t^{s,F} vac_t^s \tag{33}$$

$$= (1-\delta_x^s) nde_{t-1}^s + p_t^{s,W} un_t^s, \tag{34}$$

where δ_x^s is the exogenous separation rate in each sector. The aggregate number of employed workers, nde, is

$$nde_t = nde_t^P + nde_t^G. \tag{35}$$

The number of unemployed workers at the end of the period, une, is

$$une_t = 1 - nde_t^P - nde_t^G. \tag{36}$$

As in the basic model, the number of searching workers is not the same as the number of unemployed workers, because breakups occur in the beginning of the period. The aggregate number of searching workers, un, in the beginning of the period is

$$un_t = 1 - nde_{t-1}^P - nde_{t-1}^G + \delta_x^P nde_{t-1}^P + \delta_x^G nde_{t-1}^G. \tag{37}$$

Budget Constraints and Aggregation

The introduction of frictional labor market and public-sector employment affects several other parts of the model. Here we give an overview of the conditions affected.

Labor Market Clearing. Labor demand in the public sector is set exogenously by the government and is determined through the posting of public-sector vacancies. The amount of labor services provided by the workers in the public sector is affected by the hours choice, determined analogously to the private sector (equation (15)). The market clearing for public-sector labor services is thus

$$N_{G,t}^{D} = nde_t^G h_t^{G\ \alpha_H}. \tag{38}$$

All available labor services produced by employed workers in labor firms are demanded by private-sector intermediate firms, either in tradable or in non-tradable sectors (N_T^D and N_{NT}^D, respectively):

$$N_{P,t}^{D} = nde_t^P h_t^{P\ \alpha_H} = N_{T,t}^{D} + N_{NT,t}^{D}. \tag{39}$$

Total demand for labor in the economy is the sum of demands for labor in the private and public sectors:

$$N_t^D = N_{P,t}^D + N_{G,t}^D. \tag{40}$$

Note that capital is free to move between all sectors, i.e., there are no frictions on movement of capital between sectors, but there is a friction (adjustment costs) for changing the aggregate level of capital. Labor, on the other hand, is completely free to move within the private sector (but there is a matching friction for increasing the number of workers in the private sector), while the movement of workers between the private and public sectors is only possible for unemployed workers. Changing the number of workers employed in a particular sector is therefore subject to matching frictions.

Government Budget Constraint. The budget constraint of the government now includes unemployment benefits, spending on public-sector wages, and payments for public-sector vacancies on the expenditure side. The revenue side includes tax revenues from income taxes on households and firms, which are adjusted for hours worked, and differences in wage levels in the public and private sectors.

We assume that unemployment benefits are paid in terms of consumption goods. Vacancy posting costs are also in terms of consumption goods and are assumed not to be a real resource cost. We assume these costs are the same in the private and in the public sector.

The budget constraint of the government is

$$\begin{aligned}\Theta_t &+ u_{ben,t} un_t + P_{GG,t} G_{G,t} + \psi vac_t^G \\ &= \ldots + \tau_t^{wh} w_t^G nde_t^G h_t^G + \tau_t^{wh} w_t nde_t^P h_t^P + \tau_t^{wf} w_t^G nde_t^G h_t^{G\alpha_H} \\ &\quad + \tau_t^{wf} w_t nde_t^P h_t^{P\alpha_H} + \Gamma_t,\end{aligned}$$

where Θ_t includes the remaining government spending (on private-sector-produced goods), transfers not related to unemployment (assumed to be zero), and interest payments. Γ_t includes other revenues (consumption taxes, lump-sum taxes, capital tax, and dividend tax, with the latter assumed to be zero).

Aggregate Demand and Aggregate Resources. Aggregate demand includes the government's gross wage bill:

$$\begin{aligned}P_{Y,t} Y_t &= Q_{C,t} + P_{I,t} Q_{I,t} + P_{NT,t} G_t + P_{GG,t} G_{G,t} \\ &\quad + (1 + \tau_t^{wf}) w_{G,t} nde_t^G h_t^{G\alpha_H} + trade\ balance. \end{aligned} \tag{41}$$

Aggregate real demand is equal to total production, plus the government's gross wage bill:

$$Y_t = Y_{T,t}^S + Y_{NT,t}^S + (1 + \tau_t^{wf}) w_{G,t} nde_t^G h_t^{G\alpha_H}. \tag{42}$$

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