Macroeconomic effects of reducing labor tax in the euro area. A structural model-based approach*

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Abstract

We evaluate the effects of reducing labor tax rates in the euro area, by simulating a large-scale dynamic general equilibrium model. The model features the euro area as monetary union, split in two regions, region-specific labor markets, formalized in terms of search and matching frictions, and public employment. Our results are as follows. First, reducing labor tax rates for Home firms would have stimulating effects on economic activity and employment. Second, the same is true when tax rates paid by Home households are reduced. Third, reducing labor tax rates simultaneously in both Home and REA would have expansionary effects on the EA economy and unemployment. Fourth, effects are expansionary not only in the new long-run equilibrium, but also in the short-run, when households and firms have to pay adjustment costs to change their allocations in response to the lower tax rate. Fifth, the reallocation of workers to a more efficient labor market segment can substantially amplify the expansion. Overall, results suggest that both short- and long-run labor-tax multipliers are not negligible.

JEL classification: C53; D91; E21; E32; E52; E62; F47.

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1 Introduction

Cyclical factors, associated with the recent deep and prolonged crisis, have certainly contributed to the rise in euro area (EA) unemployment rate, which is now equal to 11.5%. However, it cannot be excluded that, in some EA countries at least, structural factors have a non negligible role in explaining unemployment. Estimates provided by international organizations – in particular, the European Commission, the OECD and the IMF – suggest that the crisis has resulted in an increase in structural EA unemployment, rising from an average (across the three institutions) of 8.8% in 2008 to 10.3% by 2013.

Moreover, the EA cross-country picture for unemployment is rather heterogeneous. For example, in Germany and in Spain unemployment rates are equal to 5% and 25%, respectively. Persistent and large cross-country differences can make rather difficult the management of the monetary policy, because the decisions are necessarily taken by looking at the EA economy performance as a whole.

Several reforms can be enacted to permanently reduce the unemployment rate. Among them, 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.[1] High labour taxes increase labour costs to employers and reduce net take-home pay of employees, negatively impacting both labour demand and labour supply. Shifting taxes away from labour can contribute to increasing employment and activity rates in the euro area (EA) by increasing incentives to hire and to look for, and take up, work.

In this paper we evaluate the macroeconomic effects of a fiscal reform in the EA aimed at permanently reducing taxes on labour. To that purpose, we simulate an augmented version of EAGLE (Euro area and the global economy) model, enriched with a labor market with search and matching frictions.

The model is calibrated to Germany, rest of the EA (REA), the United States (US) and the rest of the world (RW).[2] It is New Keynesian, as nominal prices of goods and services are sticky. In each country there are households and firms. Households consume, invest in physical capital and supply labor. Both capital and labor are used by domestic firms, that produce

[1] See European Commission (2015).

[2] For the documentation of the standard EAGLE model, see Gomes et al. (2010).

intermediate goods and set their prices under monopolistic competition regime. There are two types of intermediate goods, tradable and nontradable. All of them are combined to produce a final nontradable 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 EA- wide inflation rate and economic activity. For US and RW, the Taylor rules react to corresponding country-specific variables. Crucially, fiscal policies are conducted at regional level. Each regional fiscal authority can finance fiscal measures by appropriately changing expenditure items, tax rates, and public debt. The latter is stabilized according to a fiscal rule. The presence of countries outside the EA allows 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, nontradable intermediate goods, and incomplete markets at international level (one riskless bond is internationally traded). Finally, the response of main variables to the shocks reflects the assumptions of habit in consumption, adjustment costs on investment changes and import changes, and price indexation.

On top of this, rather exhaustive, model setup we add the labor market, formalized in terms of search and matching frictions. The labor market is country-specific, so that labor services are nontradable. Moreover, we introduce a public sector, with the possibility of directed search between private and public sector labour market, along the lines of Afonso and Gomes (2014). One of the novelties introduced in the model is the ability of the unemployed to choose the sector in which they search for jobs. This is different than in other large models featuring multiple sectors and frictional unemployment, where unemployed workers are typically passive (e.g., Stähler and Thomas, 2012). There are two 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 et al., 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.

We initially simulate, for simplicity, a "basic" version of the model, where there is no role for public employment. Thus, the basic version includes a labor market with matching frictions in the New Keynesian model of monetary union. Thereafter, we report results obtained by

simulating the "full" model, which also includes public employment.

We simulate a permanent reduction in the labor tax rate paid by firms and households implemented by German fiscal authorities apart. The tax rate reduction is implemented over a two-year horizon and is calibrated to get a reduction in labor tax revenues equal to 1% of pre-shock German GDP. The reduction is financed by reducing lump-sum transfer by an equal amount, so that the measure is (ex ante) budget-neutral. The use of lump-sum transfers, which are not distortionary, allows 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. Subsequently, we simulate the simultaneous implementation of the measure in both Germany and REA.

Our results, which are qualitatively similar across the two versions of the model, are as follows. First, permanently reducing labor tax rates by Home firms would have stimulating effects on economic activity and employment, and would reduce the unemployment rate. Second, the same is true when tax rates paid by Home households are reduced. Third, reducing the labor tax rates simultaneously in both Home and REA would have expansionary effects on the EA economy and employment. Fourth, effects are expansionary not only in the new long-run equilibrium, but also in the short-run, when households and firms have to pay adjustment costs to change their allocations in response to the lower tax rate. Fifth, when workers reallocate from a sector with less efficient labor market to a sector with a more efficient labor market in response to tax changes, expansionary effects of tax reforms can be substantially larger.

Our paper is related to other contributions existing in the literature on the macroeconomic effects of labor market reforms in the EA. Coenen et al. (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%. Forni et al. (2010) 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 formalized in terms of search frictions. Moreover, we consider 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. To the best of our knowledge,

this is the first paper that considers directed search in a New Keynesian model of a monetary union.

The paper is organized as follows. Section 2 reports the main features of the model and the calibration. Section 3 reports results. Section 4 compares the full model with public sector employment with the basic model. Section 5 concludes.

2 The model

2.1 Overview

We introduce the frictional labour market in two stages. In the first stage, which we refer to as the *basic model*, we have one labour market that serves two private sectors, tradable and non-tradable. In the second stage, we add a public sector with its own labour market, but which is related to the private-sector labour market by the ability of workers to choose in which market to search. We call this model with public-sector employment the *full model*.

The timing in both models is such that that new matches become productive immediately and the break-up of employment relationships occurs in the beginning of the period.[3] Because the model is quarterly, this assumption allows employment to react to shocks in the same quarter.[4] Posting vacancies is assumed to be costly, but is not a real resource cost.[5]

Throughout the paper we assume that labour taxes are paid by households and by intermediate goods firms.[6] Unemployment benefits are distributed by the government, and are assumed to be the same in all sectors. We assume there are no non-Ricardian households.

[3] In the beginning of the period, a proportion of employment relationships ends exogenously. The separated workers join the unemployed from the previous period in the searching process. Then aggregate shocks are realised, the number of matches is determined, wages are set, and production takes place. At the end of the period, workers bring their income (wages or unemployment benefits) home, dividends are distributed and taxes are paid. Household then decides on consumption. This setup avoids explicit consideration of heterogeneity and is based on Merz (1995) and Andolfatto (1996).

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

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

[6] Therefore, labour taxes paid by firms enter their marginal costs equation directly.

2.2 Basic model

The basic model assumes that there is a continuum of labour firms in the private sector, each employing one worker. There is one labour market that serves firms in both tradable and non-tradable sectors. Labour firms enter the market by posting a vacancy and, if matched with a worker, sell homogeneous labour services from hired workers to private intermediate goods firms at a competitive price.

2.2.1 Matching and labour market flows

The matching process is modelled using a matching function, where M_t^P denotes the number of matches in each period. If vac_t^P denotes the number of vacancies in the private sector, 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, then the matching function can be written as follows:

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

The probability for a searching worker to find a job, $p^{P,W}$, is defined as:

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

Similarly, the probability for a firm to find a worker, $p^{P,F}$, is defined as:

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

Because of our assumption that break-ups 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. The number of employed workers *after matching has been completed*, is denoted by nde_t. These are workers who are in an employment relation in period t. The number of employed workers at the beginning of the 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. Similarly, the number

of unemployed workers who search for work at the beginning of the period (the number of workers who enter the matching process), is equal to those who were unemployed at the end of the previous period, une_{t-1}, plus the newly separated workers, $\delta_x^P nde_{t-1}^P$. The number of unemployed at the end of the period, after matching has been completed, is denoted as une_t. The number of employed workers evolves according to the following law of motion:

$$nde_t^P = (1-\delta_x^P)nde_{t-1}^P + M_t^P \tag{4}$$

$$= (1-\delta_x^P)nde_{t-1}^P + p_t^{P,F} vac_t^P \tag{5}$$

$$= (1-\delta_x^P)nde_{t-1}^P + p_t^{P,W} un_t^P. \tag{6}$$

The number of unemployed workers after the matching process is completed is:

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

The number of searching workers in the beginning of the period, un, is:

$$un_t = 1 - nde_{t-1}^P + \delta_x^P nde_{t-1}^P. \tag{8}$$

2.2.2 Value functions

Value functions of job market participants are given by the current-period payoff and the continuation value, conditional on the probabilities of remaining in the current state or transition to another state.

A worker is either employed, in which case she works h_t^P hours, receives a hourly real (expressed in domestic consumption units) wage w_t^P, and has to be compensated for the foregone leisure. In case of a break-up in the beginning of the next period she will be unemployed, conditional on not matching successfully in the next period. Unemployed workers receive unemployment benefits paid by the government, $u_{ben} > 0$, which are assumed to be constant and identical across sectors. 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.

The value of being employed, $E_{P,t}$, is

$$E_{P,t} = (1-\tau_t^{wh})w_t^P h_t^P - \frac{\chi}{\lambda_t}\frac{h_t^{P\ 1+\zeta}}{1+\zeta} + \\ + \beta\frac{\lambda_{t+1}}{\lambda_t}\left(\delta_x^P(1-p_{t+1}^{P,W})U_{P,t+1} + (1-\delta_x^P(1-p_{t+1}^{P,W}))E_{P,t+1}\right), \quad (9)$$

where $0 < \tau_t^{wh} < 1$ is the labour tax rate, $1/\xi$ is the Frisch labour 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 consumption, and $0 < \delta_x^P < 1$ is the 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 $\beta\lambda_{t+1}/\lambda_t$ is the stochastic discount factor.

The value of being unemployed is defined as follows:

$$U_{P,t} = u_{ben,t} + \beta\frac{\lambda_{t+1}}{\lambda_t}\left((1-p_{t+1}^{P,W})U_{P,t+1} + p_{t+1}^{P,W}E_{P,t+1}\right). \quad (10)$$

Unless stated explicitly, we assume that unemployment benefits remain constant. The value of being unemployed depends on the level of unemployment benefits, but also on future states and probabilities of transition to those states.

Unemployment benefits are determined as a percentage of steady-state wage in the private sector, where the fraction $rr > 0$ of the steady-state wage, $\overline{w}$, is chosen to match the replacement ratio:

$$u_{ben} = rr\overline{w}. \quad (11)$$

Given our assumption of a continuum of labour firms with one worker, it is possible to define value functions for labour firms. Labour firms sell labour services to intermediate-goods firms at a price x_t. To obtain labour 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 labour firm into labour services, $y_t^{s,h}$, according to the following technology:

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

where $0 < \alpha_H < 1$. For every hour worked, labour firm pays the worker a wage w_t^P. The value for a labour firm of having a worker, $J_{P,t}$, is defined as

$$J_{P,t} = x_t h_t^{P\ \alpha_H} - w_t^P h_t^P + \beta \frac{\lambda_{t+1}}{\lambda_t}(1-\delta_x)\left(J_{P,t+1}\right). \tag{12}$$

The value of having a worker is determined by per-period profits of the labour firm, which are the difference between the revenues from selling labour services and costs of paying workers. If there is no break-up of the employment relationship, the firm keeps the value of having a worker in the next period.[7]

The value for a labour firm of having a vacancy open is

$$V_{P,t} = -\psi + p_t^{P,F} J_{P,t} + \beta \frac{\lambda_{t+1}}{\lambda_t}\left((1-p_{t+1}^{P,F})V_{P,t+1}\right). \tag{13}$$

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.[8] If the firm does not find a worker, it remains with a vacancy. Labour firms enter the labour 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 13 can thus be simplified, which is known as the free-entry condition:

$$\psi = p_t^{P,F} J_{P,t}. \tag{14}$$

The free-entry condition determines the number of vacancies in the model. Because the cost of having a vacancy open is fixed and unemployment moves gradually, an increase in the value of having a worker induces firms to enter and therefore the number of vacancies increases, which,

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

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

everything else equal, reduces the probability of a firm to find a worker.

2.2.3 Wages and hours worked

The presence of labour market frictions implies that wage is not equal to the marginal product of labour, as wage determination has to take into account the costs incurred during the search process.

We assume that wages in the private sector are determined by the Nash bargaining between labour firms and household members working in the private sector. They maximise the Nash surplus with respect to wages and hours worked, where $0 < \eta < 1$ is the bargaining power of workers. Such setting is often called efficient bargaining (Trigari, 2009), as the surplus of the match between a labour firm and a worker is maximised with respect to the number of hours worked. The role of the wage is to split this surplus between the firm and the worker.[9] The first-order condition with respect to wages is:[10]

$$\eta(1-\tau_t^{wh})J_{P,t} = (1-\eta)\left(E_{P,t} - U_{P,t}\right). \tag{15}$$

Equation 15 implicitly determines wages in the private sector. Note that labour taxes influence the bargaining by modifying the bargaining power of workers. The larger is the share of the surplus that goes to the worker, the bigger is the tax base and hence taxes paid to the government. Changes in the tax rate payable by households affect not only the asset values, but also reduce the share of firm surplus that workers are able to appropriate.

Hours in the private sector are determined as (see Appendix A for derivation):

$$\alpha_H x_t h_t^{P,\ \alpha_H - 1} = \frac{\chi h_t^{P\ \zeta}}{\lambda_t(1-\tau_t^{wh})}, \tag{16}$$

where the marginal product for a labour firm of additional hour of labour services sold to intermediate goods firms is equated to the disutility of the worker having to work an additional hour (measured in consumption units). Note that condition 16 does not depend on wages, but it does depend on labour taxes. An increase in labour taxes reduces the number of hours worked and

[9] In this sense, wages are non-allocational.
[10] The derivations are provided in Appendix A.

with it the total surplus of the match between a worker and a firm.

2.3 Model with public-sector employment (full model)

The structure of the model with public-sector employment is in terms of timing assumptions and in terms of the private-sector labour market identical to the basic model described above. The most important difference is the addition of a new segment of the labour market for the public sector. Private and public labour 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 break-up, 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 modelled as in the basic model, with the difference that there are two matching functions, one for the private and one for the public sector. M_t^s is the number of matches in 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 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 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 basic model, we list them in Appendix B.

2.3.2 Value functions for a worker

A worker is either employed in one of the sectors, in which case she works h_t^s hours, receives an hourly wage w_t^s, and has to be compensated for the foregone leisure. In case of a break-up 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 basic model, because it includes the possibility to relocate to a different sector. Without the break-up, she will receive

the continuation value of being employed. Unemployed workers receive unemployment benefits from the government, u_{ben}, which are constant and identical across sectors. The value of being employed in sector s is

$$E_{s,t} = (1-\tau^{wh})w_t^s h_t^s - \frac{\chi}{\lambda_t}\frac{{h_t^s}^{1+\zeta}}{1+\zeta} + \beta\frac{\lambda_{t+1}}{\lambda_t}\left(\delta_x^s \widetilde{U}_{t+1} + (1-\delta_x^s)E_{s,t+1}\right). \tag{17}$$

The value of being unemployed is

$$U_{s,t} = u_{ben,t} + \beta\frac{\lambda_{t+1}}{\lambda_t}\widetilde{U}_{t+1}, \tag{18}$$

where $\widetilde{U}_{t+1}$ is the value of having an option to choose a sector in the beginning of the next period, including the probability of finding a job in that sector. This value is defined below.

For the private sector firm, the value of having a worker and the value of having a vacancy are identical to those in the basic model, equation 12 and 13, respectively. The free-entry condition is also the same as in equation 14. While the value functions of having a worker or a vacancy for a labour firm in the public sector can be defined, they have no meaning, given that the number of public sector vacancies is an exogenous decision of the government (which renders free-entry condition superfluous) and that government also sets wages in the public sector (implying that there is no need for Nash bargaining and the value functions for the public sector firm).

2.3.3 Directed search

Searching workers can decide in which sector they wish to search. We define the value for an unemployed worker of being in a sector as $\widetilde{U}_t$:

$$\widetilde{U}_t \equiv (1-p_t^{P,W})U_{P,t} + p_t^{P,W}E_{P,t} = (1-p_t^{G,W})U_{G,t} + p_t^{G,W}E_{G,t}. \tag{19}$$

Because unemployed workers are free to move across sectors, they will reallocate as long as the value of searching in one sector is higher 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 equalised. 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. This is why there is only one value of $\widetilde{U}_t$, even though there are two sectors.

Because matching takes place after workers reallocate, workers take into account that by switching sectors they can get either employed in that sector or unemployed. The directed search condition that determines how many workers search in each sector is

$$(1 - p_t^{G,W})U_{G,t} + p_t^{G,W}E_{G,t} = (1 - p_t^{P,W})U_{P,t} + p_t^{P,W}E_{P,t}. \tag{20}$$

Here, U_s is the value of being unemployed in each sector, while E_s is the values for the worker of being employed in each sector. 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. The reason for including the values of being employed is that workers in our model can become productive in the current period, whereas in Afonso and Gomes (2014) it takes one period before they match.[11] Note that if the part of equation 19 for the private sector is used in equation 18, one obtains identical expression for the value of being unemployed in the private sector as in equation 10 of the basic model.

The sorting condition 20 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 exogenous 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:

$$un_t = un_t^P + un_t^G. \tag{21}$$

[11] Because of the delay in matching, Afonso and Gomes (2014) can use only the values of being unemployed in the particular sector.

2.3.4 Public-sector vacancies

Government sets public sector vacancies according to the following law of motion:

$$vac_t^G = (1 - \rho_{vac})\overline{vac^G} + \rho_{vac} vac_{t-1}^G + \varepsilon_{t,vac}. \tag{22}$$

The steady-state level of public sector vacancies, $\overline{vac^G}$, is determined to match the share of employment in the public sector, defined as nde^G/nde. If the government wishes to increase public sector employment, it has to manipulate vacancies accordingly, either temporarily through shocks $\varepsilon_{t,vac}$ or permanently by changing $\overline{vac^G}$.

2.3.5 Public-sector wages and hours

Public sector wages, w_G, are set exogenously by the government. 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, some type of wage norm depending on private-sector wages, etc.), we model public-sector wages as a constant tied to private-sector wages. This is in line with Lamo et al. (2008), who find private and public-sector wages cointegrated in OECD countries. We assume public sector wages in the steady state have a premium, $pr > 1$, over what labour firms charge to intermediate goods firms in the private sector in the steady state, $\overline{x}$:

$$w_{G,t} = pr_t \overline{x}, \tag{23}$$

where the public sector wage premium evolves according to

$$pr_t = (1 - \rho_{pr})\overline{pr} + \rho_{pr} pr_{t-1} + \varepsilon_{t,pr}. \tag{24}$$

A change in public sector wages, $\varepsilon_{t,pr}$, is therefore equivalent to a shock in public sector wage premium.

Hours in the public sector are chosen optimally, taking the public-sector wage as given. The decision is identical to that in the private sector (see equation 16), with hourly wage set by the government replacing private-sector wage and hours worked in the public sector replacing

hours worked in the private sector.[12] As in the basic model, labour taxes payable by households influence the choice of hours worked.[13]

2.4 Calibration

We calibrate at the quarterly frequency the model blocs to Germany (Home country, as in the standard EAGLE), REA, US and RW. We set a subset of model parameters to match the (usual) "great" ratios (as a ratio to GDP). The remaining parameters are calibrated in line with the literature, in particular with the calibration of models such as EAGLE, GEM and NAWM.

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 share of world GDP (IMF data). The sources of EA and of US net foreign asset position data are Eurostat and Bureau of Economic Analysis, respectively.[14]

Table 2 reports preference and technology parameters. Preferences are assumed to be the same across regions. We set the discount factor of households to 0.9926 (implying a steady-state annualized real interest rate of about 3%). Habit persistence parameter, the intertemporal elasticity of substitution and the Frisch elasticity are respectively set to 0.70, 1 and 0.50. We set quarterly depreciation rate of capital to be consistent with a 10% annual depreciation rate.

On the production side, in the Cobb-Douglas production functions of tradable and nontradable intermediate goods the bias towards capital is set to around 0.30 and the bias towards housing to 0.01 in both tradable and nontradable sectors. As for the final goods baskets, the degree of substitutability between domestic and imported tradables is higher than that between tradables and nontradables, consistent with existing literature (elasticities equal to 2.5 and 0.5, respectively).[15] The biases towards the tradable bundle in the consumption and investment baskets are equal respectively to 0.45 and 0.75 in 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

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

[13] 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, $h_t = \frac{nde^P}{nde} h_t^P + \frac{nde^G}{nde} h_t^G$.

[14] Given the import shares, net foreign asset position and international interest rate, the steady-state trade balance and real exchange rate level endogenously adjust. The RW is obtained as a residual.

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

and investment tradable baskets is different across countries, to be coherent with multilateral import-to-GDP ratios.

Markups in the EA nontradables sector (a proxy for the services sector) and labor market 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 and the markup in the nontradables sector is higher than that in the labor market.[16]

Table 4 reports nominal and real rigidities. We set Calvo price parameters in the domestic tradables and nontradables sector to 0.92 (12.5 quarters) in the EA, consistently with estimates by Christoffel, Coenen, and Warne (2008) and Smets and Wouters (2003). Corresponding nominal rigidities outside the EA are equal to 0.75, implying an average frequency of adjustment equal to 4 quarters, in line with Faruqee, Laxton, Muir, and Pesenti (2007). Calvo wage parameters and price parameters in the export sector are equal to 0.75 in all the regions. The indexation parameters on prices and wages are equal respectively to 0.50 and 0.75, so to get sufficiently hump-shaped response of wages and price. 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 weights of bilateral imports on the bundles to match the trade matrix reported in Table 5.[17]

Table 6 reports parameters in the monetary rules and fiscal rules. The interest rate reacts to its lagged value (inertial component of the monetary policy), annual inflation and quarterly output growth. In the monetary union, monetary policy reacts to 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. We calibrate vacancy posting costs, matching efficiency, break-up rate and the disutility of hours to target matching probability for workers, $p^W = 0.7$, matching probability for firms, $p^F = 0.7$,

[16]The chosen values are consistent with estimates from Martins, Scarpetta and Pilat (1996), suggesting that the degree of competition in the nontradable 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, Laxton, Muir, and Pesenti (2007) and Everaert and Schule (2008).

[17]The trade matrix is calibrated using Eurostat and IMF trade statistics.

hours per worker are standardised to 1 in the steady state, and unemployment rate is equal to 8% in Home and the rest of the euro area, and to 6% in the rest of the world and in the U.S. The estimates of matching probabilities are based on den Haan et al. (2000) and unemployment rates are close to what is reported in the literature (e.g., Stähler and Thomas, 2012).

Matching elasticity is set to 0.6, following Petrongolo and Pissarides (2001). Unemployment benefits are set as a proportion of the steady-state wage, where the proportion is the replacement ratio. This is in line with the OECD estimates and is set to be higher in the euro area, at 0.5, and lower in the U.S. and the rest of the world, at 0.2. The labour supply elasticity is set to 0.5 (implying its inverse, $\zeta = 2$) and follows Gomes et al. (2012). Tax rates correspond to effective tax rates in each of the blocs and are also taken from Gomes et al. (2012). The calibration is detailed in Table 7. The calibration of trade linkages and the remaining parameters of the model is reported in the Appendix.

The full model with the public sector is calibrated based largely on Gomes (2010), Stähler and Thomas (2012), and Afonso and Gomes (2014). Because the model has two matching functions, there are two sets of matching probabilities and two sets of matching function efficiencies, elasticities, and two break-up rates (one in each sector). To calibrate the model, we follow some guiding principles from the above literature. First, the matching probability for the worker in the public sector is lower than the matching probability in the private sector. Second, break-up rate in the public sector is 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.

Similarly as in the basic model, we calibrate vacancy posting costs (assumed to be the same in all sectors), both matching efficiencies, break-up rates and the disutility of hours to target matching probability for workers in the private sector, $p^{P,W} = 0.7$, matching probability for firms in the private sector, $p^{P,F} = 0.7$, and matching probability for firms in the public sector, $p^{G,F} = 0.7$. Hours per worker are standardised to 1 in the steady state, and unemployment rates in Home and the rest of the euro area are set to 8%, and to 6% in the rest of the world and in the U.S. To achieve the guiding principles above, the break-up rate in the public sector has been set to 1% and the break-up rate in the private sector has been used to match the aggregate

unemployment levels (note that it always exceeds the break-up rate in the public sector). The number of public-sector vacancies is set to target the share of public-sector employment. We take this to be 20% in Home and the rest of the euro area (close to Quadrini and Trigari (2007) for the US, Stähler and Thomas (2012) for Germany, Afonso and Gomes (2014) for the UK), and 10% in the U.S. and the rest of the world, reflecting that euro area countries have larger public sectors. The probability that a worker finds a job in the public sector is the residual of this calibration procedure, and the outcomes are in line with those implied in Afonso and Gomes (2014).[18] We set the public-sector wage premium to 5%, which is close to Quadrini and Trigari (2007) or Afonso and Gomes (2014).[19] The calibration is detailed in Table 8 in the Appendix.

The calibration of public-sector production is analogous to the production function of the non-tradable goods sector. We set α_G to 0.3, assume that prices are reset once per year (Calvo parameter is 0.75), and assume the prices of government-produced goods are partially indexed to target inflation. Government consumption spending is taken from Gomes et al. (2012) and is reduced for government spending on own-produced goods. The latter is assumed to be 10% of nominal GDP in each of the four blocs (similar as in Stähler and Thomas (2012) for Germany).

In all other respects, we align the calibration of the full model with the public sector with that of the basic model. That is, we set unemployment rates, hours worked, replacement ratios, and tax rates to be the same as in the basic model. The same applies to country sizes, great ratios, taxes, and trade linkages.

To illustrate the dynamics of the model with the above calibration, we simulate a standard monetary policy shock in the basic model.[20] Figures 1 and 2 report the effects of an initial drop in the EA monetary policy rate equal to 1 pp. The reduction is persistent, because of the presence of a parameter for inertia in the Taylor rule. The effects are rather cross-country symmetric. GDP and inflation increase (see Figure 1). Consumption and investment increase as well.

Exports initially decrease, because the prices of EA goods increase, following the higher EA

[18] See Table 3 in their paper.

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

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

aggregate demand. The depreciation of the euro nominal exchange rate is gradual, given the assumption of short-run pass/through. Thus, it takes time for 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 EAGLE.

Figure 2 reports the dynamics of the labor market variables. Their dynamics is consistent with the increase in EA economic activity. 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 labour firms, because wages do not adjust sufficiently. The value of having a worker for a labour firm increases, which leads to larger number of vacancies posted. The probabilities and of finding a job and of filling a vacancy increase and decrease, respectively. The number of new matches increases. Consistently, employment and unemployment increases and decreases, respectively. Higher job finding probability for workers implies that 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 labour, a product of the number of employed and the number of hours worked, increases.

3 Results

We consider the following scenarios. 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 permanently reduced. In the third and fourth, the labor tax rates paid by firms are simultaneously reduced in both Home and REA. In every scenario, the tax rate reduction is such that the corresponding tax revenues decrease by 1% of pre-shock (steady-state) GDP. All tax rate reductions are permanent. The new lower tax rate is achieved in around two years since the beginning of the simulations. The latter are run under the assumption of perfect foresight, so that households and firms perfectly anticipate the future path of the variables, and the decisions taken by the fiscal authorities are fully credible.

3.1 Decrease in labour tax rate paid by Home firms

Figure 3 reports the effects on labor market variables of a reduction in the labor tax rate paid by Home firms. The tax rate is reduced by 2pp. Both hours worked and employment increase in the Home country. Home firms face a lower labor cost, and, thus, increase labor demand. The number of matches increases as well and, consistently, the probability of finding a job and that of filling a vacancy increase and decrease, respectively. Unemployment decreases, by roughly 0.2 pp after two years and 0.1 pp in the medium and long run. The decrease in unemployment is slightly larger in the short- than in the long-run because the real wage gradually and permanently increases, inducing firms to increase employment relatively more in the short-run.

Figure 4 shows the main macroeconomic effects. The Home GDP increases by 0.4% in the first two years, and by 0.6% In the long-run. Both consumption and investment increase: the former because of households have a larger permanent income, associated with the increase in employment, hours and production; the latter because firms increase physical capital to augment the productivity of employed. Both Home exports and imports increase. Exports benefit from the deterioration in the Home real exchange rate, due to the expansion in Home supply-side. Imports are favored by the increase in Home aggregate demand. The Home consumer price inflation slightly decrease in the short run, because Home production increases by more than Home aggregate demand. The EA monetary policy rate slightly increases. The REA economic activity and inflation, not reported, increase, because of higher exports towards the Home regions. The spillover effects are relatively small.[21]

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

3.2 Decrease in labour 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 decrease is equal to 2 pp (trough level). Qualitatively, results are similar to those obtained in the previous scenario, and are consistent with the expansionary

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

consequences of reducing labor taxes. Hours worked, employment, matches, probability of finding a job increase, while the probability of filling a vacancy decreases. Only one qualitative difference holds: the response of the real wage. Different from previous scenario, in which it increases, now the real wage decrease, because households have an incentive to increase their labor supply, given the lower taxation. The reduction in the real wage induces firms to increase employment and hours worked more than in the previous scenario. Hours worked now increase by more than 0.4% (less than 0.4% in the previous simulation), employment by 0.4 pp (0.12 pp).

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, which are larger in the current than in previous simulation. Home GDP increases by around 0.7% after two years, and by 0.9% in the long run.

Overall, we do find that reducing the labor tax rate paid by Home households has nontrivial, expansionary effects in the long run and along the transition on Home labor market and macroeconomic variables.

3.3 Decrease in labour tax rate paid by EA firms

Figures 7 and 8 report results when the labour tax rate paid by firms is simultaneously reduced in both Home and REA regions. The responses of the labor market variables are similar across the regions (Figure 7). The tax rate reduction does favor employment and hours worked in the short- and long-run. Similarly, aggregate economic activity is stimulated in both regions, in both short- and long-run (Figure 8).

The effects are qualitatively similar to the responses in the case of unilateral Home labor tax reduction described above. Quantitatively, the expansionary effects on the Home economy are slightly larger than in the case of (unilateral) Home tax reduction. There is an additional increase in Home exports, favored by the larger REA aggregate demand. At the same time, Home households income benefit from the increase in REA production, because goods imported from REA become cheaper (consistently, the Home real exchange rate depreciates to a lower extent). This is an incentive for Home households to further increase aggregate demand and

imports.

Finally, note that the impact on both Home and REA inflation and, thus, on EA inflation is rather contained, implying a rather modest increase in the EA monetary policy rate.

3.4 Decrease in labour tax rate paid by EA households

Figures 9 and 10 report results when the labour tax rate paid by households is simultaneously reduced in both Home and REA regions. The responses of the labor market variables and aggregate economic activity are again similar across the regions. The tax rate reduction increases employment and hours worked in the short- and long-run, with similarly expansive effects for output, consumption, investment and trade.

As for the unilateral Home household labor tax reduction described above, the effects are again qualitatively similar. In quantitative terms, the expansion in Home is not materially different from the case when labor taxes paid by firms are reduced in Home alone. Stronger exports in Home than in the unilateral case are driven by higher aggregate demand in REA. However, the additional contribution of exports is almost entirely offset by lower increase in consumption and investment, which is caused by higher area-wide interest rate increase (all compared to the case when taxes are decreased unilaterally in Home). Interest rates increase because the expansion now affects the entire EA, which induces the central bank to react more (although the increase in the EA policy rate is small, as inflation does not increase by much).

4 Comparison of results in the basic and full model

In this section we compare the results in the basic model with those in the full model, with public-sector employment. The key difference between both models is that workers can move between sectors and that the public sector labor market is characterised by lower matching efficiency. The latter, together with reallocation of workers between sectors, plays the main role in explaining the differences between the models.[22] To save space, we only report unilateral tax changes in Home. Results for EA-wide tax changes are available upon request.

[22]Note that private and public sectors do not differ in terms of production functions.

4.1 Decrease in labor taxes paid by Home firms, full model

Figures 11 and 12 report results of the full model with public employment superimposed on the results of the basic model. Figure 11 reports variables related to labor market and Figure 12 reports the main macroeconomic variables.

The underlying transmission of lower labor taxes paid by Home households is the same as in the basic model. What makes the difference is the ability of workers to relocate between sectors. As in the basic model, aggregate wages increase (Figure 11). This increase is lower than in the basic model, because aggregate wages are an average of wages in the public sector (which remain unchanged, as they are set by the government) and wages in the private sector. The latter increase for the same reasons as in the basic model. Wages in the private sector therefore become relatively higher than wages in the public sector. The value of being employed in the private sector increases relative to the value of being employed in the public sector, which induces unemployed to reallocate their search towards the private sector. Because the matching process in the private sector is more efficient than in the public sector and the elasticity of the matching function with respect to the number of unemployed is higher, this leads to a strong increase in employment and the corresponding drop in unemployment. Consistently with the reallocation of workers, the probability for firms of filling a vacancy increases (despite higher number of vacancies) and the probability for workers of finding a job in the private sector decreases.

Note that because of worker reallocation, the responses of matching probabilities in the full model are qualitatively different from the responses in the basic model. This is particularly important for matching in the private sector. In the basic model, firms increased the number of vacancies for a given pool of unemployed, which led to congestion and lower probability for a firm to find a worker. In the full model, unemployed move into the private sector, where firms increase the number of vacancies. There is no congestion for firms and this leads to a substantially higher number of matches.

Efficiency gains in matching increase production, while at the same time permanently higher employment and higher wages imply additional resources for households and consumption increases.[23] Investment increases because firms increase capital to match the newly-employed labor

[23]The joint effect of employment and wages dominates the decrease in hours worked, which is due to the stronger wealth effect in the full model.

force. While imports increase due to stronger demand in Home. Exports increase because of improved competitiveness. Both effects are stronger in the full model than in the basic model. The reason for improved competitiveness in the full model is the stronger decline in Home inflation, due to faster expansion of production compared to the basic model.

Note the stronger persistence in the full model.[24] The reason for this is that it takes time before the reallocation of workers from the public to the private sector is completed. Workers first have to separate in the public sector, which occurs at a rate of 0.01 per period, and then have to match in the private sector, which also takes time.[25]

4.2 Decrease in labor taxes paid by Home households, full model

Finally, we compare the responses of the full model to the basic model for the case when labor taxes paid by Home households are reduced. Figures 13 and 14 report results of the full model with public employment superimposed on the results of the basic model. Figure 13 reports variables related to labor market and Figure 14 reports the main macroeconomic variables.

When labor taxes paid by home households are decreased, there are much less differences between the basic and full models. The reason is again related to the reallocation of workers. Recall that the main motive for the reallocation to the private sector when labor taxes paid by firms are decreased is the higher value of having a job in the private sector, which is the result of higher wages and higher probability of finding a job in the private sector. When labor taxes paid by households are decreased, wages in the private sector *decrease*. This makes them relatively lower than wages in the public sector (which are again kept constant). While the probability of finding a job in the private sector increases due to more vacancies posted by firms, this increases the value of having a job by much less, reducing the incentive of workers to reallocate. This implies that vacancies posted by private-sector firms still congest the market, reducing the probability of firms to find a worker. Matches increase by much less than when taxes paid by firms are reduced (Figure 13).

Less matches than in the basic model imply that employment increase (unemployment de-

[24] The persistence of the labor tax shock paid by firms was set to 0.6 to achieve the reduction in labor taxes within two years, consistently with the basic model.

[25] Our results regarding the amplification due to worker reallocation do not hinge on the fact that the sector with lower matching efficiency is the public sector. The same mechanism would operate if the sector with higher matching frictions would, e.g., be a sector within the private sector.

crease) is not as pronounced as when labor taxes paid by firms are decreased, although still more pronounced than in the basic model. Household income does not increase as much, resulting in consumption being close to that in the basic model. Similarly, because employment does not increase much more than in the basic model, there is no need for much higher capital and investment increases approximately as much as in the basic model. Imports increase because domestic consumption and investment are higher, but the response of imports is not materially different from the basic model. Exports increase is slower in the full model, because prices do not decrease as much as in the basic model and competitiveness does not improve as much.[26] Over the very long run, the outcomes in the full model are still more expansive than in the basic model. The reason why it takes so long is the higher persistence due to the slow reallocation of workers, as explained above.

4.3 Sensitivity analysis. The role of public-sector wages, vacancies, and unemployment benefits

So far, we have assumed that after a permanent tax change, government policies regarding public sector wages remain unchanged. However, this is not necessarily the case after a permanent tax change. For instance, if a permanent labour tax reduction results in a change in private-sector wages, then it s likely that in the long run, wages in the public sector will follow. This is consistent with the evidence in e.g. Lamo et al. (2008), who find private and public-sector wages cointegrated. Similarly, the level of unemployment benefits typically adjusts to new levels in the long run, and so can the number of vacancies in the public sector.

In this section we examine what is the role of changes in government policies regarding public sector wages, unemployment benefits, and vacancies. We take as benchmark the case where public-sector wages, vacancies, and unemployment benefits can adjust to the level consistent with the steady state after tax reduction. We call this the flexible case. At the other extreme, none of these variables is allowed to adjust and is kept at the original (flexible) level. We call this the fixed case. Intermediate cases are when only public-sector wages adjust, when only unemployment benefits adjust, and when only vacancies adjust. In all cases, we focus on Home

[26] Prices still decrease because the supply of goods increases faster than demand, due to more employments.

country only.

4.3.1 Reduction in labour taxes payable by Home firms

The results of the sensitivity exercise when labour taxes payable by firms are reduced are shown in Table 9. In the flexible case, a reduction in labour taxes payable by firms directly reduces marginal costs of intermediate goods firms, which leads to lower prices and higher output. This increases demand for labour, but also wages. The latter attenuates the expansion, as it counters the effect of the tax decrease on firms' marginal costs. Because public-sector wages follow private-sector wages, there is less reallocation of employment to the more efficient labour market and therefore lower increase in employment.

When public-sector wages are fixed (second column of Table 9), it becomes relatively worse to search for jobs in the public sector (even though after-tax wages are higher). Workers therefore tend to move towards the private sector, which attenuates the wage increase in that sector. This causes an increase in employment in the private sector despite the decrease in vacancies.[27] Keeping unemployment benefits fixed at their original (lower) level attenuates wage increase, but also induces employed workers to work more hours. The combined effect of keeping public-sector wages and unemployment benefits fixed causes the strongest reallocation and therefore the strongest output increase. This is the only case where the public debt ratio decreases after tax reduction. Note that after-tax wage income of private and public-sector workers increases in all cases (and pre-tax income in all except when public-sector wages are kept fixed).[28] Given that all groups increase their take-home income, such policy changes may be easier to achieve than policy changes that require wage reductions.

4.3.2 Reduction in labour taxes payable by Home households

The results from the sensitivity analysis are shown in Table 10. First, note that when all variables are allowed to adjust to new levels, both private and public-sector wages decrease. Note also that after-tax wage income is higher, because labour tax payable by households decreases by 1.67%

[27] Note that with directed search, the decrease in vacancies is not a sufficient condition for a decrease in employment. If the number of workers searching in the market increases sufficiently, the number of matches can still increase.

[28] Keeping public-sector vacancies fixed has small effects.

and hours worked remain almost unchanged.[29] Wage decrease induces private-sector firms to post more vacancies, which increases employment, incomes, demand and production.

In general, all measures that lead to higher employment are expansive. In particular, measures that make workers reallocate to the sector with more efficient matching, in this case the private sector, are more expansive. The main reason why the flexible case is one of the most expansive, is that wages in the public sector follow private-sector wages, leading to more reallocation of workers into the sector with more efficient matching. If public-sector vacancies do not increase (the case with fixed vacancies in Table 10), reallocation is further amplified. Because unemployment benefits in the flexible case decrease in line with wages (replacement ratio is kept constant), workers' outside option becomes worse and they are willing to accept (pre-tax) pay cuts. If unemployment benefits are kept at their original level, private-sector wages do not decrease as much, vacancies increase by less, leading to lower employment and output. Note that in all cases, government debt ratio increases.

5 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 of labor taxes with the aim of supporting job creation and growth.

We address the implications of such tax reform propositions in a micro-founded structural model of the euro area and the global economy, with an emphasis on the labor market. In particular, we consider an explicit labor market with search and matching frictions. Moreover, we introduce public-sector employment to account for the fact that, in euro area in particular, a substantial proportion of employment is in the public sector. We add the possibility for unemployed to decide in which sector they will search for work, which is particularly appealing because we consider structural reforms, i.e., long-run developments where agents can adjust.

Our results indicate that the implementation of permanent reductions in labor taxes, either paid by firms or by households, have expansionary effects on economic activity and can significantly reduce unemployment. These effects are expansionary both in the long-run equilibrium

[29] The percent decrease in the public-sector wage is somewhat smaller than the percent decrease in private-sector wages, which is partly due to the wage premium in the public sector.

and in the short run, during the time when households and firms have to pay adjustment costs to change their allocations in response to the lower tax rate. When labor tax rates are reduced simultaneously throughout the monetary union, they have expansionary effects on both the Home economy and on the REA, while reducing unemployment rates in both. The expansion in the REA can amplify the expansion in Home, although this effect is not very large.

When there are two sectors with different degrees of frictions on the labor market, then labor tax changes can induce workers to reallocate to the market where the matching process is more efficient. We find that this occurs when labor taxes paid by firms are reduced. In this case, workers reallocate from a sector with less efficient labor market to a sector with a more efficient labor market in response to tax changes, leading to a substantially larger expansionary effects of tax reforms.

This paper does not consider that workers may have different skills or any other type of heterogeneity. For similar reasons, we do not consider that labor tax schedules are typically progressive and that there can be distributional issues, depending on the propensity of households to consume. While the latter would typically be modelled in a large-scale model by the introduction of a proportion of liquidity-constrained households, we leave this for future research.

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Appendix

A 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 labour taxes. The key difference from the case without taxes is that the labour tax payable by households enters the bargaining problem and influences both the determination of wages and hours worked. We reproduce here the key equations before turning to the derivation of Nash bargaining.

Value of being employed:

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

Value of being unemployed:

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

Value of having a worker:

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

Nash bargaining When a firm and a worker meet, they determine the wage and the number of hours worked by maximising the following Nash product (η is the bargaining power of a worker):

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

The first-order condition with respect to wages is:

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

Note that labour taxes influence the bargaining by modifying the share of the surplus that goes to the worker. The larger is the share of the surplus that goes to the worker, the bigger is

the tax base and hence taxes paid to the government, which is taken into account during wage bargaining.

The first-order condition with respect to hours worked is:

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

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

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

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

B 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:

$$M_t^s=\phi_{mat}^s un_t^{s\ \mu_{mat}^s} vac_t^{s\ 1-\mu_{mat}^s}. \tag{25}$$

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

$$p_t^{s,W}=M_t^s/un_t^s=\phi_{mat}^s\left(\frac{vac_t^s}{un_t^s}\right)^{1-\mu_{mat}^s}. \tag{26}$$

$$p_t^{s,F}=M_t^s/vac_t^s=\phi_{mat}^s\left(\frac{vac_t^s}{un_t^s}\right)^{-\mu_{mat}^s}. \tag{27}$$

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

$$nde_t^s = (1-\delta_x^s)nde_{t-1}^s + M_t^s \tag{28}$$

$$= (1-\delta_x^s)nde_{t-1}^s + p_t^{s,F} vac_t^s \tag{29}$$

$$= (1-\delta_x^s)nde_{t-1}^s + p_t^{s,W} un_t^s. \tag{30}$$

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

$$nde_t = nde_t^P + nde_t^G. \tag{31}$$

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

$$une_t = 1 - nde_t^P - nde_t^G. \tag{32}$$

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

$$un_t = 1 - nde_{t-1}^P - nde_{t-1}^G + \delta_x^P nde_{t-1}^P + \delta_x^G nde_{t-1}^G. \tag{33}$$

C Government sector production and demand

Government production. Government production is a standard Cobb-Douglas production function. Government rents capital from competitive market, but decides on its own employment by posting vacancies.

$$Y_{G,t} = {K_{G,t}^D}^{\alpha_G} {N_{G,t}^D}^{1-\alpha_G}, \tag{34}$$

where N_G^D denotes effective labour in the public sector and K_G^D capital services used in the public sector. Demand for capital services in the public sector is chosen optimally as

$$r_{K,t} = \alpha_G \frac{Y^S_{G,t}}{K^G_t} mc_{G,t}. \tag{35}$$

Because government decides on the number of vacancies posted (which determines employment), this is not in the first-order condition of the public sector firm. Public sector firms only choose the amount of capital rented. Therefore, their marginal costs are not analogous to those of private-sector firms, because they treat the number of workers hired as given. Marginal costs of a public-sector firm are therefore:[30]

$$mc_{G,t} = \frac{R_{K,t} K^D_{G,t}}{\alpha_G Y_{G,t}}, \tag{36}$$

Government pricing. Public sector has sticky prices and sets them according to a Calvo scheme. Calvo parameters are currently assumed to be the same as in the private non-tradable sector. All other characteristics are also the same as in the private non-tradable sector.

Government-produced good demand. We assume that government consumes all its own-produced goods. These goods are wasteful in the sense that they neither enter households' utility nor are used as public capital in production. Government spending on own-produced goods is assumed to be a fixed percentage of nominal GDP. In the calibration, the share of government consumption on other goods (not own-produced) is reduced by the amount of own-produced goods, so that the sum of government own-produced consumption and non-own-produced consumption is equal to the share of government consumption in the original EAGLE model.

Government own-produced good spending is therefore

$$P_{GG,t} G_{G,t} = gg_t \overline{P_Y Y}, \tag{37}$$

where P_{GG} is the price of government own-produced good, G_G is the quantity of government own-produced good consumption, and gg is the share of government own-produced good consumption in nominal GDP, $\overline{P_Y Y}$.

Government own-spending shock evolves according to the following rule

[30] Public sector firms minimise their cost, $R_{K,t} K^D_{G,t} + (1+\tau^{wf}_t) w^G_t h^G_t N^D_{G,t}$, subject to the production function. Real marginal costs, $mc_{G,t}$ are the Lagrange multiplier of the problem.

$$gg_t = (1 - \rho_{GG})\overline{gg} + \rho_{gg} gg_{t-1} + \varepsilon_{G,t}, \tag{38}$$

where $\overline{gg}$ is the steady-state share of government own-spending in nominal GDP, and $\varepsilon_{G,t}$ is government own-spending shock.

For the public sector, the assumption that government buys its own-produced goods implies:

$$Y^S_{G,t} = sx_{G,t} G_{G,t}, \tag{39}$$

where sx_G is the price dispersion in the public sector.

D Budget constraints and aggregation

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

Capital market clearing. Public sector capital services, K^D_G are taken from the aggregate pool of available capital services, K^D, which results in the following market-clearing condition for capital services (K^D_T and K^D_{NT} are demands for capital services by the tradable and non-tradable sectors, respectively):

$$K^D_t = K^D_{T,t} + K^D_{NT,t} + K^D_{G,t}. \tag{40}$$

Labour market clearing. Labour demand in the public sector is set exogenously by the government and is determined through the posting of public sector vacancies. The amount of labour services provided by the workers in the public sector is affected by the hours choice, determined analogously to the private sector (equation 16). The market clearing for public sector labour services is thus

$$N^D_{G,t} = nde^G_t h^{G\ \alpha_H}_t. \tag{41}$$

All available labour services produced by employed workers in labour firms are demanded by private sector intermediate firms, either in tradable or in non-tradable sectors (N^D_T and N^D_{NT},

respectively):

$$N_{P,t}^D = nde_t^P h_t^{G\ \alpha_H} = N_{T,t}^D + N_{NT,t}^D. \tag{42}$$

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

$$N_t^D = N_{P,t}^D + N_{G,t}^D. \tag{43}$$

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. Labour, 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 own-produced goods, 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 the introduction of hours worked, differences in wage levels in the public and private sectors, and differences in the tax bases of income taxes payable by firms and income taxes payable by workers.

The assumption is that unemployment benefits are paid in terms of consumption goods. Vacancy posting costs in the public sector are assumed to be the same as in the private sector, but denominated in public sector goods. This is why vacancy posting costs are multiplied by the relative price of government own-produced goods.

Labour tax base for intermediate goods firms is the cost of the amount of effective labour services obtained, $x_t^s nde_t^s h_t^{s\alpha_H}$, while the tax base for the household is the amount of hours and workers supplied to the labour firm. Note that because $\alpha_H = 0.99$, the two tax bases are almost identical.

The budget constraint of the government is

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

where Θ includes the remaining government spending (on private-sector-produced goods), transfers not related to unemployment (assumed to be zero), and interest payments. Γ 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 demand for government own-produced goods.

$$P_{Y,t} Y_t = Q_{C,t} + P_{I,t} Q_{I,t} + P_{NT,t} G_t + P_{GG,t} G_{G,t} + trade\ balance \tag{44}$$

Aggregate real demand is equal to total production

$$Y_t = Y_{T,t}^S + Y_{NT,t}^S + Y_{G,t}^S. \tag{45}$$

Table 1: Steady-State National Accounts (Ratio to GDP, %)

	Home	REA	US	RW
Domestic demand				
Private consumption	59	60	62	63
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	40	40
Production				
Tradables	40	39	37	36
Nontradables	60	61	63	64
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

Table 2: Households, Entrepreneurs and Firms Behavior

	Home	REA	US	RW
Households				
Discount factor (β)	$1.03^{-\frac{1}{4}}$	$1.03^{-\frac{1}{4}}$	$1.03^{-\frac{1}{4}}$	$1.03^{-\frac{1}{4}}$
Intertemporal elasticity of substitution (σ^{-1})	1.00	1.00	1.00	1.00
Inverse of the Frisch elasticity of labor (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 nontrad. sectors)				
Substitution btw. 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 - nontradables (α_N)	0.30	0.30	0.30	0.30
Production - labour services (α_H)	0.99	0.99	0.99	0.99
Final consumption-good firms				
Substitution btw. domestic and imported trad. goods (μ_{TC})	2.50	2.50	2.50	2.50
Bias towards domestic tradables goods (v_{TC})	0.27	0.21	0.65	0.59
Substitution btw. tradables and nontradables (μ_C)	0.50	0.50	0.50	0.50
Bias towards tradable goods (v_C)	0.45	0.45	0.35	0.35
Substitution btw. consumption good imports (μ_{IMC})	2.50	2.50	2.50	2.50
Final investment-good firms				
Substitution btw. domestic and imported trad. goods (μ_{TI})	2.50	2.50	2.50	2.50
Bias towards domestic tradables goods (v_{TI})	0.40	0.76	0.71	0.56
Substitution btw. tradables and nontradables (μ_I)	0.50	0.50	0.50	0.50
Bias towards tradable goods (v_I)	0.75	0.75	0.75	0.75
Substitution btw. 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

Table 3: Price Markups (Implied Elasticities of Substitution)

	Tradables (θ_T)	Nontradables (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

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 nontradables (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 nontradables (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

Table 5: International Linkages (Trade Matrix, Share of Domestic GDP, %)

	Home	REA	US	RW
Consumption-good imports				
Substitution btw. consumption good imports (μ_{IMC})	2.50	2.50	2.50	2.50
Total consumption good imports	18.3	20.1	7.2	8.6
From partner				
Home	-	3.1	0.3	1.1
REA	8.9	-	0.8	3.6
US	1.1	0.5	-	3.9
RW	8.3	16.5	6.1	-
Investment-good imports				
Substitution btw. investment good imports (μ_{IMI})	2.50	2.50	2.50	2.50
Total investment good imports	9.2	3.6	4.2	6.2
From partner				
Home	-	2.2	0.2	0.7
REA	4.4	-	0.4	2.2
US	0.6	0.6	-	3.3
RW	4.2	0.8	3.6	-

Note: REA=Rest of Euro Area; US=United States; RW=Rest of World

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_{B_Y})	0.1	0.1	0.1	0.1
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)	0.183	180	0.154	0.149
Labor income tax rate (τ_N)	0.122	0.122	0.154	0.154
Rate of social security contribution by firms (τ_{W_f})	0.219	0.219	0.071	0.071
Rate of social security contribution by households (τ_{W_h})	0.118	0.118	0.071	0.071

Note: REA=Rest of Euro Area; US=United States; RW=Rest of World

Table 7: Labor market in the basic model

	Home	REA	US	RW
Matching efficiency, ϕ_{mat}	0.70	0.70	0.70	0.70
Vacancy posting cost, ψ	0.0978	0.0961	0.5132	0.5095
Break-up rate, δ_x	0.0574	0.0574	0.0428	0.0428
Disutility of labour, χ	2.2232	2.1822	2.7061	2.6491
Unemployment benefits, *uben*	0.5017	0.4931	0.2359	0.2342
Matching elasticity, μ_{mat}	0.60	0.60	0.60	0.60
Replacement ratio, *rr*	0.50	0.50	0.20	0.20
Labour supply elasticity, ζ	0.5	0.5	0.5	0.5
Labour tax payable by households, τ^{wh}	0.118	0.118	0.071	0.071
Labour tax payable by firms, τ^{wf}	0.219	0.219	0.071	0.071

Note: REA=Rest of Euro Area; US=United States; RW=Rest of World

Table 8: Calibration of the full model with public sector

Parameter	Home	REA	US	RW
Matching efficiency, private, ϕ^P_{mat}	0.7000	0.7000	0.7000	0.7000
Matching efficiency, public, ϕ^G_{mat}	0.3743	0.3742	0.4518	0.4538
Vacancy posting cost, ψ	0.1034	0.1024	0.5159	0.5078
Break-up rate, private, δ^P_x	0.0173	0.0173	0.0380	0.0380
Break-up rate, public, δ^P_x	0.01	0.01	0.01	0.01
Disutility of labour, χ	2.6615	2.6113	2.7536	2.6974
Job finding prob. in pub. s., $p^{P,W}$	0.0304	0.0304	0.0784	0.0784
Unemployment benefits, *uben*	0.5124	0.5076	0.2361	0.2324
Matching elasticity, private, μ^P_{mat}	0.6	0.6	0.6	0.6
Matching elasticity, public, μ^G_{mat}	0.2	0.2	0.2	0.2
Replacement ratio, rr	0.5	0.5	0.2	0.2
Labour supply elasticity, ζ	0.5	0.5	0.5	0.5
Public sector wage premium	5%	5%	5%	5%
Government cons., $\frac{\overline{P_{NT}G}}{\overline{P_Y Y}}$	10%	10%	6%	6%
Government own-cons., $\frac{\overline{P_G G_G}}{\overline{P_Y Y}}$	10%	10%	10%	10%

Table 9: Long-run responses, labour taxes payable by firms

Variable	All flexible	W. fixed	Vac. fixed	Ben. fixed	All fixed
Output	0.51	1.76	0.52	0.85	2.08
Consumption	0.65	2.21	0.65	1.07	2.62
Investment	0.33	1.15	0.33	0.55	1.36
Export	0.56	1.90	0.56	0.92	2.25
Import	0.34	1.17	0.34	0.56	1.39
Debt ratio	5.09	1.52	5.10	3.35	-0.05
Private s. wages	1.26	1.00	1.25	1.17	0.92
Public s. wages	1.27	0.00	1.27	1.27	0.00
Employment	0.12	1.13	0.12	0.42	1.40
Emp. in priv. s.	0.22	2.38	0.23	0.80	2.93
Emp. in pub. s.	-0.27	-3.86	-0.30	-1.10	-4.74
Vacancies	1.87	-0.34	1.86	4.94	2.88
Vacancies in priv. s.	2.13	-0.40	2.12	5.65	3.29
Vacancies in pub. s.	0.04	0.04	0.00	0.04	0.00
Hours worked	0.30	-0.72	0.30	0.06	-0.95
Hours in priv. s.	0.30	-0.60	0.30	0.06	-0.83
Hours in pub. s.	0.31	-1.08	0.31	0.10	-1.28

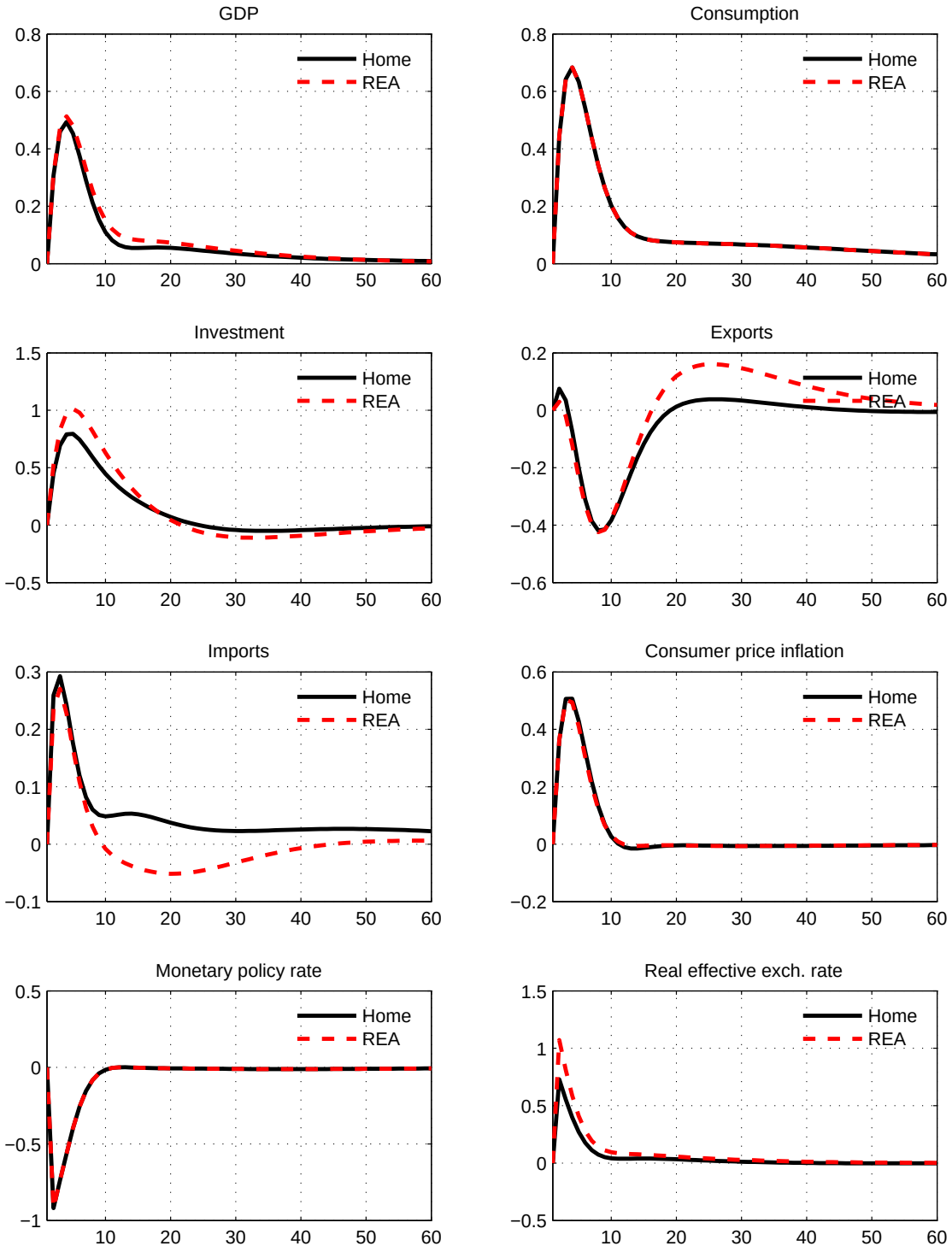
Note: All are percent deviations from the initial steady state, except the public debt ratio, which is in percentage points. Hours are hours per worker.

Table 10: Long-run responses, taxes payable by households

Variable	All flexible	W. fixed	Vac. fixed	Ben. fixed	All fixed
Output	1.28	1.08	1.30	1.20	1.02
Consumption	1.61	1.36	1.64	1.52	1.29
Investment	0.83	0.70	0.85	0.78	0.66
Export	1.38	1.17	1.41	1.30	1.11
Import	0.84	0.72	0.85	0.79	0.68
Debt ratio	5.56	6.10	5.61	5.96	6.57
Private s. wages	-0.32	-0.27	-0.32	-0.29	-0.25
Public s. wages	-0.23	0.00	-0.23	-0.23	0.00
Employment	0.69	0.52	0.68	0.62	0.44
Emp. in priv. s.	1.30	0.94	1.35	1.17	0.84
Emp. in pub. s.	-1.78	-1.17	-1.96	-1.58	-1.17
Vacancies	6.40	6.74	6.34	5.63	5.90
Vacancies in priv. s.	7.29	7.68	7.26	6.41	6.75
Vacancies in pub. s.	0.23	0.23	0.00	0.23	0.00
Hours worked	-0.01	0.16	-0.03	0.04	0.20
Hours in priv. s.	-0.01	0.14	-0.03	0.04	0.18
Hours in pub. s.	0.02	0.26	0.01	0.07	0.30

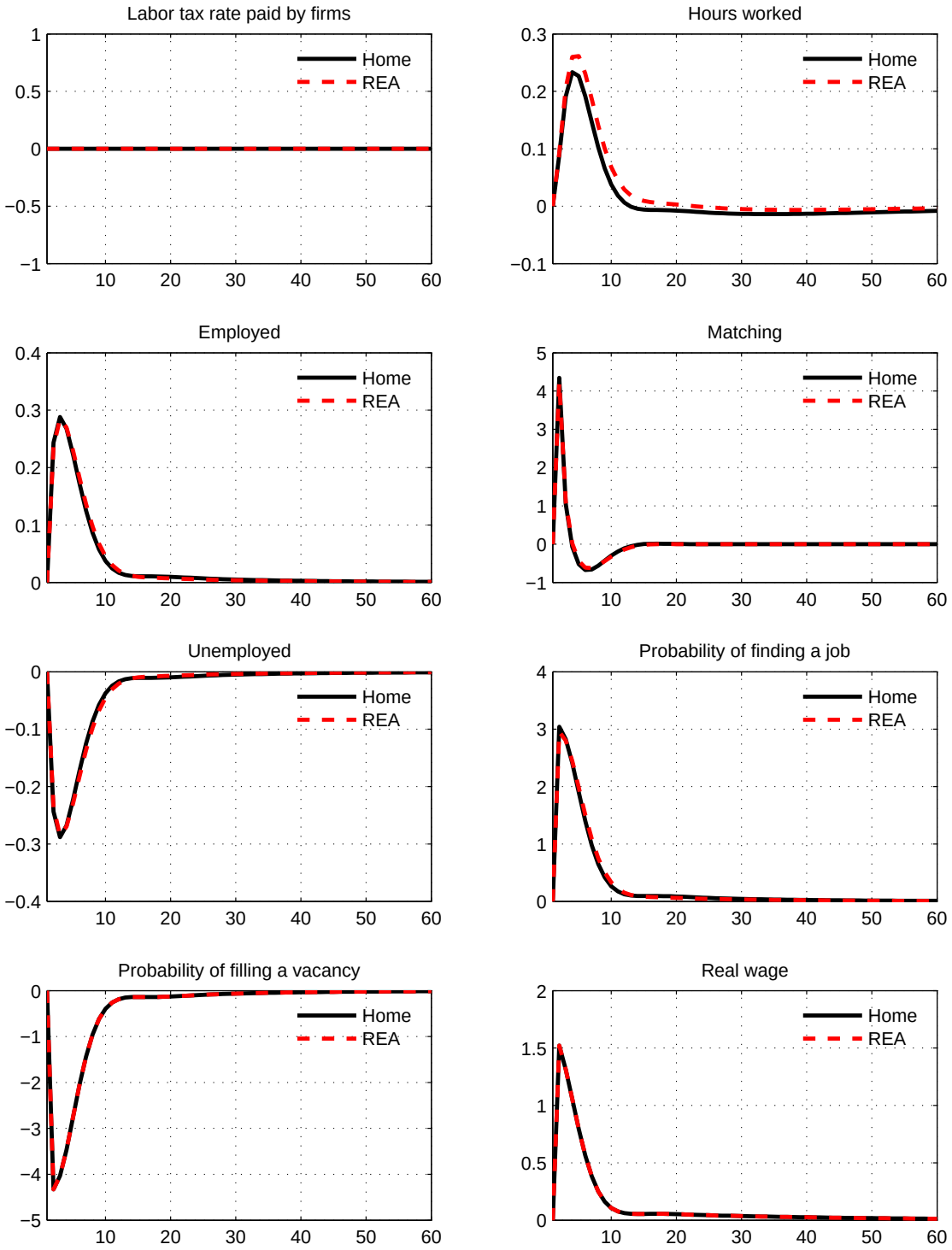
Note: All are percent deviations from the initial steady state, except the public debt ratio, which is in percentage points. Hours are hours per worker.

Figure 1. Decrease in the monetary policy rate. Main macroeconomic variables



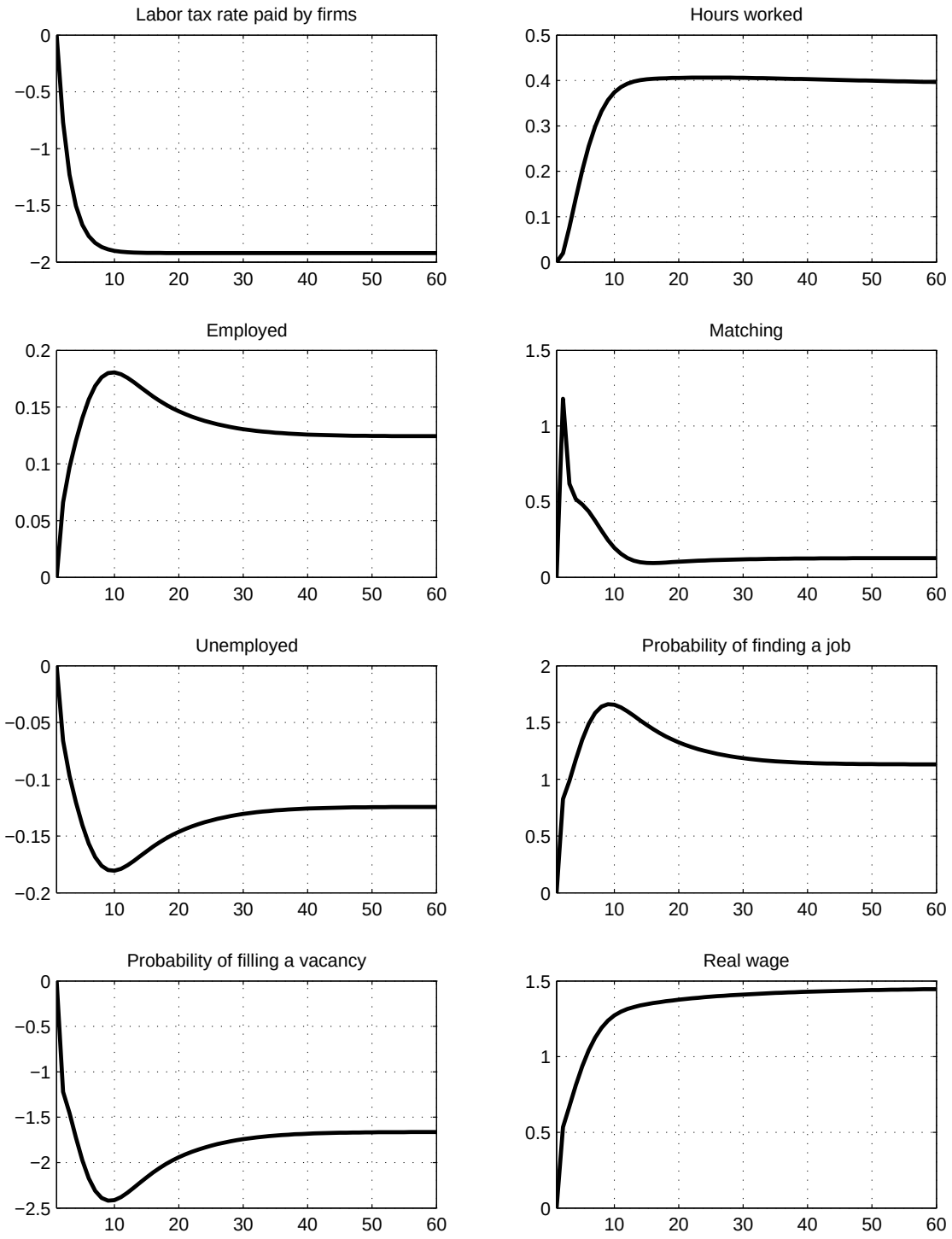
Note. Horizontal axis: quarters. Inflation and interest rate in % point dev. from initial steady state. Remaining variables in % dev.

Figure 2. Decrease in the monetary policy rate. Labor market variables



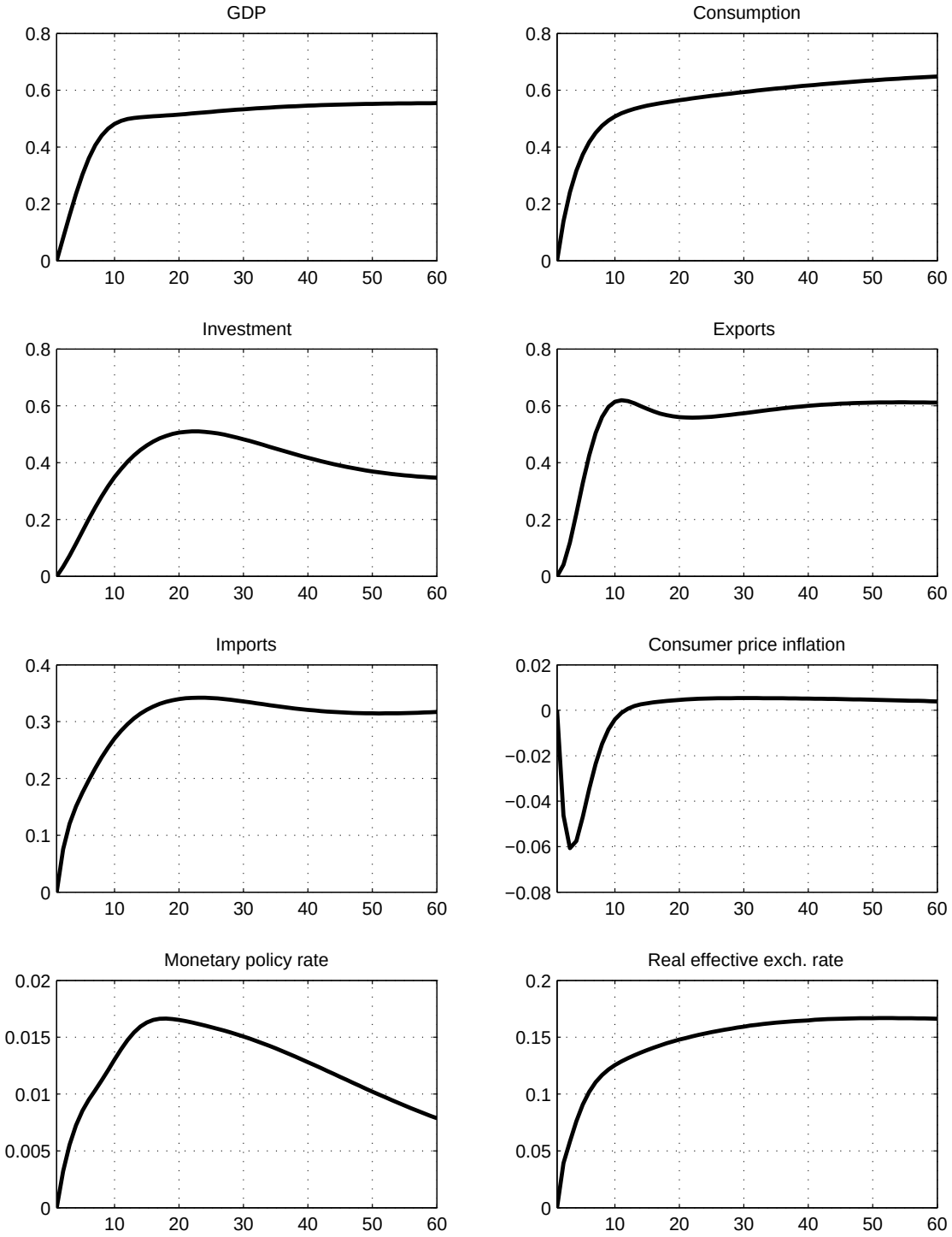
Note. Horizontal axis: quarters. Tax rate, probabilities, employment and unemployment rates in % point dev. from initial steady state. Remaining variables in % dev.

Figure 3. Decrease in the labor tax rate paid by Home firms. Labor market variables



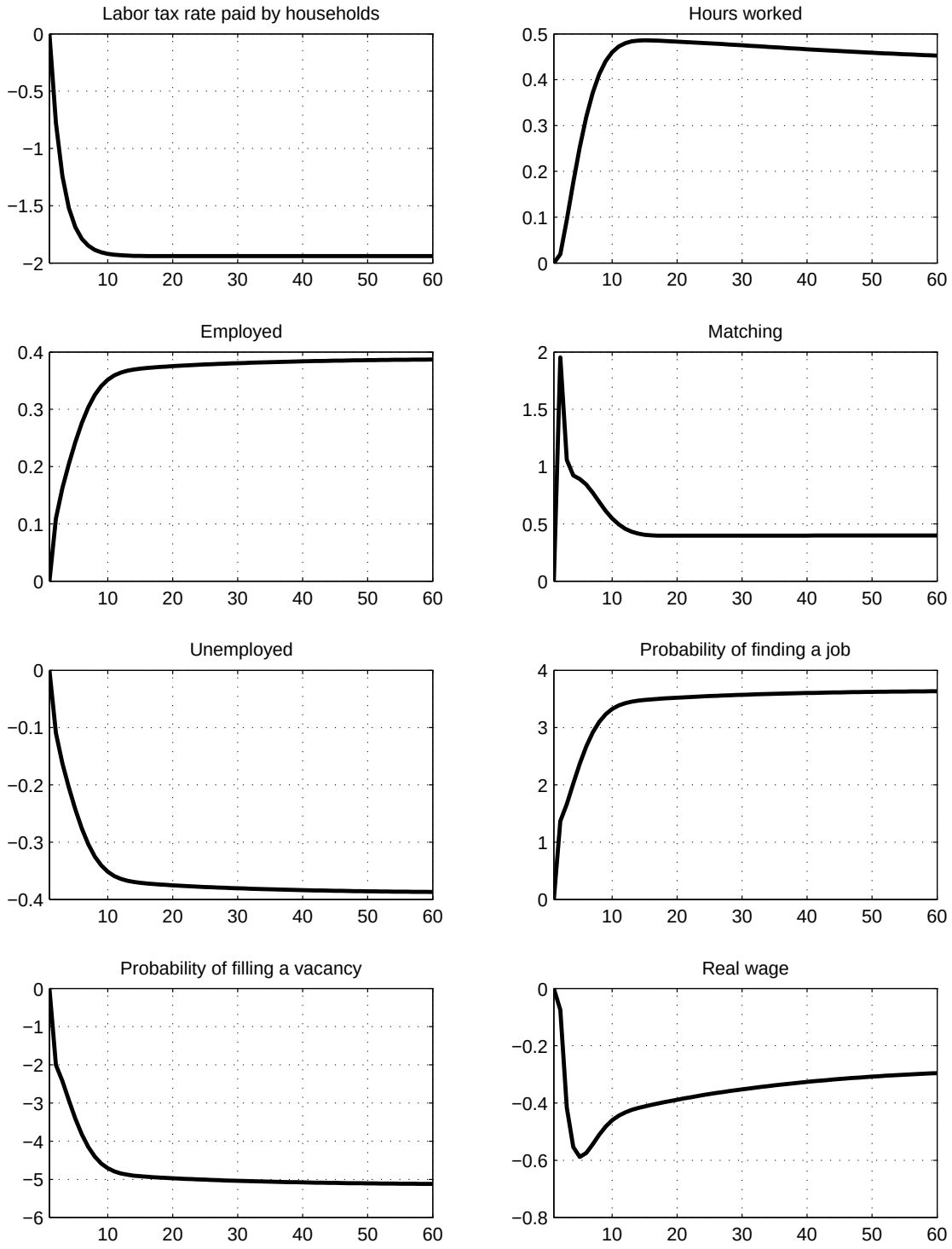
Note. Horizontal axis: quarters. Tax rate, probabilities, employment and unemployment rates in % point dev. from initial steady state. Remaining variables in % dev.

Figure 4. Decrease in the labor tax rate paid by Home firms. Macroeconomic variables



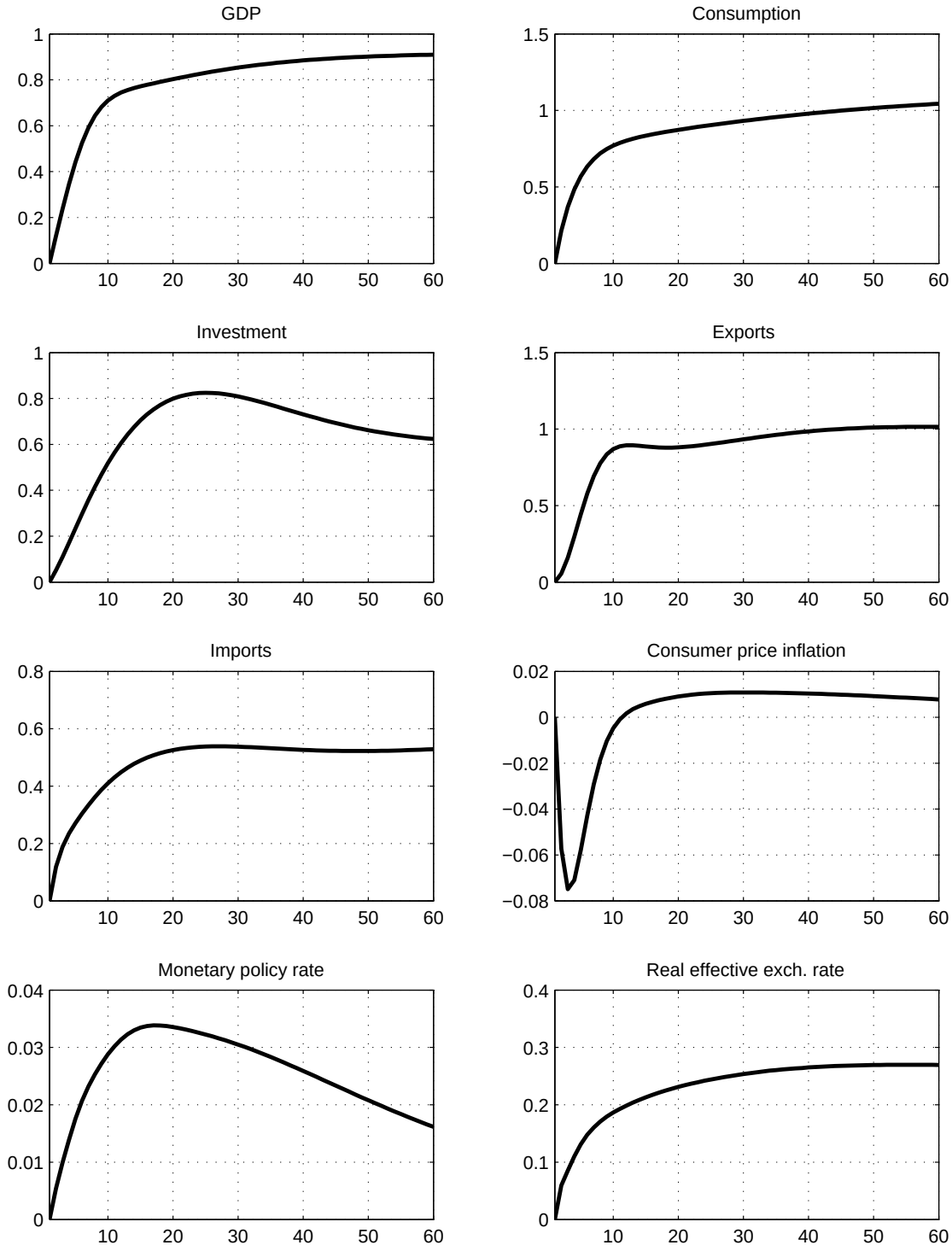
Note. Horizontal axis: quarters. Inflation and interest rate in % point dev. from initial steady state. Remaining variables in % dev.

Figure 5. Decrease in the labor tax rate paid by Home households. Labor market variables



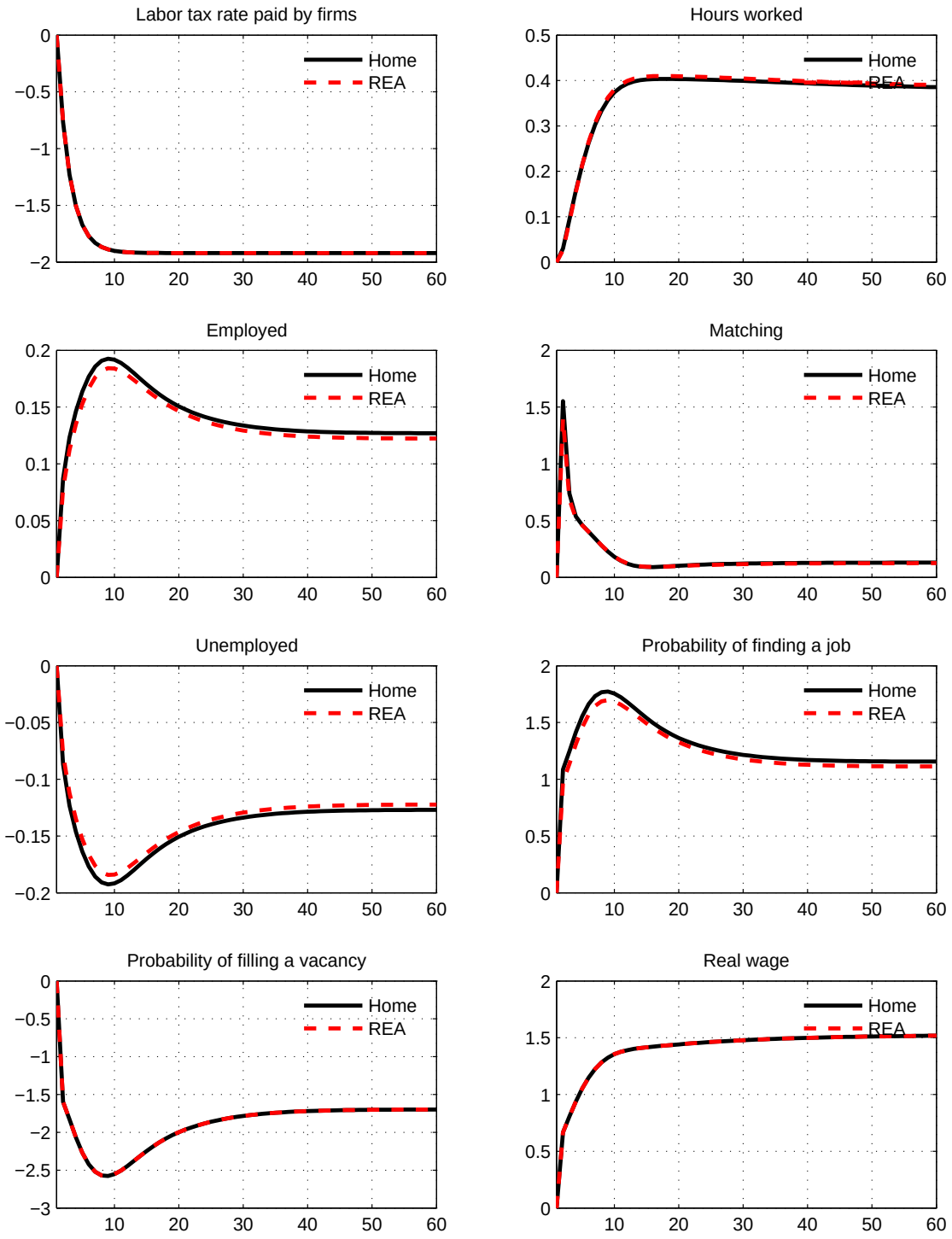
Note. Horizontal axis: quarters. Tax rate, probabilities, employment and unemployment rates in % point dev. from initial steady state. Remaining variables in % dev.

Figure 6. Decrease in the labor tax rate paid by Home households. Macroeconomic variables



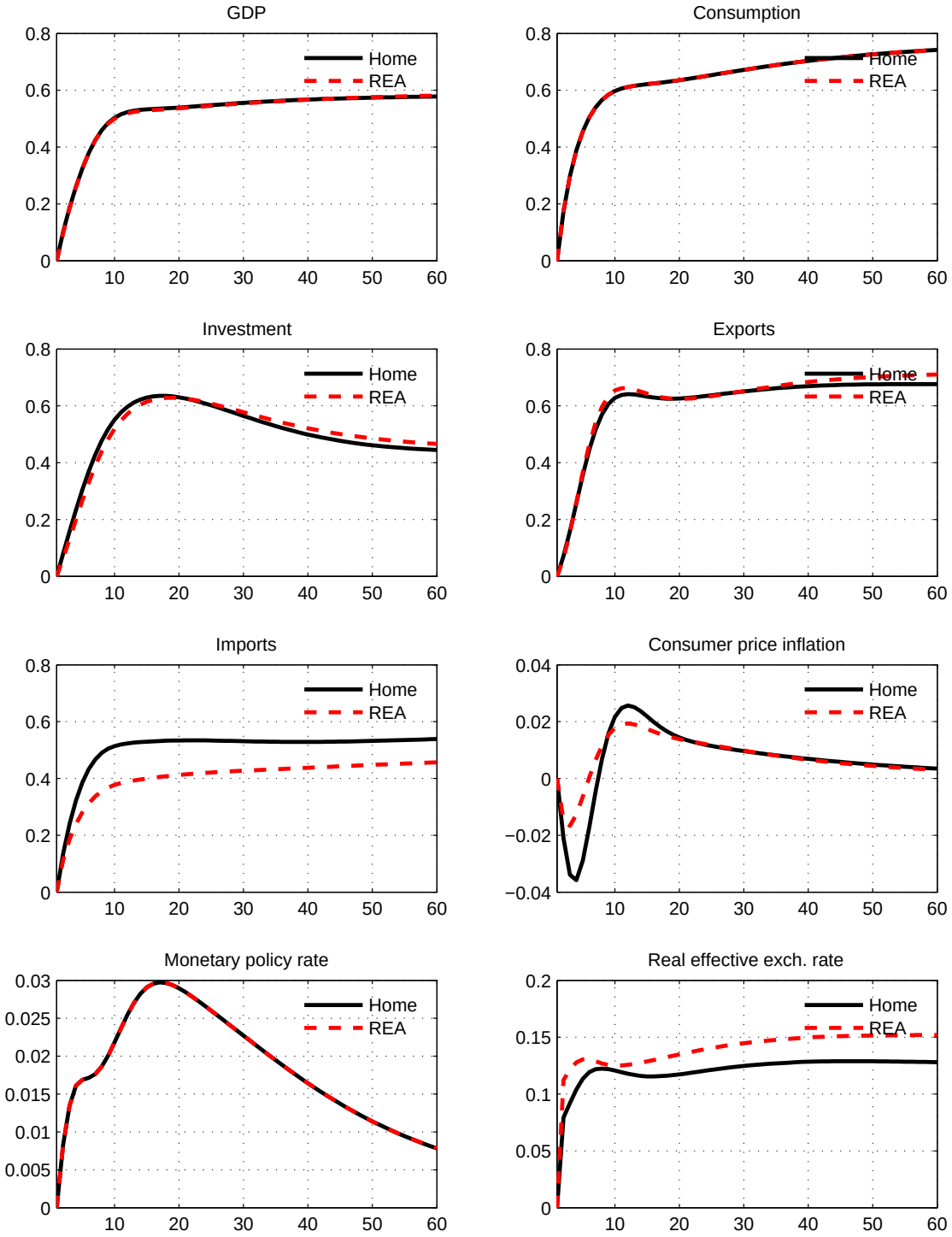
Note. Horizontal axis: quarters. Inflation and interest rate in % point dev. from initial steady state. Remaining variables in % dev.

Figure 7. Decrease in the labor tax rate paid by EA Firms. Labor market variables



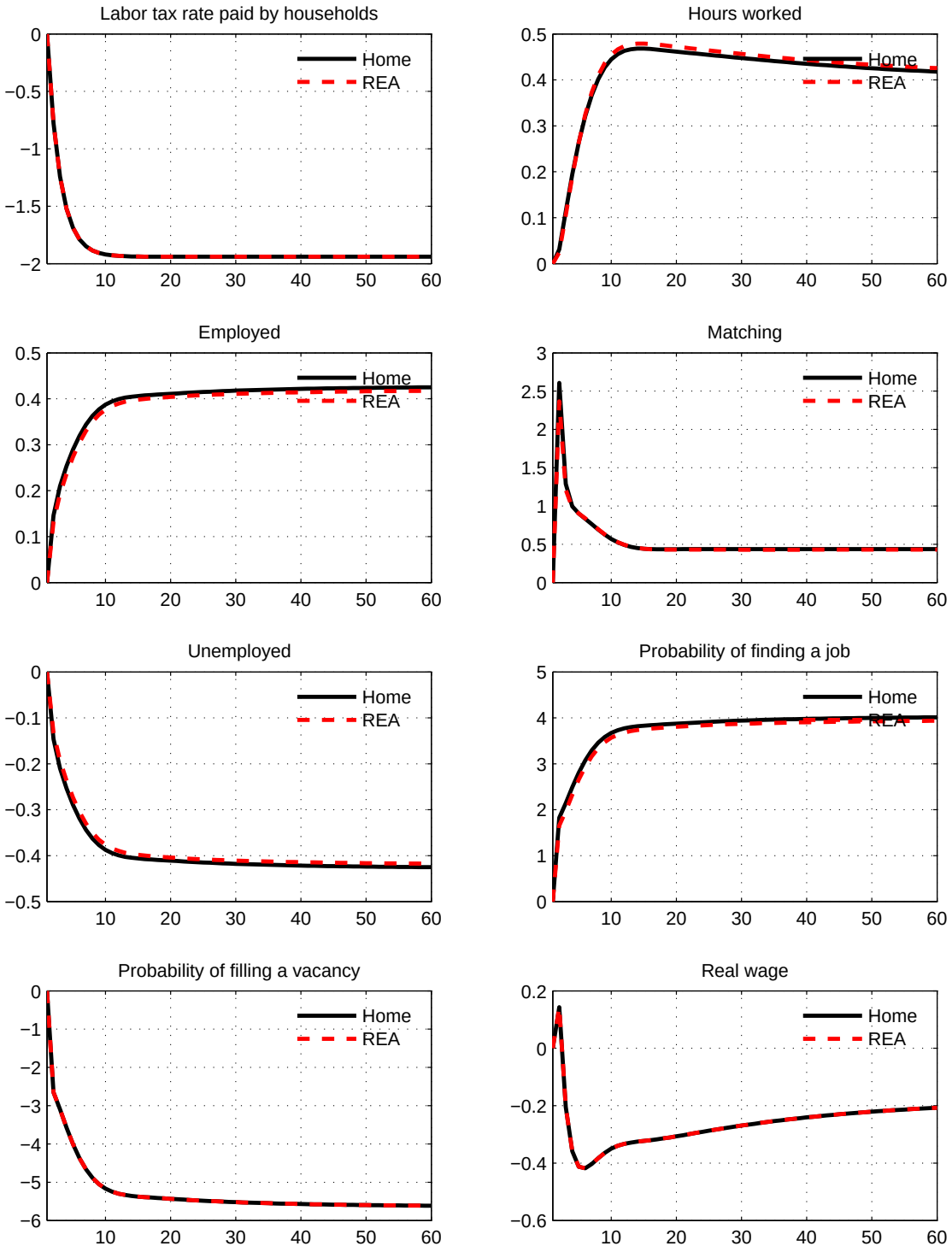
Note. Horizontal axis: quarters. Tax rate, probabilities, employment and unemployment rates in % point dev. from initial steady state. Remaining variables in % dev.

Figure 8 Decrease in the labor tax rate paid by EA firms. Macroeconomic variables



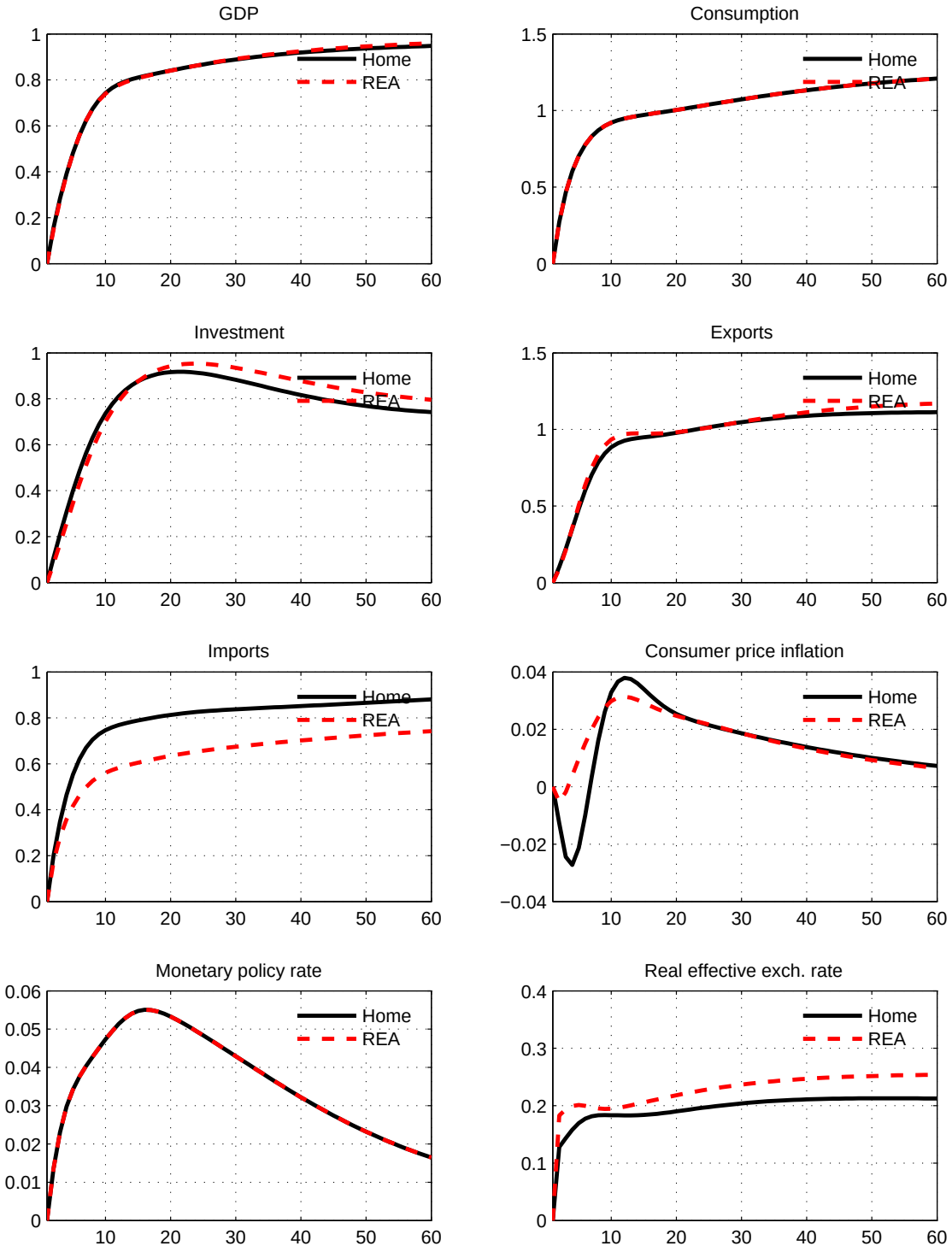
Note. Horizontal axis: quarters. Inflation and interest rate in % point dev. from initial steady state. Remaining variables in % dev.

Figure 9. Decrease in the labor tax rate paid by EA households. Labor market variables



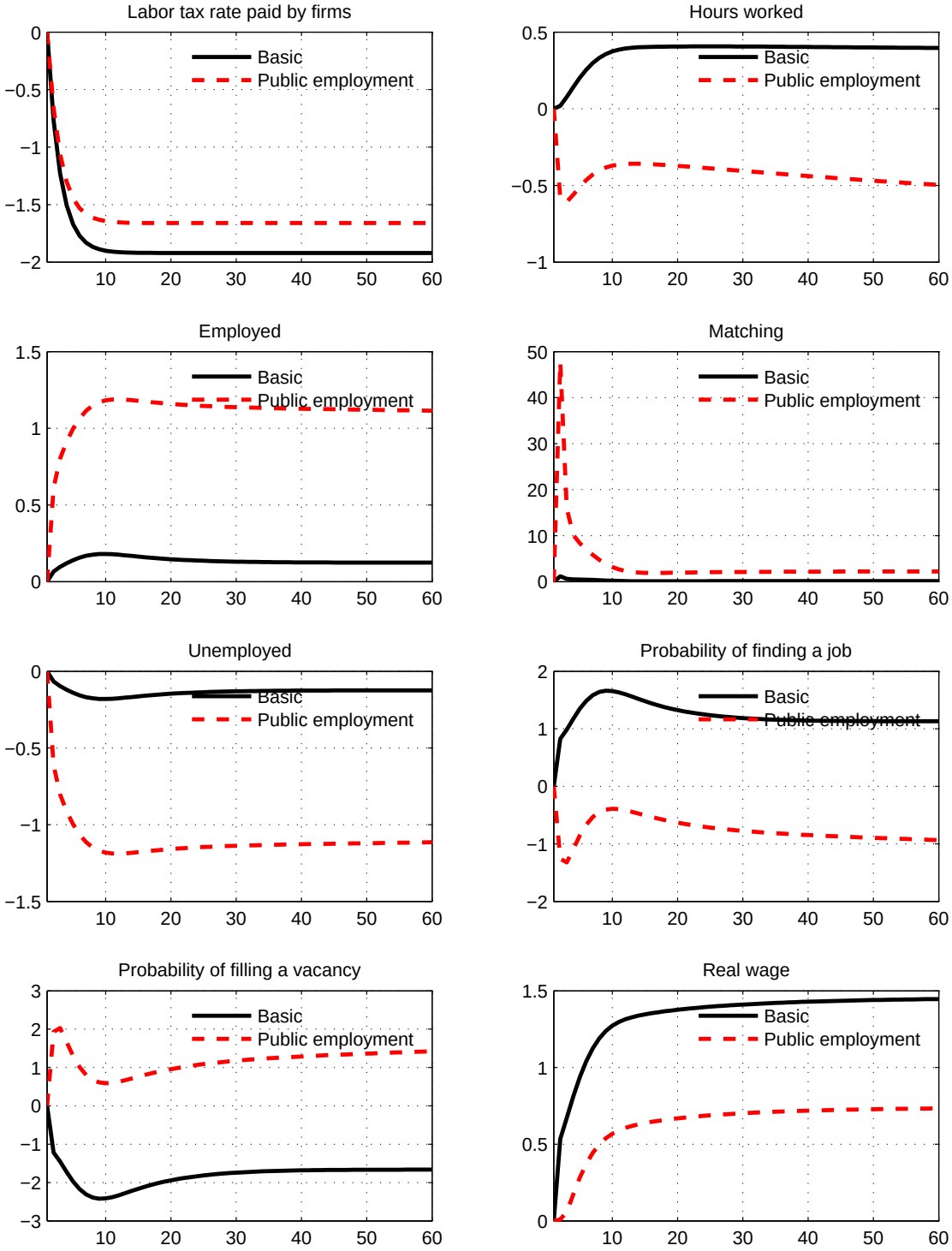
Note. Horizontal axis: quarters. Tax rate, probabilities, employment and unemployment rates in % point dev. from initial steady state. Remaining variables in % dev.

Figure 10. Decrease in the labor tax rate paid by EA households. Macroeconomic variables



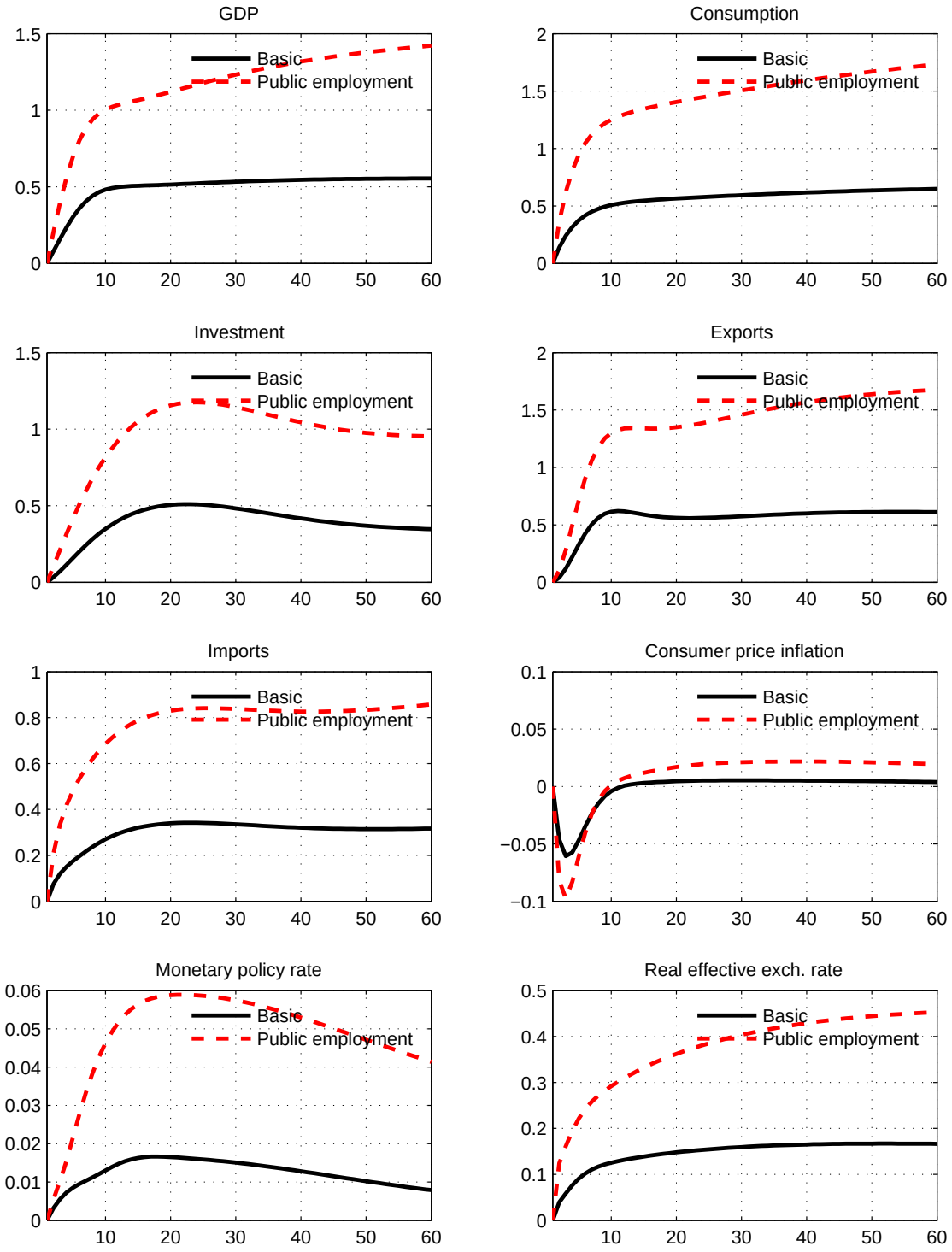
Note. Horizontal axis: quarters. Inflation and interest rate in % point dev. from initial steady state. Remaining variables in % dev.

Figure 11. Decrease in the labor tax rate paid by Home firms, full model. Labor market variables



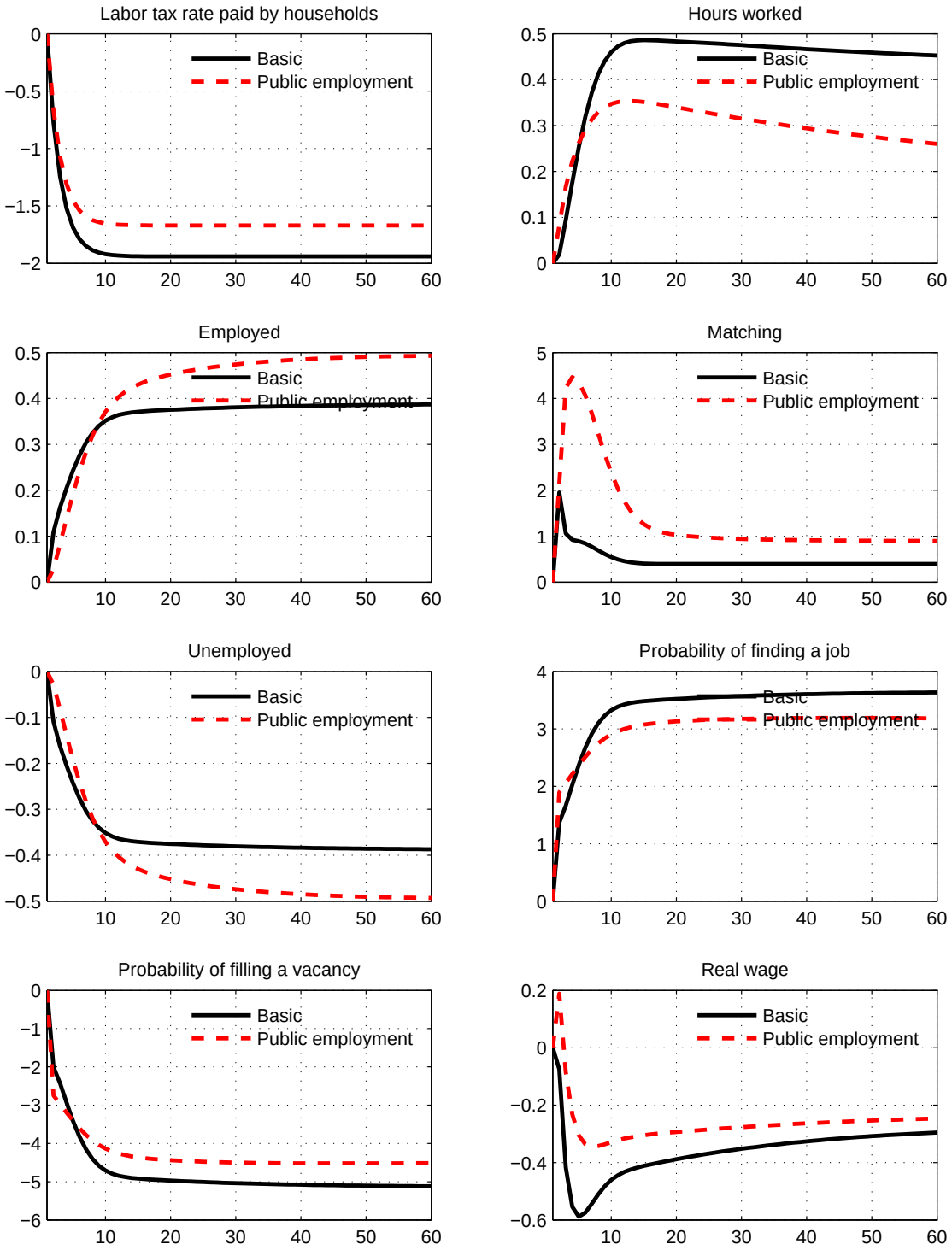
Note. Horizontal axis: quarters. Tax rate, probabilities, employment and unemployment rates in % point dev. from initial steady state. Remaining variables in % dev.

Figure 12. Decrease in the labor tax rate paid by Home firms, full model. Macroeconomic variables



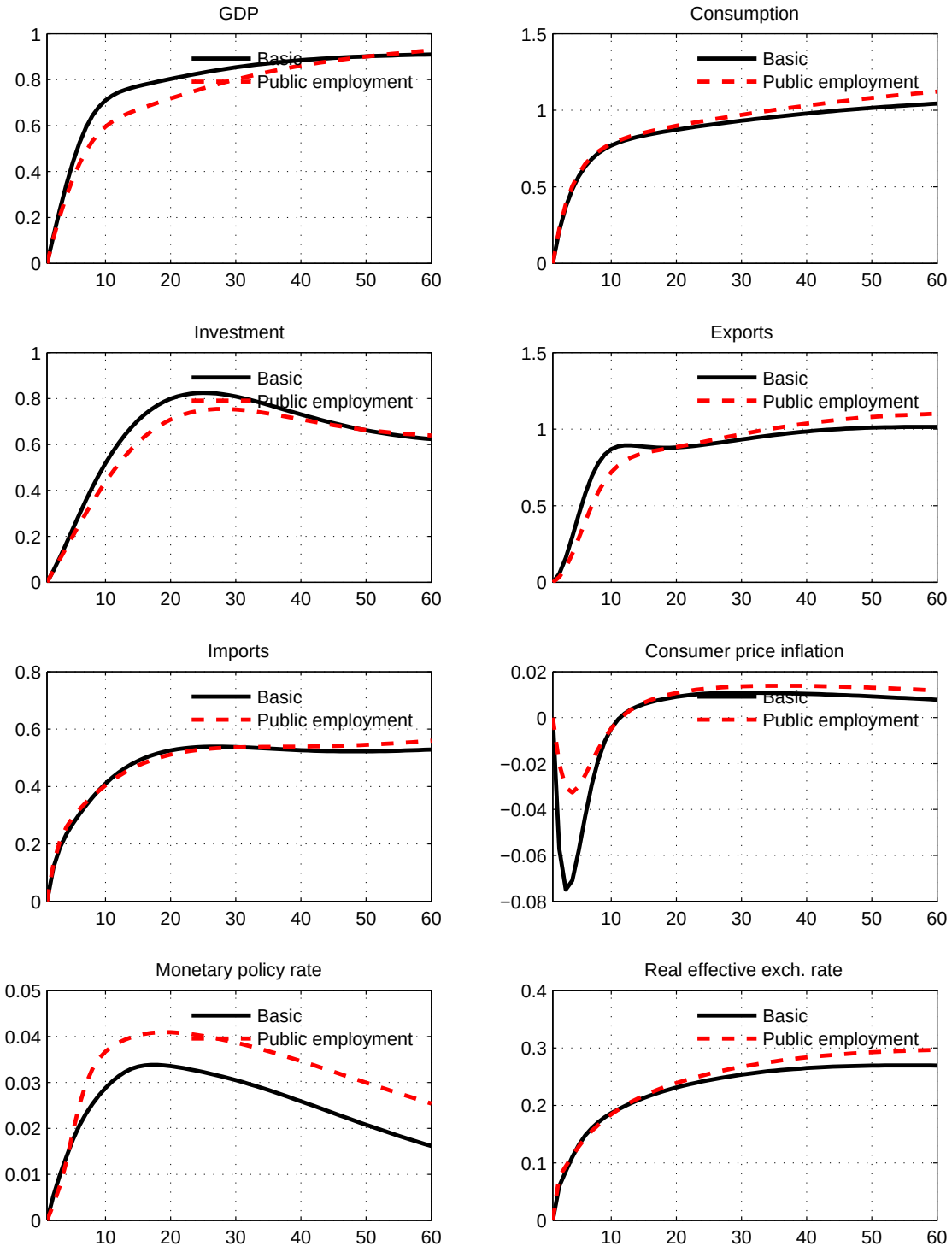
Note. Horizontal axis: quarters. Inflation and interest rate in % point dev. from initial steady state. Remaining variables in % dev.

Figure 13. Decrease in the labor tax rate paid by Home households, full model. Labor market variables



Note. Horizontal axis: quarters. Tax rate, probabilities, employment and unemployment rates in % point dev. from initial steady state. Remaining variables in % dev.

Figure 14. Decrease in the labor tax rate paid by Home households, full model. Macroeconomic variables



Note. Horizontal axis: quarters. Inflation and interest rate in % point dev. from initial steady state. Remaining variables in % dev.