Tax Reform and Labour-Market Performance in the Euro Area: A Simulation-Based Analysis Using the New Area-Wide Model*,†

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Abstract

In this paper, we employ a calibrated two-country version of the New Area-Wide Model (NAWM) currently under development at the European Central Bank to examine the potential benefits and spillovers of reducing labour-market distortions caused by euro area tax structures. Our analysis shows that lowering tax distortions to levels prevailing in the United States would result in an increase in hours worked and output by more than 10 percent. At the same time, tax reductions would have positive spillovers to the euro area's trade partners, bolstering the case for tax reforms from a global perspective. Finally, we illustrate that, in the presence of heterogenous households, distributional effects may be of importance when gauging the impact of tax reforms.

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1 Introduction

What are the important driving forces and economic mechanisms behind the cross-country differences in labour utilisation that have emerged over the recent decades? This question has triggered an intense debate about *institutions versus preferences* as potential explanations of lower labour utilisation in Europe relative to the United States. Prescott (2004) argues forcefully that institutions, and in particular taxes on labour income, are the main explanation for lower labour utilisation in Europe, as measured by the average number of hours worked. In contrast, Blanchard (2004) suggests that European preferences for leisure are an important determinant of the observed downward trend in hours worked. Similarly, Alesina, Glaeser and Sacerdote (2005) claim that Europeans work much less because of the influence of trade unions in the seventies, eighties and part of the nineties (partly reflecting preferences for social cohesion) and because of widespread labour-market regulations creating disincentives to work.

In this paper, we start from Prescott's (2004) analysis and ask the counterfactual question of what would happen in terms of hours worked and overall economic performance if the labour-market distortions originating in European tax structures were to be reduced to levels prevailing in the United States. To answer this question, we employ a calibrated two-country version of the New Area-Wide Model (NAWM) currently under development at the European Central Bank.[1] The specification of the NAWM builds on recent advances in developing micro-founded DSGE models suitable for quantitative policy analysis, as exemplified by the closed-economy model of the euro area by Smets and Wouters (2003), the International Monetary Fund's Global Economy Model (GEM; cf. Bayoumi, Laxton and Pesenti, 2004) or the Federal Reserve Board's new open economy model named SIGMA (cf. Erceg, Guerrieri and Gust, 2005). Thus, it incorporates numerous nominal and real rigidities in an effort to improve its empirical fit regarding both the domestic and the international dimension. The employed version of the NAWM consists of two symmetric countries of different size: the euro area and the United States, the latter representing the

[1] The existing Area-Wide Model (AWM; cf. Fagan, Henry and Mestre, 2001) is a traditional macroeconometric model for the euro area, which features Keynesian behaviour in the short run, with output determined by aggregate demand, and is classical in the long run, with output determined by aggregate supply.

rest of the industrialised world. International linkages arise from the trade of goods and international assets, allowing for imperfect exchange-rate pass-through and financial frictions. Thus, the model permits us to also gauge the international repercussions that may arise from the unilateral reduction of labour-market distortions.[2]

In addition, building on Coenen and Straub (2005), the NAWM features two distinct types of households which differ with respect to their ability to access financial markets, with one type of household only holding money as opposed to also trading bonds and accumulating physical capital.[3] Due to the existence of these two types of households, fiscal policies other than government spending – notably, lump-sum taxes and transfers – also have real effects even though both types of households are optimising subject to intertemporal budget constraints. As regards the labour market, it is assumed that both types of households supply differentiated labour services and act as wage setters in monopolistically competitive markets by charging a markup over their marginal rate of substitution. Specifically, wage setting is characterised by sticky nominal wages à la Calvo (1983) as well as indexation, eventually resulting in two separate wage Phillips curves.[4]

For the purpose of the present study, particular emphasis is given to quantifying the various labour-market distortions originating in national tax structures. In this context, we focus on three major government revenue components that drive a wedge between the effective consumption wage of households (the purchasing power of the after-tax wage) and the effective labour cost of firms: income taxes, social security contributions (both employers' and employees'), and indirect taxes on consumption goods. The size and composition of this tax wedge differ markedly across the euro area and the United States (see OECD, 2004a

[2]Focusing on a unilateral tax reform aimed at replacing a country's tax on capital income with a consumption tax, Mendoza and Tesar (1998) show that the ability to borrow from abroad reduces the transition costs and shifts some of the burden of the adjustment onto the rest of the world. In more recent work, Mendoza and Tesar (2003) consider the strategic interaction that are likely to result from the international externalities of unilateral tax reforms. Such interactions are not addressed in the present study.

[3]As a result, also households with limited ability to participate in asset markets can intertemporally smooth consumption by adjusting their holdings of money. In contrast, Coenen and Straub (2005) follow Galí, López-Salido and Vallés (2004) and assume that one group of households is subject to liquidity constraints and cannot even participate in the money market. These households follow a simple rule of thumb and just consume their after-tax disposable income.

[4]In Coenen and Straub (2005) it is assumed that the wage rates for the liquidity-constrained households correspond to those optimally chosen by the unconstrained households, resulting in a single wage Phillips curve. As we show below, depending on the type of structural shock, this assumption is not innocuous.

and 2004b; and our own calculations presented below). While the overall tax wedge in the euro area currently amounts to roughly 64 percent of the earnings of an average production worker, that of the United States is limited to about 37 percent. Also, the way governments raise revenue differs considerably across the euro area and the United States, with employers' social security contributions for example accounting for 22 percent of earnings in the euro area versus 7 percent in the United States.

As argued by Prescott (2004), the existing large differences in the overall tax wedge across the euro area and the United States (possibly more than its composition) should at least partly explain the euro area's relatively poor performance in terms of labour utilisation when compared to the United States. Indeed, many empirical studies (see for instance those surveyed in IMF, 1999; European Commission, 2004; and Nickell, 2004) report detrimental effects of tax wedges on labour-market outcomes in Europe. Thus, lowering the euro area tax wedge to the level prevailing in the United States ought to lead to a significant rise in labour utilisation and, thereby, to an improvement in overall economic performance.[5] How a reduction in the tax wedge will exactly affect labour utilisation and overall economic performance, however, will largely depend on the particular characteristics of the economy, notably the elasticity of labour supply and the details of the wage-setting process, but also on how the implied losses in revenue are financed and the importance of international spillovers. Hence, a systematic quantitative assessment using a well-articulated dynamic model like the NAWM seems central to making progress towards a better understanding of the effects of tax reforms on labour-market performance.[6]

Our assessment based on the NAWM confirms the widely-held view that reductions in tax distortions have beneficial effects on labour-market outcomes and general economic

[5] Because of the assumed monopoly power of households, the implied steady-state wage markup introduces another labour-market distortion. Thus, as shown in Bayoumi, Laxton and Pesenti (2004) for the euro area and in Kilponen and Ripatti (2005) for Finland, a reduction in the wage markup would be conducive to enhancing labour utilisation and overall economic performance, like a reduction in the tax wedge. Indeed, since the steady-state wage markup is isomorphic to the tax wedge arising from labour income taxes and employees' social security contributions, our study could easily be extended to the case of reducing the steady-state wage markup as well.

[6] While our model accounts for labour-market frictions arising from monopolistic competition and sticky nominal wages, a richer description of labour markets would include an explicit modelling of employment choices (that is, the extensive margin of labour utilisation) and involuntary unemployment. Similarly, real wage rigidities, bargaining and minimum wages all have implications for a policy design conducive to enhancing labour utilisation. However, the analysis of these features is beyond the scope of this study.

performance. In fact, lowering euro area tax wedges to levels prevailing in the United States is found to result in a rise in hours worked and output by more than 10 percent in the long run. At the same time, our analysis shows that tax reforms aimed at reducing labour-market distortions would have beneficial spillovers to the euro area's trade partners, bolstering the case for such reforms from a global perspective. Finally, we illustrate that, in the presence of heterogenous households, distributional effects may be of importance when gauging the macroeconomic impact of tax reforms which, in the first place, have been designed to meet efficiency considerations.

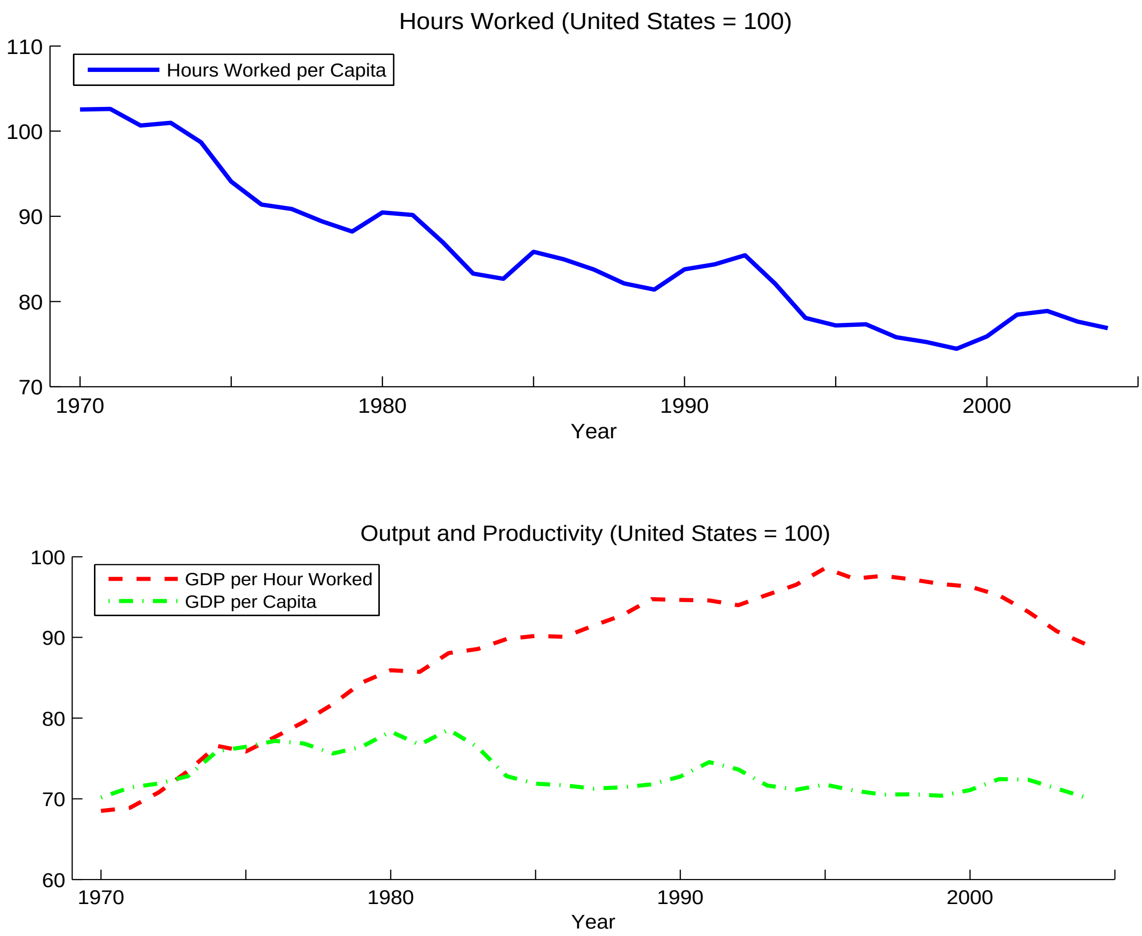
The remainder of the paper is organised as follows. Sections 2 briefly characterises historical developments in labour-market outcomes in the euro area relative to the United States and documents cross-country differences in tax distortions. Section 3 outlines the specification of the NAWM, while Section 4 provides details on its calibration, together with some dynamic simulations illustrating its dynamic properties. Section 5 employs the NAWM to evaluate the benefits and spillovers of reducing the labour-market distortions caused by euro area tax structures to levels prevailing in the United States. Finally, Section 6 summarises our conclusions and suggests directions for future research.

2 Labour-Market Performance and Tax Distortions

While our ultimate objective is to assess the potential benefits and spillovers of reducing the tax distortions that have been identified as a main cause for the deterioration of labour-market outcomes in the euro area, we start our analysis by reviewing some important facts often cited to characterise the euro area's rather poor labour-market performance when compared to the United States. We also take stock of existing cross-country differences in the tax wedges weighing on labour markets.

To document the evolution of labour-market outcomes for the euro area versus the United States, **Figure 1** depicts the time series for hours worked, output per capita and labour productivity (measured as output per hour worked) over the period 1970 to 2004. The upper panel of the figure reveals that, while average hours worked were roughly similar at the start of the 1970s, there has been a notable secular downward trend for the euro area

Figure 1: Hours Worked, Output and Productivity in the Euro Area, 1970–2004



Note: The per-capita measures are based on working-age population aged 15 to 64.
Source: GGDC (2005) and own calculations.

thereafter. The lower panel shows that, although this downward trend has been parallelled by a fairly steady increase in relative labour productivity, which eventually levelled off in the mid-1990s, output per capita has remained largely stable over time at a level considerably below that observed for the United States.[7] Obviously, had relative hours worked remained at the level prevailing at the start of the 1970s, the euro area would have observed roughly the same level of output per capita as did the United States over subsequent years. In other

[7]The more recent decline in relative productivity levels is not addressed here. This decline is most likely attributable to a slowdown in productivity *growth* relative to the United States, while our study assumes the existence of a stationary steady state.

words, the stable difference in output per capita would largely reflect the secular downward trend in labour utilisation.

As argued by Prescott (2004), disparities in national tax structures constitute a key factor in explaining such striking differences in labour utilisation and economic performance in per-capita terms across the euro area and the United States. And indeed, focusing on the three major government revenue components that drive a wedge between the effective consumption wage of households and the effective labour cost of firms, **Table 1** reveals that tax wedges in the euro area are notably higher than in the United States: in 2004, the overall tax wedge amounts to roughly 64 percent of the earnings of an average production worker, while that in the United States is limited to about 37 percent. Thus, the euro area has an overall tax wedge about 27 percentage points higher than that of the United States.[8] In addition, the way governments raise revenue differs markedly across countries. For example, most governments in the euro area have skewed social security contributions heavily towards employers, compared with a balanced incidence in the United States: on average, employers' social security contributions in the euro area account for almost 22 percent of the earnings of an average production worker, which contrasts with little more than 7 percent in the United States. Consequently, euro area governments tend to raise a relatively high amount of revenue from non-wage labour costs adversely affecting labour demand.[9] Similarly, euro area consumption taxes are found to be more than twice as high as those in the United States.

To illustrate the potential importance of the documented tax wedges for explaining the observed differences in labour utilisation between the euro area and the United States, it is useful to consider a simple static example aimed at highlighting the basic economic mechanism. Specifically, consider the real effective wage income of households (the purchasing power of the after-tax wage), $(1-\tau^n-\tau^{w_h})\,W/((1+\tau^c)\,P)$, and the real effective labour cost

[8]Notice that the difference between the tax wedges in the euro area and the United States has been widening since the mid-1990s, mainly because of a rising tax wedge in the euro area: in 1994, the tax wedge in the euro area totalled 55 percent, while it stood at 35 percent in the United States (cf. IMF, 1999).

[9]Though in the long run we might expect non-wage labour costs to be borne fully by workers in the form of lower wages – since capital is internationally mobile with equalised real rates of return – the adjustment period following tax reforms aimed at reducing non-wage labour costs may be protracted reflecting the existence of both nominal and real rigidities as well as other institutional impediments.

Table 1: Tax Wedges in the Euro Area and the United States, 2004

	Consumption Tax	Income Tax	Social Security Contr.		Overall Tax Wedge
			Employees	Employers	
Euro Area					
Austria	20.0	8.4	14.0	22.5	64.9
Belgium	21.0	20.5	10.7	23.0	75.2
Finland	22.0	19.5	4.9	19.4	65.8
France	19.6	9.4	9.8	28.2	67.0
Germany	16.0	16.2	17.3	17.3	66.8
Greece	18.0	0.5	12.5	21.9	52.9
Ireland	21.0	9.6	4.5	9.7	44.8
Italy	20.0	14.0	6.9	24.9	65.8
Luxembourg	15.0	7.9	12.1	11.9	46.9
Netherlands	19.0	7.3	22.2	14.0	62.5
Portugal	19.0	5.1	21.1	17.0	62.2
Spain	16.0	9.7	4.9	23.4	54.0
Average	18.3	12.2	11.8	21.9	64.1
United States	7.7	15.4	7.1	7.1	37.3

Note: Data on consumption taxes are standard rates of VAT for the euro area member states and for the United States the average of state plus maximum local sales tax rates calculated using 2004 GDP weights. Data on labour income taxes and social security contributions (in percent of labour cost) are based on single individuals without children at the income level of the average production worker denominated in US Dollars with equal purchasing power. The overall tax wedge is defined as the sum of the individual tax wedges. The euro area average has been calculated using 2004 GDP weights at PPP exchange rates.

Source: OECD (2004a, 2004b), Tax Policy Center (2005) and own calculations.

of firms, $(1+\tau^{w_f})\,W/P$, where W is the nominal wage rate and P denotes the aggregate price level. The terms τ^n and τ^c are, respectively, the labour income and consumption tax rates; and τ^{w_h} and τ^{w_f} are the social security contributions paid by households and firms. Then, the overall tax wedge $\bar{\tau}$ is the ratio of the two relevant wage rates, or approximately, the sum of its components:

$$\bar{\tau} \;=\; 1 - \frac{(1-\tau^n-\tau^{w_h})}{(1+\tau^c)\,(1+\tau^{w_f})} \;\approx\; \tau^c + \tau^n + \tau^{w_h} + \tau^{w_f}.$$

In equilibrium, the households' real after-tax consumption wage equals the marginal rate of substitution between consumption and leisure, and the firms' real effective wage cost equals the marginal product of labour. Assuming, as in Prescott (2004), logarithmic utility, $\ln(C) + \varphi \ln(1 - N)$ (where C is consumption, N denotes hours worked and φ measures the value of leisure relative to consumption), and a constant-returns-to-scale production technology, $Y = K^{\alpha} N^{1-\alpha}$ (where K is the capital stock and α defines the capital share), we obtain a simple analytical expression, revealing that hours worked are diminishing in the size of the overall tax wedge $\bar{\tau}$:

$$N = \frac{1-\alpha}{1-\alpha + (C/Y)\,\varphi/(1-\bar{\tau})}.$$

Clearly, this simple static example, which focuses on the households' intratemporal consumption-leisure margin and the firms' intratemporal labour-capital margin, neglects the intertemporal aspects associated with capital accumulation and the acquisition of foreign assets and the presence of nominal and real rigidities. With regard to the latter, for example, it disregards distortions arising from monopolistic competition in the labour market that would increase the real wage above the competitive level. It also does not take into account the effects of changes in both domestic and international relative prices. Consequently, the static example ignores several potentially important economic factors, and it also does not provide insights into the transitional dynamics triggered by reductions in the overall tax wedge and its components. In the following section we therefore outline a well-articulated dynamic model of the euro area and the United States which we will employ as a laboratory for evaluating alternative scenarios aimed at reducing the labour-market inefficiencies caused by euro area tax structures.

3 A Model of the Euro Area and the United States

The model consists of two symmetric countries of normalised population size s and $1 - s$, respectively: the euro area, denoted as the home country, and the United States, representing the rest of the industrialised world and denoted as the foreign country. In each country, there are four types of economic agents: households, firms, a fiscal authority, and a monetary authority. We further distinguish between two households which differ with respect to their ability to access financial markets, with one household only holding money as opposed to also trading bonds and accumulating physical capital. As regards firms, we distinguish between producers of tradable differentiated intermediate goods and producers of three non-tradable final goods: a private consumption good, a private investment good, and a public consumption good.

In the following, we outline the behaviour of the different types of agents, characterise the model's aggregate outcomes and state the resource constraints which need to be satisfied in equilibrium. We focus on the exposition of the home country, with the understanding that the foreign country is similarly characterised. To the extent needed, foreign variables and parameters are indexed with an asterisk, '*'.[10]

3.1 Households

There are two households indexed by I and J. The members of household I are indexed by $i \in [0, 1-\omega]$. They have access to financial markets, where they buy and sell domestic government bonds as well as internationally traded bonds, accumulate physical capital, the services of which they rent out to firms, and hold money for transaction purposes. This enables the members of household I to smooth their consumption profile in response to shocks. The members of household J are indexed by $j \in (1-\omega, 1]$. They cannot trade in financial and physical assets. Nevertheless, they can intertemporally smooth consumption by adjusting their holdings of money. The members of both households supply differentiated labour services and act as wage setters in monopolistically competitive markets. As a consequence, they supply sufficient labour services to satisfy labour demand.[11]

3.1.1 Household I

Each member i of household I maximises its lifetime utility by choosing purchases of the consumption good, $C_{i,t}$, purchases of the investment good, $I_{i,t}$, next period's physical capital stock, $K_{i,t+1}$, the intensity with which the existing capital stock is utilised, $u_{i,t}$, next period's holdings of domestic government bonds as well as internationally traded bonds, $B_{i,t+1}$ and

[10] See the working paper version (cf. Coenen, McAdam and Straub, 2006) for a more detailed description of the model.

[11] In case no distinction between the two households needs to be made, household members will occasionally be indexed by $h \in [0, 1]$.

$B^F_{i,t+1}$, and current period's holdings of money, $M_{i,t}$, given the following lifetime utility function:

$$\mathrm{E}_t\left[\sum_{k=0}^{\infty}\beta^k\left(\frac{1}{1-\sigma}\left(C_{i,t+k}-\kappa\, C_{I,t+k-1}\right)^{1-\sigma}-\frac{1}{1+\zeta}\left(N_{i,t+k}\right)^{1+\zeta}\right)\right], \tag{1}$$

where β is the discount factor, σ denotes the inverse of the intertemporal elasticity of substitution and ζ is the inverse of the elasticity of work effort with respect to the real wage. The parameter κ measures the degree of external habit formation in consumption. Thus, the utility of household member i depends positively on the difference between the current level of individual consumption, $C_{i,t}$, and the lagged average consumption level of household I as a whole, $C_{I,t-1}$, and negatively on individual labour supply, $N_{i,t}$.

Household member i faces the following period-by-period budget constraint:

$$\begin{aligned}
&(1+\tau^c_t+\Gamma_v(v_{i,t}))\,P_{C,t}\,C_{i,t}+P_{I,t}\,I_{i,t} \qquad (2)\\
&\qquad +R_t^{-1}B_{i,t+1}+((1-\Gamma_{B^F}(B^F_t))\,R_{F,t})^{-1}S_t\,B^F_{i,t+1}+M_{i,t}+\Xi_{i,t}+\Phi_{i,t}\\
&= (1-\tau^n_t-\tau^{w_h}_t)\,W_{i,t}\,N_{i,t}+(1-\tau^k_t)\,(R_{K,t}\,u_{i,t}-\Gamma_u(u_{i,t})\,P_{I,t})\,K_{i,t}\\
&\qquad +\tau^k_t\,\delta\,P_{I,t}\,K_{i,t}+(1-\tau^d_t)\,D_{i,t}+TR_{i,t}-T_{i,t}+B_{i,t}+S_t\,B^F_{i,t}+M_{i,t-1},
\end{aligned}$$

where $P_{C,t}$ and $P_{I,t}$ are the prices of a unit of the private consumption good and the investment good, respectively. R_t and R^F_t denote, respectively, the risk-less returns on domestic government bonds and internationally traded bonds. Internationally traded bonds are denominated in foreign currency and, thus, their domestic value depends on the nominal exchange rate S_t (expressed in terms of units of home currency per unit of foreign currency). $N_{i,t}$ denotes the labour services provided to firms at wage rate $W_{i,t}$; $R_{K,t}$ indicates the rental rate for the effective capital services rent to firms, $u_{i,t}\,K_{i,t}$, and $D_{i,t}$ are the dividends paid by household-member-owned firms.

The purchases of the consumption good are subject to a proportional transaction cost, $\Gamma_v(v_{i,t})$ (defined in **Appendix A**), which depends on the household member's money-to-consumption ratio, or, inversely, on consumption-based velocity, $v_{i,t}=(1+\tau^c_t)P_{C,t}C_{i,t}/M_{i,t}$. Similarly, $\Gamma_{B^F}(B^F_t)$ (defined in Appendix A) represents a financial intermediation premium that the household member must pay when taking a position in the international bond market. The incurred premium is rebated in a lump-sum manner, being indicated by $\Xi_{i,t}$.[12] As regards the provision of effective capital services, varying the intensity of capital utilisation is subject to a proportional cost $\Gamma_u(u_{i,t})$ (defined in Appendix A).

The fiscal authority absorbs part of the gross income of the household member to finance its expenditure. In this context, τ_t^c denotes the consumption tax rate levied on consumption purchases; and τ_t^n, τ_t^k and τ_t^d are the tax rates levied on the different sources of household income; that is, wage income $W_{i,t}\, N_{i,t}$, rental capital income $R_{K,t}\, K_{i,t}$ and dividend income $D_{i,t}$.[13] Here, for simplicity, we assume that the utilisation cost of physical capital and physical capital depreciation are exempted from taxation. $\tau_t^{w_h}$ is the additional pay-roll tax rate levied on household wage income (representing the household member's contribution to social security). The terms $TR_{i,t}$ and $T_{i,t}$ indicate transfers received and lump-sum taxes paid, respectively.

Finally, it is assumed that household member i holds state-contingent securities, $\Phi_{i,t}$. These securities are traded amongst members of household I and provide insurance against individual wage-income risk. This guarantees that the marginal utility of consumption out of wage income is identical across individual household members. As a result, all household members will choose identical allocations in equilibrium.[14]

The capital stock owned by household member i evolves according to the following capital accumulation equation,

$$K_{i,t+1} \quad = \quad (1-\delta)\, K_{i,t} + (1 - \Gamma_I(I_{i,t}/I_{i,t-1}))\, I_{i,t}, \tag{3}$$

where δ is the depreciation rate and $\Gamma_I(I_{i,t}/I_{i,t-1})$ represents a generalised adjustment cost formulated in terms of changes in investment (defined in Appendix A).

Choice of Allocations

Defining as $\Lambda_{i,t}/P_{C,t}$ and $\Lambda_{i,t}\, Q_{i,t}$ the Lagrange multipliers associated with the budget constraint (2) and the capital accumulation equation (3), respectively, the first-order conditions for maximising the household member's lifetime utility function (1) with respect to $C_{i,t}$, $I_{i,t}$,

[12] We assume that the members of the foreign household I^* are not subject to a financial intermediation premium when trading in international bonds.

[13] For simplicity, it is assumed that dividends are taxed at the household level.

[14] This in turn guarantees that $C_{i,t} = C_{I,t}$ in equilibrium.

$K_{i,t+1}$, $u_{i,t}$, $B_{i,t+1}$, $B^F_{i,t+1}$ and $M_{i,t}$, are given by:

$$\Lambda_{i,t} = \frac{(C_{i,t} - \kappa\, C_{I,t-1})^{-\sigma}}{1 + \tau^c_t + \Gamma_v(v_{i,t}) + \Gamma'_v(v_{i,t})\, v_{i,t}}, \tag{4}$$

$$\frac{P_{I,t}}{P_{C,t}}, = Q_{i,t}\left(1 - \Gamma_I(I_{i,t}/I_{i,t-1}) - \Gamma'_I(I_{i,t}/I_{i,t-1})\,\frac{I_{i,t}}{I_{i,t-1}}\right) + \beta\,\mathrm{E}_t\left[\frac{\Lambda_{i,t+1}}{\Lambda_{i,t}}\, Q_{i,t+1}\, \Gamma'_I(I_{i,t+1}/I_{i,t})\,\frac{I^2_{i,t+1}}{I^2_{i,t}}\right], \tag{5}$$

$$Q_{i,t} = \beta\,\mathrm{E}_t\left[\frac{\Lambda_{i,t+1}}{\Lambda_{i,t}}\Big((1-\delta)\, Q_{i,t+1} + (1-\tau^k_{t+1})\,\frac{R_{K,t+1}}{P_{C,t+1}}\, u_{i,t+1} + \Big(\tau^k_{t+1}\,\delta - (1-\tau^k_{t+1})\,\Gamma_u(u_{i,t+1})\Big)\,\frac{P_{I,t+1}}{P_{C,t+1}}\Big)\right], \tag{6}$$

$$R_{K,t} = \Gamma'_u(u_{i,t})\, P_{I,t}, \tag{7}$$

$$\beta\, R_t\, \mathrm{E}_t\left[\frac{\Lambda_{i,t+1}}{\Lambda_i, t}\,\frac{P_{C,t}}{P_{C,t+1}}\right] = 1, \tag{8}$$

$$\beta\,(1 - \Gamma_{B^F}(B^F_t))\, R_{F,t}\, \mathrm{E}_t\left[\frac{\Lambda_{i,t+1}}{\Lambda_i, t}\,\frac{P_{C,t}}{P_{C,t+1}}\,\frac{S_{t+1}}{S_t}\right] = 1, \tag{9}$$

$$\beta\,\mathrm{E}_t\left[\frac{\Lambda_{i,t+1}}{\Lambda_i, t}\,\frac{P_{C,t}}{P_{C,t+1}}\right] = 1 - \Gamma'_v(v_{i,t})\, v^2_{i,t}. \tag{10}$$

Here, $\Lambda_{i,t}$ represents the shadow price of a unit of the consumption good expressed in terms of consumption-based utility; that is, the marginal utility of consumption. Similarly, $Q_{i,t}$ measures the shadow price of a unit of the investment good; that is, Tobin's Q.[15]

Combining the first-order conditions with respect to the holdings of domestic and internationally traded bonds, (8) and (9), yields a risk-adjusted uncovered-interest-parity condition, reflecting that the return on internationally traded bonds is subject to a financial intermediation premium.

Wage Setting

The members of household I act as wage setters for their differentiated labour services $N_{i,t}$

[15]Notice that the first-order condition (7) implies that the intensity of capital utilisation is identical across household members; that is, $u_{i,t} = u_t$.

in monopolistically competitive markets. We assume that the wages for the differentiated labour services, $\tilde{W}_{i,t}$, are determined by staggered nominal wage contracts à la Calvo (1983). Thus, household members receive permission to optimally reset their nominal wage contract in a given period t with probability $1 - \xi_I$. All household members that receive such permission choose the same wage rate $\tilde{W}_{i,t}$. Those members that do not receive permission are allowed to adjust it according to the following scheme:

$$W_{i,t} = \left(\frac{P_{C,t-1}}{P_{C,t-2}}\right)^{\chi_I} \pi_C^{1-\chi_I} W_{i,t-1}, \tag{11}$$

that is, the wage contract is indexed to a geometric average of past changes in the price of the private consumption good, $P_{C,t}$, and the steady-state consumer-price inflation rate, π_C, where χ_I is an indexation parameter.

The members of household I that receive permission to optimally reset their wage contracts in period t are assumed to maximise lifetime utility, as represented by equation (1), taking into account the indexation scheme (11) and the demand for their labour services (the formal derivation of which we postpone until we consider the firms' problem).

Hence, we obtain the following first-order condition for the optimal wage-setting decision in period t:

$$\mathrm{E}_t \left[\sum_{k=0}^{\infty} \xi_I^k \beta^k \left(\Lambda_{i,t+k} (1 - \tau_t^n - \tau_t^{w_h}) \frac{\tilde{W}_{i,t}}{P_{C,t+k}} \left(\frac{P_{C,t+k-1}}{P_{C,t-1}} \right)^{\chi_I} \pi_C^{(1-\chi_I)k} - \frac{\eta_I}{\eta_I - 1} (N_{i,t+k})^{\zeta} \right) N_{i,t+k} \right] = 0. \tag{12}$$

This expression states that in those labour markets in which wage contracts are re-optimised, the latter are set so as to equate the household members' discounted sum of expected after-tax marginal revenues, expressed in consumption-based utility terms, $\Lambda_{i,t+k}$, to the discounted sum of expected marginal cost, expressed in terms of marginal disutility of labour, $\Delta_{i,t+k} = -N_{i,t+k}^{\zeta}$. In the absence of wage staggering ($\xi_I = 0$), the factor $\eta_I/(\eta_I - 1)$ represents the markup of the real after-tax wage over the marginal rate of substitution between consumption and leisure,[16] reflecting the degree of monopoly power on the part of

[16] The markup depends on the intratemporal elasticity of substitution between the differentiated labour services supplied by the members of household I, which in turn determines the firms' price elasticity of demand for these services.

the household members; that is,

$$(1 - \tau_t^n - \tau_t^{w_h}) \frac{\tilde{W}_{i,t}}{P_{C,t}} = - \frac{\eta_I}{\eta_I - 1} \frac{\Delta_{i,t}}{\Lambda_{i,t}}. \tag{13}$$

Notice that the wage markup drives an additional wedge between the effective consumption wage and the marginal rate of substitution. Obviously, the distortions arising from the markup wedge $\eta_I/(\eta_I - 1)$ and the tax wedge $1 - \tau_t^n - t^{w_h}$ are isomorphic.

3.1.2 Household J

The members of household J do not have access to capital and bond markets. Nevertheless, they can intertemporally smooth consumption by adjusting their holdings of money. Thus, using self-explanatory notation, the members of household J optimally choose purchases of the consumption good $C_{j,t}$ and holdings of money $M_{j,t}$ by maximising their lifetime utility function, which is assumed to be symmetric to that of the members of household I, subject to the following period-by-period budget constraint:

$$\begin{aligned} &(1 + \tau_t^c + \Gamma_v(v_{j,t}))\, P_{C,t}\, C_{j,t} + M_{j,t} \\ &\qquad = (1 - \tau_t^n - \tau_t^{w_h})\, W_{j,t}\, N_{j,t} + TR_{j,t} - T_{j,t} + M_{j,t-1} + \Phi_{j,t} \end{aligned} \tag{14}$$

with the transaction cost $\Gamma_v(v_{j,t})$ depending on the household members' money-to-consumption ratio, or, inversely, on consumption-based velocity.

Defining $\Lambda_{j,t}/P_{C,t}$ as the Lagrange multiplier associated with the budget constraint (14), the first-order conditions for maximising the household members' lifetime utility with respect to $C_{j,t}$ and $M_{j,t}$ are given by:

$$\Lambda_{j,t} = \frac{(C_{j,t} - \kappa\, C_{J,t-1})^{-\sigma}}{1 + \tau_t^c + \Gamma_v(v_{j,t}) + \Gamma_v'(v_{j,t})\, v_{j,t}}, \tag{15}$$

$$\beta\, \mathrm{E}_t \left[\frac{\Lambda_{j,t+1}}{\Lambda_j, t} \frac{P_{C,t}}{P_{C,t+1}} \right] = 1 - \Gamma_v'(v_{j,t})\, v_{j,t}^2, \tag{16}$$

where $\Lambda_{j,t}$ represents the shadow price of a unit of the consumption good for household member j.

The members of household J act as wage-setters for their differentiated labour services in a manner analogous to the behaviour of the members of household I. Hence, we obtain a first-order condition for their optimal wage-setting decision similar to that for the members of household I.

3.2 Firms

There are two types of firms. A continuum of monopolistically competitive firms indexed by $f \in [0,1]$, each of which produces a single tradable differentiated intermediate good, $Y_{f,t}$, and a set of three representative firms, which combine the purchases of domestically-produced intermediate goods with purchases of imported intermediate goods into three distinct non-tradable final goods, namely a private consumption good, Q_t^C, a private investment good, Q_t^I, and a public consumption good, Q_t^G.

3.2.1 Intermediate-Good Firms

Each intermediate-good firm f produces its differentiated output using an increasing-returns-to-scale Cobb-Douglas technology,

$$Y_{f,t} \;=\; \max\left[z_t\, K_{f,t}^{\alpha}\, N_{f,t}^{(1-\alpha)} - \psi,\, 0\right], \tag{17}$$

utilising as inputs homogenous capital services, $K_{f,t}$, that are rent from the members of household I in fully competitive markets, and an index of differentiated labour services, $N_{f,t}$, which combines household-specific varieties of labour supplied in monopolistically competitive markets. The variable z_t represents (total-factor) productivity which is assumed to be identical across firms and which evolves over time according to an exogenous serially correlated process, $\ln(z_t) = (1-\rho_z)\, z + \rho_z\, \ln(z_{t-1}) + \varepsilon_{z,t}$, where z determines the steady-state level of productivity. The parameter ψ represents the fixed cost of production.[17]

Capital and Labour Inputs

Taking the rental cost of capital $R_{K,t}$ and the aggregate wage index W_t (to be derived below) as given, the firm's optimal demand for capital and labour services must solve the problem of minimising total input cost $R_{K,t}\, K_{f,t} + (1+\tau_t^{w_f})\, W_t\, N_{f,t}$ subject to the technology constraint (17). Here, $\tau_t^{w_f}$ denotes the payroll tax rate levied on wage payments (representing the firm's contribution to social security).

[17] The fixed cost of production will be chosen to ensure zero profits in steady state. This in turn guarantees that there is no incentive for other firms to enter the market in the long run.

Defining as $MC_{f,t}$ the Lagrange multiplier associated with the technology constraint (17), the first-order conditions of the firm's cost minimisation problem with respect to capital and labour inputs are given, respectively, by $\alpha\,(Y_{f,t}+\psi)/K_{f,t}\,MC_{f,t} \;=\; R_{K,t}$ and $(1-\alpha)\,(Y_{f,t}+\psi)/N_{f,t}\,MC_{f,t} \;=\; (1+\tau_t^{w_f})\,W_t$, with the payroll tax rate $\tau_t^{w_f}$ introducing a wedge between the firm's effective labour cost and the marginal revenue of labour.

The Lagrange multiplier $MC_{f,t}$ measures the shadow price of varying the use of capital and labour services; that is, nominal marginal cost. We note that, since all firms f face the same input prices and since they all have access to the same production technology, nominal marginal cost $MC_{f,t}$ are identical across firms; that is, $MC_{f,t} = MC_t$ with

$$MC_t \;=\; \frac{1}{z_t\,\alpha^{\alpha}(1-\alpha)^{(1-\alpha)}}\,(R_{K,t})^{\alpha}((1+\tau_t^{w_f})\,W_t)^{(1-\alpha)}. \tag{18}$$

The labour input used by firm f in producing its differentiated output, $N_{f,t}$, is assumed to be a composite of two household-specific bundles of labour services, $N_{f,t}^{I}$ and $N_{f,t}^{J}$ which combine the differentiated labour services of the individual members of the two households I and J. Formally,

$$N_{f,t} \;=\; \left((1-\omega)^{\frac{1}{\eta}}\left(N_{f,t}^{I}\right)^{1-\frac{1}{\eta}} + \omega^{\frac{1}{\eta}}\left(N_{f,t}^{J}\right)^{1-\frac{1}{\eta}}\right)^{\frac{\eta}{\eta-1}}, \tag{19}$$

where the parameter $\eta > 1$ denotes the intratemporal elasticity of substitution between the two household-specific bundles of labour services.

Defining as $N_{f,t}^{i}$ and $N_{f,t}^{j}$ the use of the differentiated labour services supplied by household member i and j, respectively, we have:

$$N_{f,t}^{I} = \left(\left(\frac{1}{1-\omega}\right)^{\frac{1}{\eta_I}}\int_0^{1-\omega}\left(N_{f,t}^{i}\right)^{1-\frac{1}{\eta_I}}di\right)^{\frac{\eta_I}{\eta_I-1}},\quad N_{f,t}^{J} = \left(\left(\frac{1}{\omega}\right)^{\frac{1}{\eta_J}}\int_{1-\omega}^{1}\left(N_{f,t}^{j}\right)^{1-\frac{1}{\eta_J}}dj\right)^{\frac{\eta_J}{\eta_J-1}}, \tag{20}$$

where $\eta_I, \eta_J > 1$ are the intratemporal elasticities of substitution between the differentiated labour services of the members of household I and household J, respectively.

With nominal wage contracts for differentiated labour services i and j being set in monopolistically competitive markets, firm f takes wages $W_{i,t}$ and $W_{j,t}$ as given and chooses the optimal input of each labour variety i and j by minimising the cost of forming the household-specific labour bundles subject to the aggregation constraints (20). This yields the following demand functions for labour varieties i and j:

$$N^i_{f,t} = \frac{1}{1-\omega}\left(\frac{W_{i,t}}{W_{I,t}}\right)^{-\eta_I} N^I_{f,t}, \qquad N^j_{f,t} = \frac{1}{\omega}\left(\frac{W_{j,t}}{W_{J,t}}\right)^{-\eta_J} N^J_{f,t}, \tag{21}$$

where $W_{I,t}$ and $W_{J,t}$ are CES-type nominal wage indexes.

Next, taking the wage indexes $W_{I,t}$ and $W_{J,t}$ as given, the firm chooses the combination of the household-specific labour bundles $N^I_{f,t}$ and $N^J_{f,t}$ that minimise $W_{I,t}\,N^I_{f,t} + W_{J,t}\,N^J_{f,t}$ subject to aggregation constraint (19). This yields the following demand functions for the household-specific labour bundles:

$$N^I_{f,t} = (1-\omega)\left(\frac{W_{I,t}}{W_t}\right)^{-\eta} N_{f,t}, \qquad N^J_{f,t} = \omega\left(\frac{W_{J,t}}{W_t}\right)^{-\eta} N_{f,t}, \tag{22}$$

where W_t is the aggregate CES-type nominal wage index, which has the property that the minimum cost of using the composite labour index $N_{f,t}$ as an input in producing the differentiated intermediate output $Y_{f,t}$ is given by $W_t\,N_{f,t}$.

Aggregating across the continuum of intermediate-good firms f, we obtain the following demand for labour varieties i and j:

$$N^i_t = \int_0^1 N^i_{f,t}df = \frac{1}{1-\omega}\left(\frac{W_{i,t}}{W_{I,t}}\right)^{-\eta_I} N^I_t, \qquad N^j_t = \int_0^1 N^j_{f,t}df = \frac{1}{\omega}\left(\frac{W_{j,t}}{W_{J,t}}\right)^{-\eta_J} N^J_t. \tag{23}$$

Price Setting

Each firm f sells its differentiated output $Y_{f,t}$ in both domestic and foreign markets under monopolistic competition. We assume, as in Betts and Devereux (1996), that the firm charges different prices at home and abroad, pricing in local currency. In both markets, there is sluggish price adjustment due to staggered price contracts à la Calvo (1983). Accordingly, firm f receives permission to optimally reset prices in a given period t either with probability $1-\xi_H$ or with probability $1-\xi_X$, depending on whether the firm sells its differentiated output in the domestic or the foreign market.

Defining as $P_{H,f,t}$ the domestic price of good f and as $P_{X,f,t}$ its foreign price denominated in foreign currency, all firms that receive permission to reset their price contracts in a given period t choose the same price $\tilde{P}_{H,f,t}$ and $\tilde{P}_{X,f,t}$, depending on the market of destination. Those firms which do not receive permission are allowed to adjust their prices according to the following schemes:

$$P_{H,f,t} = \left(\frac{P_{H,t-1}}{P_{H,t-2}}\right)^{\chi_H} \pi_H^{1-\chi_H} \, P_{H,f,t-1}, \qquad P_{X,f,t} = \left(\frac{P_{X,t-1}}{P_{X,t-2}}\right)^{\chi_X} \pi_X^{1-\chi_X} \, P_{X,f,t-1}, \qquad (24)$$

that is, the price contracts are indexed to a geometric average of past changes in the aggregate price indexes, $P_{H,t}$ and $P_{X,t}$, and the steady-state inflation rates, π_H and π_X, where χ_H and χ_X are indexation parameters.

Each firm f receiving permission to optimally reset its domestic and/or foreign price in period t maximises the discounted sum of its expected nominal profits,

$$\mathrm{E}_t \left[\sum_{k=0}^{\infty} \Lambda_{I,t,t+k} \left(\xi_H^k \, D_{H,f,t+k} + \xi_X^k \, D_{X,f,t+k} \right) \right], \qquad (25)$$

subject to the price-indexation schemes (24) and taking as given domestic and foreign demand for its differentiated output, $H_{f,t}$ and $X_{f,t}$ (to be derived below).

Here, $\Lambda_{I,t,t+k}$ is the firm's discount rate defined as the average stochastic discount factor of the members of household I that own the firm, while $D_{H,f,t} = P_{H,f,t} \, H_{f,t} - MC_t \, (H_{f,t} + \psi)$ and $D_{H,f,t} = S_t \, P_{X,f,t} \, X_{f,t} - MC_t \, (X_{f,t} + \psi)$ are period-t nominal profits yielded in the domestic and foreign market, respectively, which are distributed as dividends to the members of household I.

Hence, we obtain the following first-order condition characterising the firm's optimal pricing decision for its output sold in the domestic market:

$$\mathrm{E}_t \left[\sum_{k=0}^{\infty} \xi_H^k \, \Lambda_{I,t,t+k} \left(\tilde{P}_{H,f,t} \left(\frac{P_{H,t+k-1}}{P_{H,t-1}} \right)^{\chi_H} \pi_H^{(1-\chi_H)k} - \frac{\theta}{\theta - 1} \, MC_{t+k} \right) \, H_{f,t+k} \right] = 0. \qquad (26)$$

This expression states that in those intermediate-good markets in which price contracts are re-optimised, the latter are set so as to equate the firms' discounted sum of expected revenues to the discounted sum of expected marginal cost. In the absence of price staggering ($\xi_H = 0$), the factor $\theta/(\theta - 1)$ represents the markup of the price charged in domestic markets over nominal marginal cost, reflecting the degree of monopoly power on the part of the intermediate-good firms.[18]

We obtain a similar first-order condition characterising the firm's optimal pricing decision for its output sold in the foreign market.

[18]The markup depends on the intratemporal elasticity of substitution between the differentiated goods supplied by the intermediate-good firms to the domestic final-good firms, which in turn determines the final-good firms' price elasticity of demand for the differentiated intermediate goods.

3.2.2 Final-Good Firms

The representative firm producing the non-tradable final private consumption good, Q_t^C, combines purchases of a bundle of domestically-produced intermediate goods, H_t^C, with purchases of a bundle of imported foreign intermediate goods, IM_t^C, using a constant-returns-to-scale CES technology,

$$Q_t^C = \left(\nu_C^{\frac{1}{\mu_C}} \left(H_t^C\right)^{1-\frac{1}{\mu_C}} + (1-\nu_C)^{\frac{1}{\mu_C}} \left((1-\Gamma_{IM^C}(IM_t^C/Q_t^C)\, IM_t^C) \right)^{1-\frac{1}{\mu_C}} \right)^{\frac{\mu_C}{\mu_C-1}}, \quad (27)$$

where the parameter $\mu_C > 1$ denotes the intratemporal elasticity of substitution between the distinct bundles of domestic and foreign intermediate goods, while ν_C measures the home bias in the production of the consumption good.

Notice that the consumption-good firm incurs a cost, $\Gamma_{IM^C}(IM_t^C/Q_t^C)$ (defined in Appendix A), when varying the use of the bundle of imported intermediate goods in producing the consumption good. As a result, the import share is relatively unresponsive in the short run to changes in the relative price of imported goods, while the level of imports is permitted to jump in response to changes in overall demand.

Defining as $H_{f,t}^C$ and $IM_{f^*,t}^C$ the use of the intermediate goods produced by the domestic firm f and the foreign firm f^*, respectively, we have

$$H_t^C = \left(\int_0^1 \left(H_{f,t}^C\right)^{1-\frac{1}{\theta}} df \right)^{\frac{\theta}{\theta-1}}, \qquad IM_t^C = \left(\int_0^1 \left(IM_{f^*,t}^C\right)^{1-\frac{1}{\theta^*}} df^* \right)^{\frac{\theta^*}{\theta^*-1}}, \quad (28)$$

where θ, $\theta^* > 1$ are the intratemporal elasticities of substitution between the differentiated intermediate goods produced domestically and abroad.

With nominal prices for differentiated intermediate goods f and f^* being set in monopolistically competitive markets, the consumption-good firm takes prices $P_{H,f,t}$ and $P_{IM,f^*,t}$ as given and chooses the optimal use of each differentiated intermediate good f and f^* by minimising the expenditure for the bundles of domestic and foreign intermediate goods subject to the aggregation constraints (28). This yields the following demand functions for the domestic and foreign intermediate goods f and f^*:

$$H_{f,t}^C = \left(\frac{P_{H,f,t}}{P_{H,t}} \right)^{-\theta} H_t^C, \qquad IM_{f^*,t}^C = \left(\frac{P_{IM,f^*,t}}{P_{IM,t}} \right)^{-\theta^*} IM_t^C, \quad (29)$$

where $P_{H,t}$ and $P_{IM,t}$ are the CES-type aggregate price indexes for the bundles of intermediate goods sold in domestic and foreign markets, respectively.

Next, taking the price indexes $P_{H,t}$ and $P_{IM,t}$ as given, the consumption-good firm chooses the combination of the domestic and foreign intermediate-good bundles H_t^C and IM_t^C that minimises $P_{H,t}\, H_t^C + P_{IM,t}\, IM_t^C$ subject to aggregation constraint (27). This yields the following demand functions for the intermediate-good bundles:

$$H_t^C = \nu_C \left(\frac{P_{H,t}}{P_{C,t}}\right)^{-\mu_C} Q_t^C, \tag{30}$$

$$IM_t^C = (1-\nu_C)\left(\frac{P_{IM,t}}{P_{C,t}\,\Gamma^{\dagger}_{IM^C,t}}\right)^{-\mu_C} \frac{Q_t^C}{1-\Gamma_{IM^C}(IM_t^C/Q_t^C)}, \tag{31}$$

where

$$P_{C,t} = \left(\nu_C\,(P_{H,t})^{1-\mu_C} + (1-\nu_C)\left(P_{IM,t}/\Gamma^{\dagger}_{IM^C,t}\right)^{1-\mu_C}\right)^{\frac{1}{1-\mu_C}}$$

is the price of a unit of the private consumption good and $\Gamma^{\dagger}_{IM^C,t} = 1-\Gamma_{IM^C}(IM_t^C/Q_t^C) - \Gamma'_{IM^C}(IM_t^C/Q_t^C)\, IM_t^C$.

The representative firm producing the non-tradable final private investment good, Q_t^I, is modelled in an analogous manner. Specifically, the investment-good firm combines its purchase of a bundle of domestically-produced intermediate goods, H_t^I, with the purchase of a bundle of imported foreign intermediate goods, IM_t^I, using a constant-returns-to-scale CES technology,

$$Q_t^I = \left(\nu_I^{\frac{1}{\mu_I}}\left(H_t^I\right)^{1-\frac{1}{\mu_I}} + (1-\nu_I)^{\frac{1}{\mu_I}}\left(IM_t^I\,(1-\Gamma_{IM^I}(IM_t^I/Q_t^I))\right)^{1-\frac{1}{\mu_I}}\right)^{\frac{\mu_I}{\mu_I-1}}, \tag{32}$$

where the parameter $\mu_I > 1$ denotes the intratemporal elasticity of substitution between the distinct bundles of domestic and foreign intermediate inputs, while ν_I measures the home bias in the production of the investment good.

All other variables related to the production of the investment good – import adjustment cost, $\Gamma_{IM^I,t}(IM_t^I/Q_t^I)$; the optimal demand for firm-specific and bundled domestic and foreign intermediate goods, $H_{f,t}^I$, H_t^I and $IM_{f^*,t}^I$, IM_t^I, respectively; as well as the price of a unit of the investment good, $P_{I,t}$ – are defined or derived in a manner analogous to that for the consumption good.[19]

[19]Notice that even in the absence of import adjustment cost, the prices of the consumption and investment goods may differ due to differences in the import content.

In contrast, the non-tradable final public consumption good Q_t^G is assumed to be a composite made only of domestic intermediate goods; that is, $Q_t^G = H_t^G$. Hence, the optimal demand for each domestic intermediate good f is given by $H_{f,t}^G = (\, P_{H,f,t}/P_{H,t}\,)^{-\theta}\, H_t^G$ and the price of a unit of the public consumption good is $P_{G,t} = P_{H,t}$.

Aggregating across the three final-good firms, we obtain the following demand for domestic and foreign intermediate goods f and f^*, respectively:

$$H_{f,t} \;=\; H_{f,t}^C + H_{f,t}^I + H_{f,t}^G = \left(\frac{P_{H,f,t}}{P_{H,t}} \right)^{-\theta} H_t, \tag{33}$$

$$IM_{f^*,t} \;=\; IM_{f^*,t}^C + IM_{f^*,t}^I = \left(\frac{P_{IM,f^*,t}}{P_{IM,t}} \right)^{-\theta^*} IM_t, \tag{34}$$

where $H_t = H_t^C + H_t^I + H_t^G$ and $IM_t = IM_t^C + IM_t^I$.

The purchase of the imported intermediate good f^* corresponds to the differentiated output sold in the home market by the foreign intermediate-good producer f^*; that is, $s\, IM_{f^*,t} \;=\; (1-s)\, X_{f^*,t}^*$, taking into account differences in country size. Similarly, with intermediate-good firms setting prices in terms of local currency, the price of the intermediate good imported from abroad (the import price index of the home country) is equal to the price charged by the foreign producer in the home country (the export price index of the foreign country); that is, $P_{IM,f^*,t} = P_{X,f^*,t}^*$ $(P_{IM,t} = P_{X,t}^*)$.

3.3 Fiscal and Monetary Authorities

The fiscal authority purchases the final public consumption good, G_t, makes transfer payments TR_t, issues bonds to refinance its debt, B_t, earns seignorage on outstanding money holdings, M_{t-1}, and raises taxes with details on the latter given above. The fiscal authority's period-by-period budget constraint then has the following form:

$$\begin{aligned} & P_{G,t}\, G_t + TR_t + B_t + M_{t-1} \\ & \quad = \tau_t^c\, P_{C,t}\, C_t + (\tau_t^n + \tau_t^{w_h}) \left(\int_0^{1-\omega} W_{i,t}\, N_{i,t}\, di + \int_{1-\omega}^{1} W_{j,t}\, N_{j,t}\, dj \right) + \tau_t^{w_f}\, W_t\, N_t \\ & \qquad + \tau_t^k\, (\, R_{K,t}\, u_t - (\Gamma_u(u_t) + \delta)\, P_{I,t}\,)\, K_t + \tau_t^d\, D_t + T_t + R_t^{-1} B_{t+1} + M_t, \end{aligned} \tag{35}$$

where all quantities are expressed in per-capita-terms (defined below), except for the labour services and wages, which are differentiated across the members of the two households.

The fiscal authority's purchases of the final public consumption good are specified as a fraction of steady-state nominal output, $g_t = P_{G,t}G_t/P_Y Y$, and are assumed to follow a serially correlated process with $g_t = (1-\rho_g)\,g + \rho_g\,g_{t-1} + \varepsilon_{g,t}$. Similarly, transfers as a fraction of steady-state nominal output, $tr_t = TR_t/P_Y Y$, are assumed to evolve according to $tr_t = (1-\rho_{tr})\,tr + \rho_{tr}\,tr_{t-1} + \varepsilon_{tr,t}$.

Lump-sum taxes as a fraction of steady-state nominal output, $\tau_t = T_t/P_Y Y$, are adjusted according to the following rule,

$$\tau_t \;=\; \phi_{B_Y}\left(\frac{B_t}{P_Y Y} - B_Y\right), \tag{36}$$

where B_Y is the fiscal authority's target for the ratio of government debt to output, while all distortionary tax rates τ_t^x with $x = c,\, d,\, k,\, n,\, w_h$ and w_f are assumed to be exogenously set by the fiscal authority and constant, $\tau_t^x = \tau^x$, unless otherwise stated.

The monetary authority is assumed to follow a Taylor-type interest-rate rule (cf. Taylor, 1993) specified in terms of annual consumer-price inflation and quarterly output growth,

$$R_t^4 \;=\; \phi_R\,R_{t-1}^4 + (1-\phi_R)\left[R^4 + \phi_\Pi\left(\frac{P_{C,t}}{P_{C,t-4}} - \Pi\right)\right] + \phi_{g_Y}\left(\frac{Y_t}{Y_{t-1}} - g_Y\right) + \varepsilon_{R,t}, \tag{37}$$

where $R^4 = \beta^{-4}\,\Pi$ is the equilibrium nominal interest rate, Π denotes the monetary authority's inflation target and g_Y is the (gross) rate of output growth in steady state (assumed to equal one). The term $\varepsilon_{R,t}$ represents a serially uncorrelated monetary policy shock.

3.4 Aggregation and Aggregate Resource Constraint

The model is closed by imposing market-clearing conditions and formulating the aggregate resource constraint. Beforehand, it is convenient to define household and firm-specific variables in aggregate per-capita terms and to derive aggregate wage and price dynamics.

3.4.1 Aggregation

Per-Capita Quantities

Except for labour services $N_{h,t}$, which are differentiated across households members, the aggregate quantity, expressed in per-capita terms, of any household member-specific variable $X_{h,t}$ is given by $X_t = \int_0^1 X_{h,t}\,dh = (1-\omega)\,X_{i,t} + \omega\,X_{j,t}$, as all members of each household choose identical allocations in equilibrium.

Aggregate Wage Dynamics

With the members of household I setting their wage contracts $W_{i,t}$ according to equation (11) and equation (12), respectively, the wage index $W_{I,t}$ evolves according to

$$W_{I,t} = \left((1-\xi_I)(\tilde{W}_{i,t})^{1-\eta_I} + \xi_I \left(\left(\frac{P_{C,t-1}}{P_{C,t-2}}\right)^{\chi_I} \pi_C^{1-\chi_I} W_{i,t-1}\right)^{1-\eta_I}\right)^{\frac{1}{1-\eta_I}}. \quad (38)$$

A similar relationship holds for the index of the wage contracts set by the members of household J; that is, $W_{J,t}$.

Aggregate Price Dynamics

With intermediate-good firms f setting their price contracts for the differentiated products sold domestically, $P_{H,f,t}$, according to equation (24) and equation (26), respectively, the aggregate price index $P_{H,t}$ evolves according to

$$P_{H,t} = \left((1-\xi_H)(\tilde{P}_{H,f,t})^{1-\theta} + \xi_H \left(\left(\frac{P_{H,t-1}}{P_{H,t-2}}\right)^{\chi_H} \pi_H^{1-\chi_H} P_{H,f,t-1}\right)^{1-\theta}\right)^{\frac{1}{1-\theta}}. \quad (39)$$

A similar relationship holds for the aggregate index of price contracts set for the differentiated products sold abroad, $P_{X,t}$.

3.4.2 Aggregate Resource Constraint

Imposing market-clearing conditions implies the following aggregate resource constraint:

$$P_{Y,t}\, Y_t = P_{C,t}\,(C_t + \Gamma_{v,t}) + P_{I,t}\,(I_t + \Gamma_u(u_t)\,K_t) + P_{G,t}\,G_t + TB_t, \quad (40)$$

where $\Gamma_{v,t} = \int_0^{1-\omega} \Gamma_v(v_{i,t})\,C_{i,t}\,di + \int_{1-\omega}^1 \Gamma_v(v_{j,t})\,C_{j,t}\,dj$ and $TB_t = S_t\,P_{X,t}\,X_t - P_{IM,t}\,IM_t$ is the home country's trade balance.

Given the aggregate resource constraint, the domestic holdings of internationally traded bonds (that is, the home country's (net) foreign assets), denominated in foreign currency, evolve according to

$$R_{F,t}^{-1} B_{t+1}^F = B_t^F + \frac{TB_t}{S_t}. \quad (41)$$

Notice that the existence of a financial intermediation premium guarantees that, in the non-stochastic steady state, holdings of internationally traded bonds are zero worldwide.

4 Calibration and Illustrative Simulations

In this section, we provide details on the baseline calibration of the NAWM and present a small number of simulations to illustrate its dynamic properties.

4.1 Calibration

In calibrating the NAWM, we follow the literature and first set key steady-state ratios, including the ratios of the various nominal expenditure categories over nominal output, equal to their empirical counterparts.[20] For example, the ratios of private consumption to output in the euro area and the United States are set to 0.60 and 0.62, respectively. In this context, given the NAWM's two-country setup, it is sufficient to calibrate the respective import-to-output ratios and the shares of imports in private consumption and investment to obtain a consistent specification of the steady-state trade linkages. Of course, since we decided to use data on total imports, our calibration overstates the existing trade linkages between the euro area and the United States. However, since we focus on the euro area in the subsequent analysis, this strategy should provide a more realistic assessment of the international repercussions of unilateral tax reforms in the euro area than using data on the actual trade flows between the euro area and the United States alone. As regards the calibration of the money-to-consumption ratios, we imputed the fractions of the monetary aggregate M1 held by the household sector over nominal consumption expenditure, which amount to, respectively, 1.34 and 0.42 per quarter.[21] Finally, the steady-state ratios of government debt over output are uniformly set equal to 2.40 per quarter, whereas the dividend income-to-output ratios are assumed to be zero in steady state.

While the calibration of the steady-state ratios is based on observed data, we have chosen the remaining structural parameters of the NAWM with the objective of closely matching the pattern of the dynamic responses to a monetary policy shock as implied by the estimated closed-economy model of the euro area by Smets and Wouters (2003).[22] Thus,

[20] The calibrated steady-state ratios are summarised in **Appendix Table B.1**.

[21] In calibrating the money-to-consumption ratios, we used data on currency in circulation and overnight deposits held by households for the euro area over the period 1999-2004, while we adopted the calibration by Schmitt-Grohé and Uribe (2005) for the United States.

[22] The calibrated values for all structural parameters are summarised in **Appendix Table B.2**. For

broadly similar values are assigned to those parameters that are common to both models.[23] Specifically, the inverse of the labour supply elasticity is set to a value of 2, although we will examine the sensitivity of our results to variations in this key parameter later on. A notable exception from our calibration strategy relates to the calibration of the inverse of the intertemporal elasticity of substitution, which is raised to a value of 2, compared with a value of about 1.35 estimated by Smets and Wouters (2003). This modification helps to partly offset the effects induced by the ability of household I to borrow from abroad.

In calibrating the behaviour of the two types of households, we set the size of household J to 0.25, in line with the estimates reported in Coenen and Straub (2005). The parameters governing the wage-setting decisions of the two households are chosen symmetrically with both the degree of wage stickiness and the degree of wage indexation fixed at a value of 0.75, in line with the empirical findings reported in Smets and Wouters (2003). Similarly, the markup power of the two households is assumed to be symmetric and equal to 20 percent, consistent with a uniform price elasticity of 6 for the demand of the intermediate-good producing firms for the households' differentiated labour services. Notwithstanding, the profile of wages and hours worked can differ across the two types of households because of differences in the households' marginal rate of substitution.

As regards the pricing behaviour of intermediate-good firms selling their differentiated outputs in domestic markets, we follow Smets and Wouters (2003) and set the degrees of stickiness and indexation equal to 0.90 and 0.50, respectively. In contrast, the degree of stickiness in the firms' pricing decision for the outputs sold in foreign markets is assumed to equal 0.30. This guarantees that the terms of trade (defined as the domestic import price relative to the export price in domestic currency) are positively correlated with the real exchange rate, as observed in the data (cf. Obstfeld and Rogoff, 2000).[24] The price elasticity of demand for the differentiated outputs is assumed to equal 6, implying a 20

details on the comparison of the dynamic responses to a monetary policy shock across the NAWM and the Smets-Wouters model see our working paper (cf. Coenen, McAdam and Straub, 2006).

[23] In our baseline calibration, we further assume that the structural parameters in the euro area and the United States are fully symmetric.

[24] A recent study by Gopinath and Rigobon (2005) suggests that the degree of price stickiness in both exports and imports is closer to 0.75, implying an average duration of price contracts of about four quarters. Such a calibration, however, would yield a counterfactual negative correlation between the real exchange rate and the terms of trade, with unintentional consequences for model-based simulations.

percent steady-state markup over marginal cost in domestic and foreign markets. The fixed cost in production is chosen to ensure zero profits in steady state, and the steady-state productivity level is normalised to unity.

The remaining open-economy parameters are calibrated largely in line with the macroeconomic literature. Specifically, the substitution elasticities between home and foreign goods in forming the consumption and investment bundles are set equal to 1.50. Ultimately, this implies a relative low sensitivity of domestic private absorption to changes in the terms of trade. Similarly, we set the parameter governing the adjustment cost associated with changing the import share in consumption equal to 5.00, thereby further dampening the sensitivity of consumption to the terms of trade in the short run. In contrast, adjusting the import share in investment is assumed to be costless. This choice of adjustment cost parameters, together with the calibration of the investment adjustment cost and the intertemporal elasticity of substitution, proves particularly important for closely matching the dynamic responses of consumption and investment to a monetary policy shock as implied by the model of Smets and Wouters (2003).

In calibrating the tax rates we use the data on the tax wedges reported in Table 1 above. Since our subsequent analysis will focus on the impact of reducing distortions that arise from these particular wedges, we set the tax rates on capital and dividend income to zero. In order to establish a more meaningful role of transfer payments made by the fiscal authority, we assume that transfers, in per-capita terms, are unevenly distributed across the two types of households, favouring the members of households J over those of household I in the proportion of 3 to 1. This guarantees that the level of consumption (hours worked) for a member of household J is not more than 25 (15) percent lower (higher) than that for a member of household I. In contrast, lump-sum taxes, in per-capita terms, are assumed to be distributed in the proportion of 3 to 1 to the detriment of household I. Both the government spending-to-output ratio and the transfer-to-output ratio are assumed to follow serially correlated processes with an autoregressive coefficient equal to 0.90. Finally, in calibrating the fiscal policy rule, we set the sensitivity of aggregate lump-sum taxes with respect to the government debt-to-output ratio to 0.10.

Last but not least, for the monetary policy rule, we set the interest-rate response coefficients on annual inflation (in deviation from an inflation target of 2 percent) and quarterly output growth equal to 2.00 and 0.10, respectively, while the coefficient on the lagged interest rate is assumed to equal 0.95.[25]

4.2 Illustrative Simulations

Given the above calibration, we proceed to illustrate the dynamic properties of the NAWM. In this context, we focus on the dynamic effects of two types of transitory, but persistent fiscal shocks: a government spending shock and a transfer shock. These two shocks have been chosen to highlight the importance of the two types of households for the model's aggregate outcomes.

Government Spending Shock

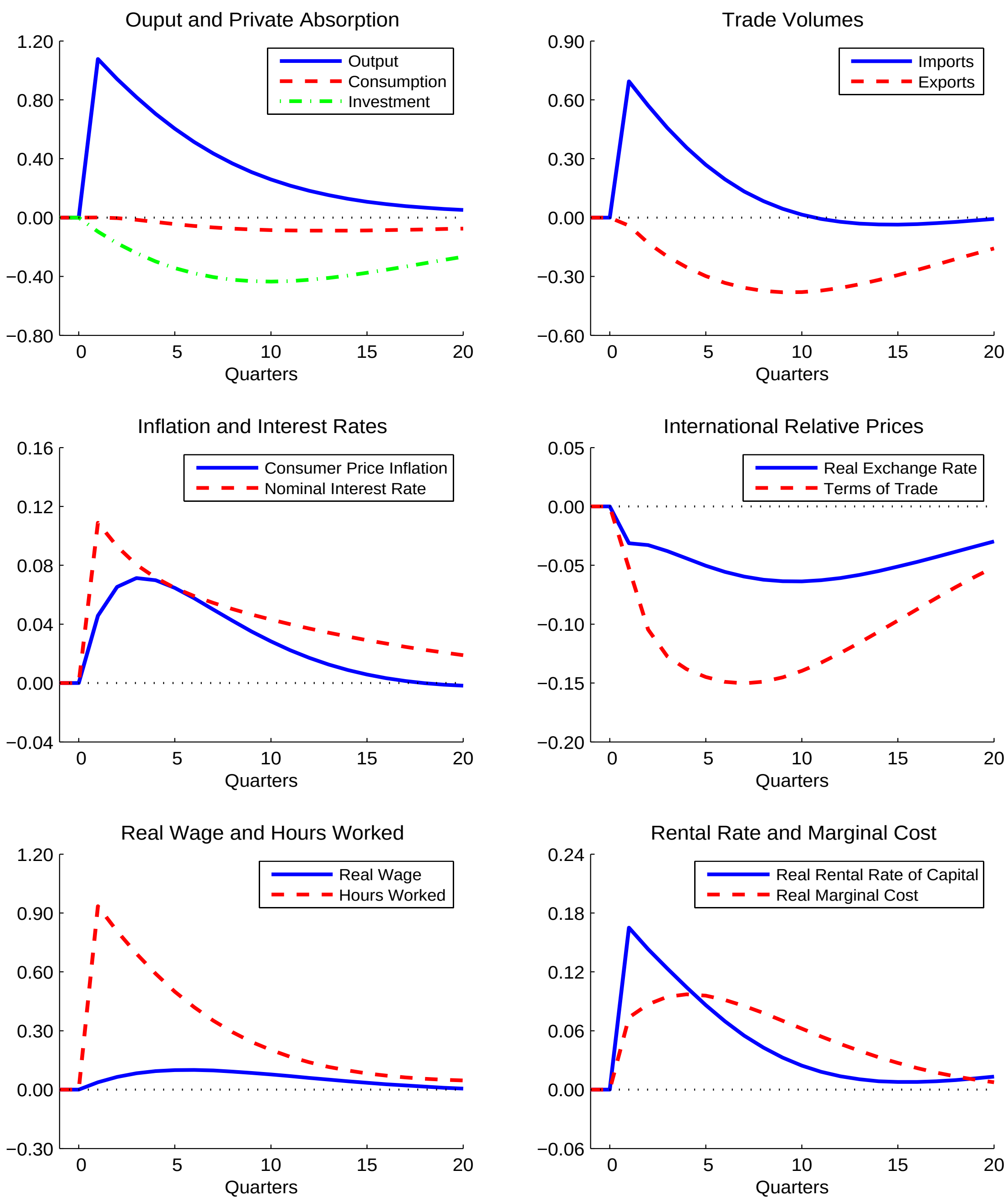
Figure 2 depicts selected dynamic responses to a persistent government spending shock equal to a one-percent increase in steady-state output. All dynamic responses are shown as percentage-point deviations from steady steady.

While the recent literature on the effects of government spending shocks is split as regards the ability of New-Keynesian DSGE models, augmented by an empirically realistic fraction of liquidity-constrained households, to crowd in private consumption (see, e.g., Galí, López Salido and Vallés, 2004; and Coenen and Straub, 2005), the upper-left panel of Figure 2 reveals a positive, although negligible initial effect for the NAWM. Whereas Coenen and Straub (2005) do not find crowding-in effects using a variant of the SW (2003) model with a fraction of liquidity-constrained households equal in size to household J, the NAWM's open-economy setting enables the members of household I to borrow from abroad, which ultimately prevents aggregate private consumption from falling.[26]

[25] The estimated interest-rate rule in SW (2003) prescribes a feedback of the nominal interest rate to the quarterly inflation rate and the output gap, as well as the first difference in these two target variables, with the output gap being defined in terms of the *natural* output level; that is, the output level that would prevail in a version of the model without nominal rigidities.

[26] As documented in Coenen, McAdam and Straub (2006), increasing the size of household J leads to a stronger crowding-in effect, as expected, while assuming a size of zero for household J results in a protracted, even though limited fall in consumption.

Figure 2: Dynamic Responses to a Government Spending Shock



Note: For the baseline version of the NAWM, this figure depicts the dynamic responses of selected domestic variables to a persistent government spending shock ($\rho_g = 0.90$) equal to an one-percent increase in steady-state output. All dynamic responses are reported as percentage-point deviations from steady state.

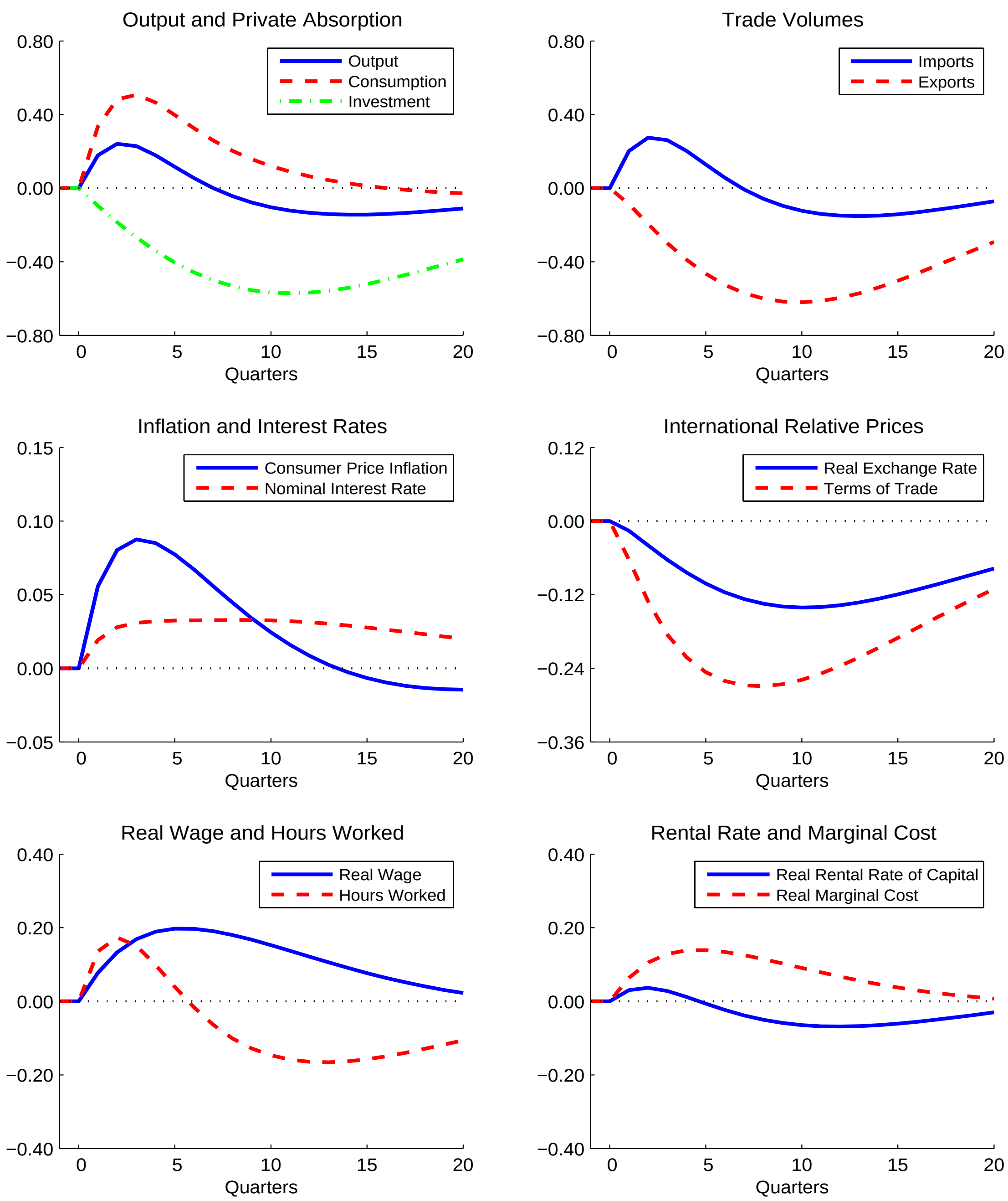
Indeed, as shown in the upper-right panel, imports rise strongly following the government spending shock. This rise in imports is driven by a strong fall in the terms of trade (defined as the domestic import price relative to the export price in domestic currency), as shown in the middle-right panel. Such an *improvement* in the terms of trade induces protracted expenditure switching away from domestic towards foreign goods. Thereby, the negative wealth effect generated by the government spending shock is largely offset by the wealth effect due to the improvement in the terms of trade. The increase in output following the government spending shock induces an increase in both the aggregate wage rate and the rental rate of capital, and the ensuing increase in marginal cost leads to a rise in inflation. Accordingly, triggered by the spike in output growth and the build up of inflationary pressures, monetary policy is tightened rather sharply, despite the appreciation of the domestic currency.

Transfer Shock

Figure 3 portrays the dynamic responses to a persistent transfer shock equal to a one-percent increase in steady-state output. Obviously, in a model with a single type of household in which all members have unlimited access to financial markets, a transfer shock would have no real effects since Ricardian equivalence holds. In the current setting, however, a transfer shock implies an income transfer from the members of household I to those of household J, the latter being characterised by a higher propensity to consume out of disposable income because of their limited ability to participate in financial markets and, thus, to smooth consumption.

As can be seen in the upper-left panel of Figure 3, the transfer shock induces an increase in aggregate private consumption which is only partially offset by a decline in investment. Thus, given the overall increase in private absorption, the demand for foreign goods rises strongly. The initial demand effect, which is brought about by an expansion in current disposable income owing to an increase in both wages and hours worked, is further strengthened by an improvement in the terms of trade switching demand away from domestic towards foreign goods. Incidentally, with short-term real interest rates initially falling by a small amount, the monetary policy response proves to be accommodative.

Figure 3: Dynamic Responses to a Transfer Shock



Note: For the baseline version of the NAWM, this figure depicts the dynamic responses of selected domestic variables to a persistent transfer shock ($\rho_{tr} = 0.90$) equal to an one-percent increase in steady-state output. All dynamic responses are reported as percentage-point deviations from steady state.

Further Analysis

In an attempt to cast further light on the influences of the two types of households on the propagation of fiscal policy shocks, **Figure 4** compares the dynamic responses of selected household-specific variables. Specifically, the panels in the left column show the household-specific responses of consumption, the real wage and hours worked following a persistent government spending shock, while the panels on the right show the respective responses to a persistent transfer shock.

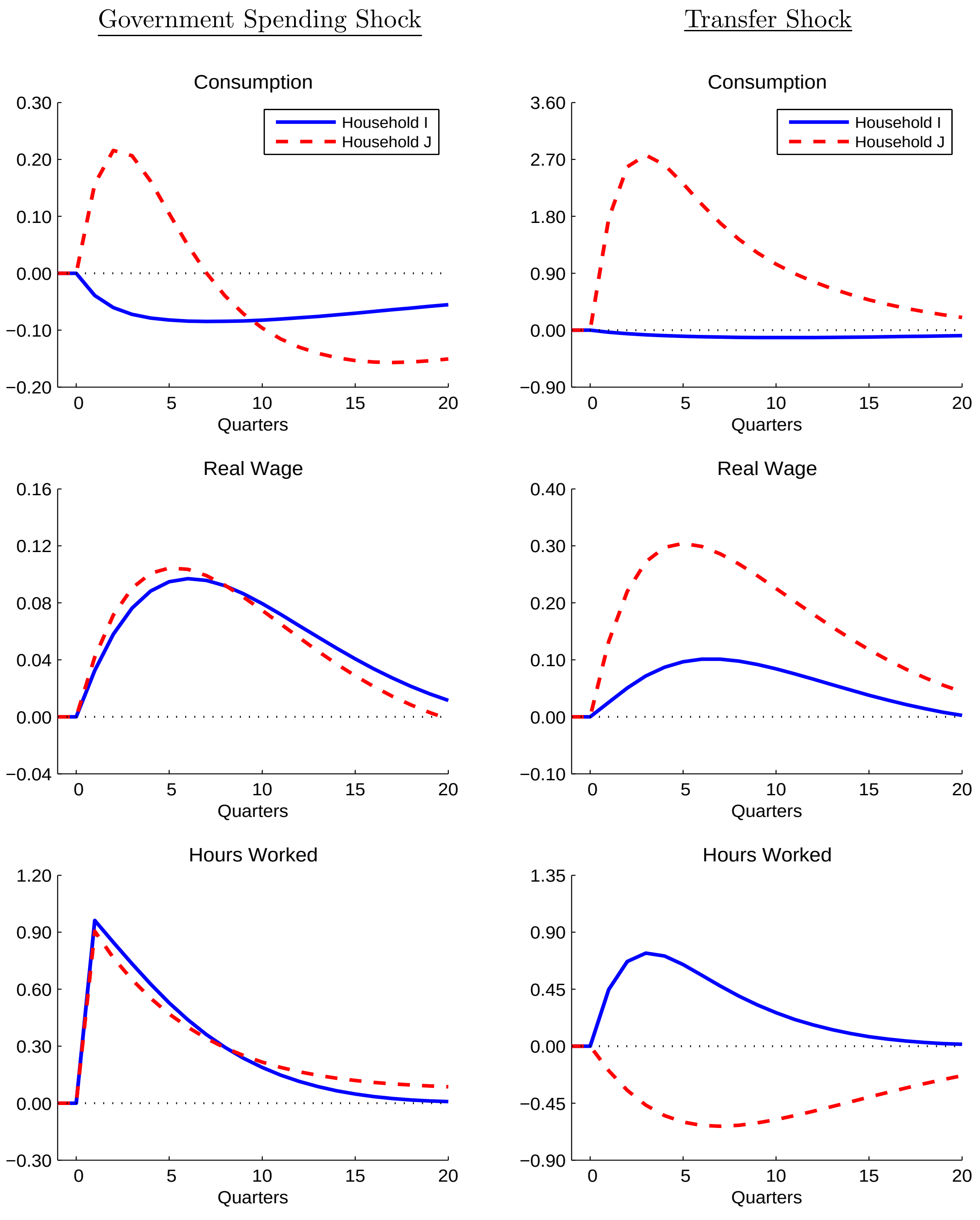
As can be observed in the upper-left panel of Figure 4, because of the negative wealth effect, consumption spending by the members of household I falls, even though moderately, in response to a government spending shock. In contrast, consumption spending on the part of the members of household J is crowded in by almost a quarter percentage point. This crowding-in is triggered by an increase in the household members' disposable income, the latter being driven by an upsurge in hours worked and, to a lesser extent, by a gradual rise in the real wage. Nevertheless, given the rather small size of household J, the aggregate effect on consumption is negligible, as documented in Figure 2 above.

Regarding the household-specific responses to a transfer shock, we observe a small, albeit negligible decline in consumption on the part of the members of household I. This decline reflects a loss in income because of the disproportionate financing requirement that this household faces. The ensuing negative wealth effect is only partially offset by an increase in wage income owing to a rise in both hours worked and the real wage. In contrast, the income transfer boosts consumption spending of the members of household J by almost three percentage points, despite the fact that the responses of hours worked and the real wage tend to offset each other.

5 Tax Reform and Economic Performance

Having illustrated the dynamic properties of the NAWM by focusing on two types of fiscal shocks, we finally proceed to examine the potential benefits and spillovers of reducing the tax distortions that have been identified as one of the primary explanations for the euro area's relatively poor labour-market performance. In particular, we utilise the NAWM to evaluate

Figure 4: Household-Specific Responses to Fiscal Policy Shocks



Note: For the baseline version of the NAWM, this figure depicts the dynamic responses of selected domestic variables to a government spending shock and a lump-sum transfer shock, equal to a 1 percent increase in steady-state output. All dynamic responses are reported as percentage-point deviations from steady state.

the long-run effects of reducing the level of the tax wedges that have been documented for the euro area in Section 2 to those prevailing in the United States. We also consider the transitional dynamics implied by such reductions, highlight the possibility of distributional effects and summarise some sensitivity analysis.

5.1 Long-Run Effects

Table 2 indicates the long-run effects on selected domestic and foreign variables of lowering euro area tax wedges to levels prevailing in the United States. All effects are reported as percentage-point changes relative to the initial steady state. We consider four alternative scenarios: a reduction in the consumption tax, a reduction in the sum of the tax on labour income and households' social security contributions (reflecting the fact that these two wedges enter the households' decision problem in an isomorphic manner), a reduction in the firms' social security contributions and, finally, the reduction of the overall tax wedge defined as the combination of the three individual scenarios. In implementing each of these scenarios, it is assumed that the implied loss in revenue is financed by a decrease in the fiscal authority's transfer payments to households such that the government spending and debt-to-output ratios remain unchanged in the long run.[27]

Starting with the reduction in the overall tax wedge, the results presented in the final column of Table 2 confirm that reducing labour-market distortions has significant beneficial effects on labour-market outcomes and overall economic performance. As regards labour-market outcomes, hours worked increase by more than 14 percentage points in the long run, while the consumption real wage of households rises by more than 11 percentage points. The implied increase in wage income boosts both consumption and investment and, thereby, aggregate output.[28] The increase in private absorption results in an expansion of

[27]We also considered an alternative financing scheme according to which the revenue loss due to the lowering of tax rates is financed by a reduction in government spending. The wealth effect of the latter tends to offset the effect on hours worked, while the consumption effect is strengthened. However, we do not find this alternative financing scheme appealing, not least owing to the size of the spending restraint that would be required to maintain the initial government debt-to-output ratio. The relevant results are available on request.

[28]Note that consumption and investment increase in different proportions because of a rise in the relative price of the investment good. In contrast, the steady-state ratios of nominal consumption and investment over nominal output remain unchanged.

Table 2: Long-Run Benefits and Spillovers of Lowering Tax Wedges in the Euro Area

	Components of Overall Tax Wedge			Overall Tax Wedge
	$\Delta\tau^c = -10.6$	$\Delta(\tau^n + \tau^{w_h}) = -1.5$	$\Delta\tau^{w_f} = -14.8$	$\Delta\bar{\tau} = -26.8$
Euro Area				
Output	4.45	0.78	5.64	12.54
Consumption	4.21	0.73	5.33	11.86
Investment	2.94	0.52	3.73	8.22
Exports	3.67	0.64	4.66	10.30
Imports	1.23	0.22	1.54	3.36
Hours worked	5.04	0.88	6.40	14.30
Real wage	-0.79	-0.14	12.69	11.40
After-tax real wage	8.97	1.82	12.69	24.78
Effective labour cost	-0.58	-0.10	-0.74	-1.58
Terms of Trade	2.51	0.44	3.18	6.99
United States				
Output	0.20	0.04	0.25	0.53
Consumption	0.42	0.07	0.53	1.15

Note: For the baseline version of the NAWM, this table indicates the steady-state effects on selected domestic and foreign variables of permanent percentage-point reductions in the euro area tax wedges to levels prevailing in the United States. All effects are reported as percentage-point changes relative to the initial steady state.

imports, despite the fact that the terms of trade deteriorate substantially, shifting domestic demand away from imports. Likewise, foreign demand for domestic goods surges, boosting consumption and, to a lesser extent, aggregate output in the United States.[29]

In order to better understand the mechanisms behind the long-run effects on labour-market outcomes, it is helpful to compare the effects of reductions in the individual components of the overall tax wedge. For instance, the reduction in the consumption tax favourably affects the intratemporal margin of households by raising the purchasing power of their wage income. Thus, consumption becomes more attractive relative to leisure, boost-

[29]With the holdings of internationally traded bonds (that is, the net foreign asset position denominated in foreign currency) being zero both in the original and in the new steady state, the improvement in the nominal trade balance denominated in domestic currency is offset by the depreciation of the latter.

ing thereby the supply of labour in the economy. The rise in labour supply in turn leads to a fall in the (pre-tax) real wage (delated with the price of the consumption good) and, consequently, to a reduction in firms' effective labour cost (deflated with the firms' implicit output price). As the reduction in the composite of the tax on labour income and households' social security contributions affects the same margin, the qualitative responses of the model are quite similar. Differences in the long-run effects of the two scenarios can be explained by the different magnitudes of the respective tax reductions and also by the differential effects that they have on government revenue.[30]

Remarkably, the permanent reduction in firms' social security contributions has a quite different long-run impact on labour-market outcomes, notably wages. The reduction in social security contributions affects the intermediate-good firms' intratemporal labour-capital margin by reducing the effective cost of labour utilisation. This decline in effective labour cost leads to a rise in labour demand, which in turn induces an increase in the real wage. In equilibrium, the latter dampens the reduction in effective labour cost, which explains its subdued negative long-run response.

Clearly, discrepancies in firms' contributions to social security account for the largest part of the difference in the overall tax wedge between the euro area and the United States. Accordingly, in the recent policy debate, calls for reductions in labour-market distortions have been largely centred around the need to lower firms' social security contributions. In the light of this debate, we will therefore focus the subsequent analysis on this component of the overall tax wedge.

5.2 Transitional Dynamics

The transitional dynamics implied by the reduction in firms' non-wage labour cost depends on the timing of its implementation and also on the way the fiscal authority compensates

[30]Conventional public finance wisdom argues in favour of consumption taxes over income taxes and social security contributions. Assessing the relative effectiveness of reducing individual tax wedges, however, is not straightforward in our framework, given the fact that in all cases the reductions in tax revenue are offset by changes in the fiscal authority's transfers to households which, as illustrated below, may have important distributional effects. In this context, for example, Krusell, Quadrini and Ríos-Rull (1996) show in a model with heterogenous households and endogenously determined transfer levels that income taxes are not necessarily worse in welfare terms.

the implied losses in revenue. Here, we assume that the reduction is gradually phased in, but fully anticipated by households and firms. This seems plausible in view of the often lengthy decision-making processes before tax reforms pass into legislation in reality and also in view of the delays in their actual implementation. Specifically, we assume that half of the reduction takes place in the course of the first year, that three quarters are implemented by the end of the second year, and so forth. We maintain the assumption that the losses in revenue are offset by reductions in transfer payments. In this context, the reduction in the steady-state transfers-to-output ratio is assumed to match the gradual reduction in non-wage labour cost.

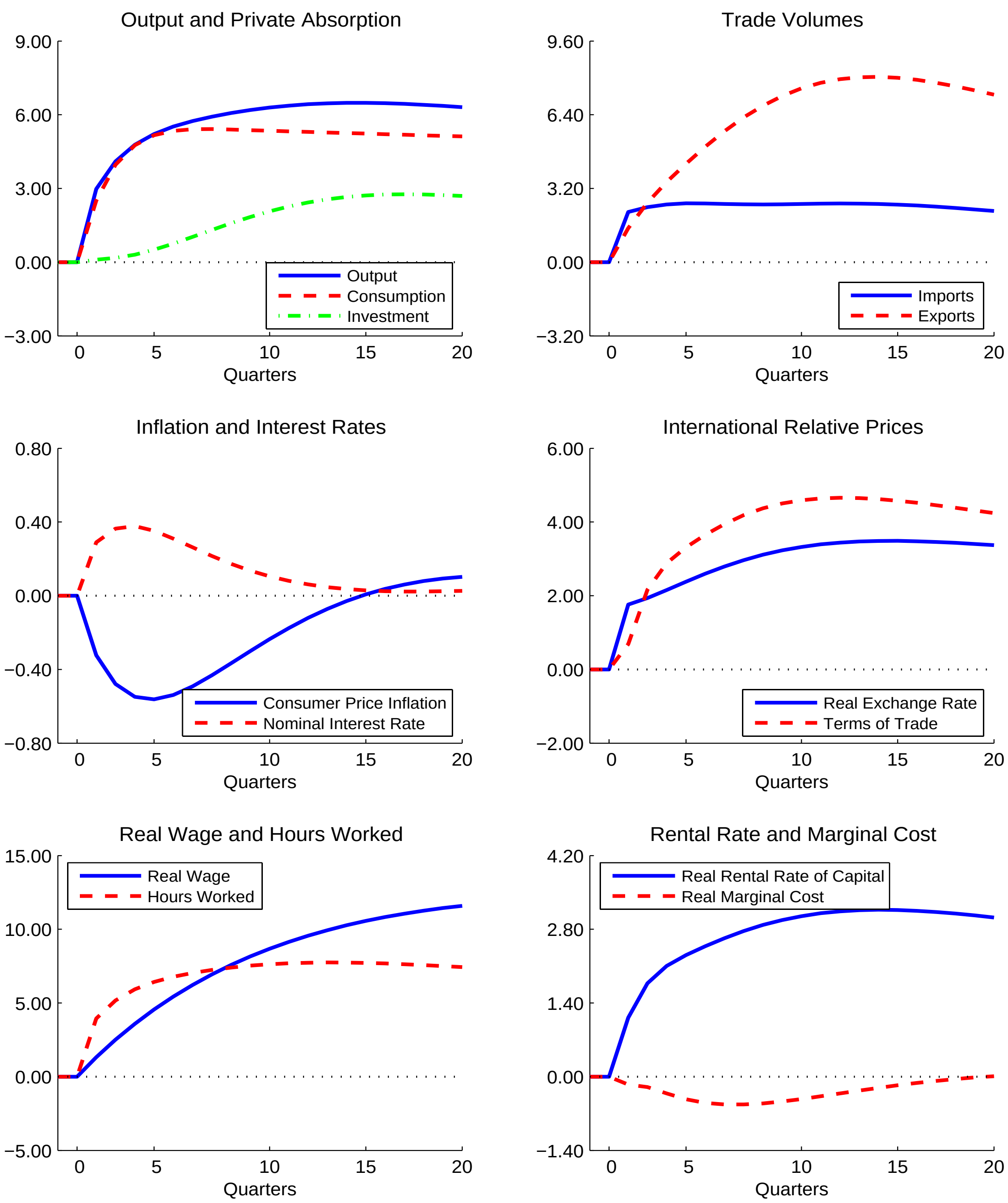
Figure 5 depicts the transitional dynamics of selected variables induced by the gradual reduction in non-wage labour cost from 21.9 to 7.1 percent. On impact, both consumer wages and hours worked start to increase, with the dynamics of wages being more more drawn out reflecting the existence of a rather high degree of inertia in the wage-setting process. The implied increase in disposable income (which is reinforced by an increase in the rental rate of capital due to the fact that capital services as an input in production have become relatively scarce) boosts private consumption, while investment only gradually builds up. The ensuing rise in the terms of trade shifts foreign demand towards domestic goods. This dampens the demand-driven increase in imports and gives rise to a lasting expansion in exports. Because of the reduction in non-wage labour cost, firms' real marginal cost gradually falls, leading to a decline in inflation. Given the strong pick up in output, however, the monetary authority raises nominal interest rates, further dampening the upsurge in domestic demand.[31]

5.3 Distributional Effects

Given our assumption that the fiscal authority's transfer payments are split amongst the two types of households in a proportion of 3 to 1 in favour of household J, the reduction in transfers required to maintain the initial government debt-to-output ratio affects the mem-

[31] As shown in Coenen, McAdam and Straub (2006), lowering non-wage labour cost instantaneously results in a front loading of the adjustment process: real marginal cost falls on impact, triggering a pronounced decline in inflation; and private absorption as well as exports overshoot their new steady-state values, the overshooting being caused by a sharp initial rise in the terms of trade.

Figure 5: Transitional Dynamics after a Gradual Reduction in Non-Wage Labour Cost



Note: For the baseline version of the NAWM, this figure depicts the transitional dynamics of selected domestic variables after a gradually phased-in permanent reduction in firms' social security contributions from 21.9 to 7.1 percent. All dynamic effects are reported as percentage-point deviations from the initial steady state.

bers of household J disproportionately. The potential distributional effects are illustrated in **Figure 6**.

As can be seen in the left column of Figure 6, the members of household J need to cut back consumption by more than 8 percent in the long run because of the loss in transfer income. In contrast, consumption spending on the part of the members of household I can be raised by almost 9 percent since the positive supply-side effects of the reduction in non-wage labour cost and the ensuing rise in labour and capital income more than offset the reduction in transfer income. With the real wages of the two types of households moving broadly in parallel, the members of household J increase their working hours significantly in order to equate the real wage and the marginal rate of substitution. In contrast, hours worked on the part of the members of household I hardly move in the long run when compared with the initial steady state.

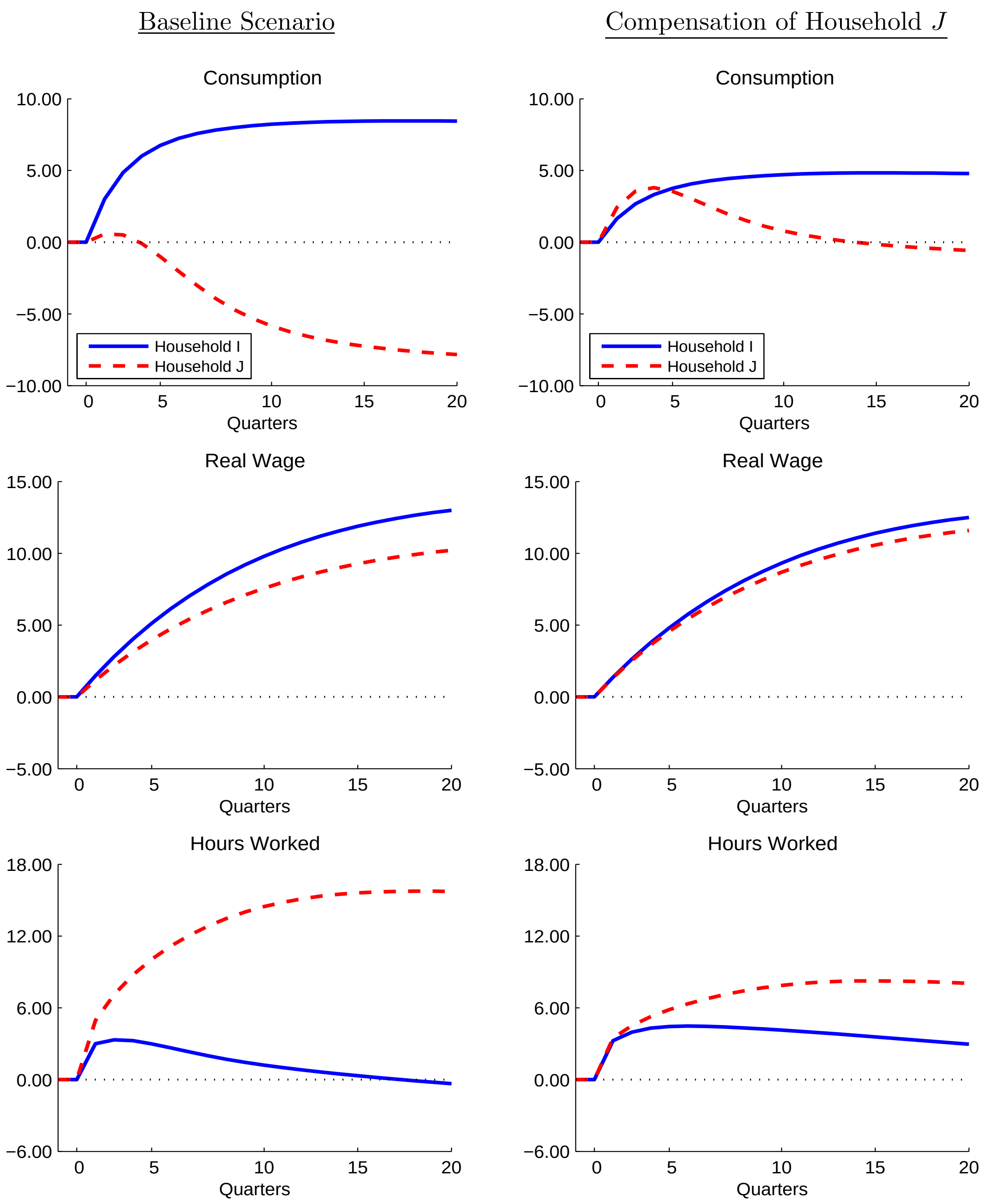
Of course, modifying the assumption regarding the details of how the decline in revenue is financed may influence the distributional effects of the reduction in non-wage labour cost in important ways. For example, gradually increasing the proportion of transfers amongst households to 5 to 1 in favour of household J when implementing the reduction in non-wage labour cost shifts more of the burden of financing the fiscal measure onto the members of household I. As shown in the column on the right of Figure 6, such a redistribution policy aimed at compensating the members of household J for the initial loss in income helps to stabilise consumption on their part, while also dampening the observed discrepancies in hours worked across households.

All in all, these results illustrate that, in the presence of heterogenous households, distributional effects may be of importance when gauging the macroeconomic impact of tax reforms, which, in the first place, have been designed to meet efficiency considerations.

5.4 Further Sensitivity Analysis

We finally summarise some additional sensitivity analysis regarding the long-run effects of lowering euro area tax wedges to levels prevailing in the United States.

Figure 6: Distributional Effects of a Gradual Reduction in Non-Wage Labour Cost



Note: For the baseline version of the NAWM, this figure depicts the distributional effects on selected household-specific variables of a gradually phased-in permanent reduction in firms' social security contributions from 21.9 to 7.1 percent under alternative assumptions regarding burden sharing amongst households. All dynamic effects are reported as percentage-point deviations from steady state.

First, we analyse the extent to which the strength of the long-run effects depend on the labour-supply elasticity of households, which is considered to be the key parameter in determining the labour-market outcomes. To this end, the upper panel in **Table 3** shows how the long-run effects vary when the baseline labour-supply elasticity of 0.5 is scaled up by a factor of two. As expected, in this case, hours worked are much more sensitive to reductions in labour-market distortions. For example, reducing all components of the overall tax wedge to the levels prevailing in the United States leads to an increase in hours worked that exceeds that reported for the baseline calibration in Table 2 by more than four percentage points. Accordingly, a stronger long-run effect on domestic output materialises which, in turn, triggers a larger deterioration in the terms of trade. The latter is needed to re-balance the demand for domestic versus foreign goods. Consequently, the spillover effects on foreign output are strengthened.

Second, we consider the implications of a higher substitution elasticity between home and foreign goods in producing the final consumption and investment goods. For the preceding analysis, we assumed a relatively low elasticity of 1.50, which resulted in a rather pronounced change in the terms of trade, but limited spillovers onto output developments in the United States. As shown in the middle panel of Table 3, doubling this elasticity leaves domestic output and labour-market outcomes largely unaffected, while it lowers the need for adjustment in the terms of trade to re-balance demand internationally.[32] As a result, the spillover effects on foreign output turn out to be even weaker.

Last but not least, we also evaluate the impact of our maintained assumption of limited asset-market participation on the part of households on our results. For this purpose, we simulate the model alternatively under the assumption that all households have access to domestic and foreign asset markets. The results are depicted in the lower panel of Table 3. It can be seen that limited asset-market participation appears to amplify the long-run responses of hours worked and output following adjustments in distortionary taxation. The more subdued responses of aggregate variables under full asset-market participation are partly driven by the absence of the previously discussed distributional channel. In

[32] Regarding the composition of aggregate demand (not shown in the table), however, somewhat larger differences emerge, notably with respect to the size of trade flows.

Table 3: Sensitivity of the Long-Run Effects of Lowering Tax Wedges in the Euro Area

	Components of Overall Tax Wedge			Overall Tax Wedge
	$\Delta\tau^c = -10.6$	$\Delta(\tau^n + \tau^{w_h}) = -1.5$	$\Delta\tau^{w_f} = -14.8$	$\Delta\bar{\tau} = -26.8$
A. Labour Supply Elasticity Scaled Up by 2				
Euro Area				
Output	5.81	1.02	7.38	16.33
Hours Worked	6.58	1.15	8.37	18.65
Terms of Trade	3.27	0.58	4.15	9.03
United States				
Output	0.27	0.05	0.33	0.69
B. Substitution Elasticity between Home and Foreign Goods Scaled Up by 2				
Euro Area				
Output	4.59	0.80	5.82	12.95
Hours Worked	4.98	0.87	6.32	14.11
Terms of Trade	1.74	0.31	2.20	4.79
United States				
Output	0.14	0.03	0.18	0.38
C. Full Asset-Market Participation ($\omega = 0$)				
Euro Area				
Output	3.53	0.65	4.59	9.58
Hours Worked	4.00	0.74	5.21	10.91
Terms of Trade	2.01	0.37	2.60	5.38
United States				
Output	0.16	0.03	0.20	0.40

Note: For alternative calibrations of the NAWM, this table indicates the steady-state effects on selected domestic and foreign variables of permanent percentage-point reductions in the euro area tax wedges to levels prevailing in the United States. All effects are reported as percentage-point changes relative to the initial steady state.

the baseline version of the model with one-fourth of the households being constrained in their ability to access asset markets, a decrease in distortionary taxation and the implied distributional effects amplify the underlying wealth effect and exacerbate the impact of tax adjustments on the intratemporal margin of households. Accordingly, the limited ability of households to optimise intertemporally makes the adjustment of labour supply an even more important channel for reacting to changes in the economic environment.[33]

6 Conclusions

To examine the effects of reducing labour-market distortions caused by euro area tax structures, we employed a calibrated version of the New Area-Wide Model currently under development at the European Central Bank. Using this model, we confirm the widely-held view that reductions in tax distortions would have beneficial effects on labour-market outcomes and overall economic performance. In fact, lowering euro area tax wedges to levels prevailing in the United States would lead to a rise in hours worked and output by more than 10 percent in the long run. At the same time, we show that tax reforms aimed at reducing labour-market distortions have beneficial spillovers to the euro area's trade partners, bolstering the case for tax reforms from a global perspective. Finally, we illustrate that, in the presence of heterogenous households, distributional effects may be of importance when gauging the impact of tax reforms.

In the future, we plan to study the consequences of differences in productivity growth across the euro area and the United States. Such differences are perceived to be an important determinant of the employment and output (growth) differentials observed over more recent years. Another interesting extension would be to examine the consequences of differences in skill levels across the two types of households. High tax wedges seem particularly problematic for low-skill, low-productivity workers since it may be difficult for workers that are protected by minimum-wage or industry pay norms to fully accommodate the required wage correction.

[33] We also explored the sensitivity of our results to variations in other structural parameters such as the intertemporal elasticity of substitution and the degree of habit persistence in consumption, but varying those parameters did not change the results in an economically important way.

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Appendix A

In this appendix we provide the functional forms for the various adjustment and transaction costs included in the NAWM.

Transaction Cost Technology
We assume that the transaction cost technology is identical across both types of households and takes the form

$$\Gamma_v(v_{h,t}) \quad = \quad \gamma_{v,1}\, v_{h,t} + \gamma_{v,2}\, v_{h_t}^{-1} - 2\,\sqrt{\gamma_{v,1}\,\gamma_{v,2}}, \tag{A.1}$$

where $\gamma_{v,1}, \gamma_{v,2} > 0$ (cf. Schmitt-Grohé and Uribe, 2005).

Capital Utilisation Cost
As in Christiano, Eichenbaum and Evans (2005), the capital utilisation cost function takes the form

$$\Gamma_u(u_{i,t}) \quad = \quad \gamma_{u,1}\,(u_{i,t} - 1) + \frac{\gamma_{u,2}}{2}\,(u_{i_t} - 1)^2, \tag{A.2}$$

where $\gamma_{u,1}, \gamma_{u,2} > 0$.

Investment Adjustment Cost
Following Christiano, Eichenbaum and Evans (2005), we assume an investment adjustment cost function of the form

$$\Gamma_I(I_{i,t}/I_{i,t-1}) \quad = \quad \frac{\gamma_I}{2}\left(\frac{I_{i,t}}{I_{i,t-1}} - 1\right)^2, \tag{A.3}$$

where $\gamma_I > 0$.

Import Adjustment Cost
Adjusting the use of imports in the production of the final consumption good is subject to adjustment costs which take the form

$$\Gamma_{IM^C}(IM_t^C/Q_t^C) \quad = \quad \frac{\gamma_{IM^C}}{2}\left(\frac{IM_t^C/Q_t^C}{IM_{t-1}^C/Q_{t-1}^C} - 1\right)^2, \tag{A.4}$$

where $\gamma_{IM^C} > 0$ and assuming that the representative firm takes the previous period's (sector-wide) import share, IM_{t-1}^C/Q_{t-1}^C, as given.

A similar specification holds for the use of imports in the production of the final investment good.

International Transaction Cost
Members of household I encounter an intermediation or "risk" premium when they take a position in the market for internationally traded bonds which depends on the per-capita (net) foreign asset position of the domestic country relative to domestic output,

$$\Gamma_{B^F}(B_t^F) \quad = \quad \gamma_{B^F}\left(\exp\left(\frac{S_t\,B_t^F}{P_{Y,t}Y_t}\right) - 1\right), \tag{A.5}$$

where $\gamma_{B^F} < 0$. This specification implies that, in the non-stochastic steady state, domestic household members have no incentive to hold internationally traded bonds and the net foreign asset position is zero worldwide.

Appendix B

This appendix summarises the details regarding the calibration of the steady-state ratios and the structural parameters of the NAWM.

Table B.1: Steady-State Ratios

Ratio	Value		Description
	Euro Area	United States	
$P_C C/P_Y Y$	0.60	0.62	Private consumption-to-output ratio
$P_I I/P_Y Y$	0.22	0.22	Private investment-to-output ratio
$P_G G/P_Y Y$	0.18	0.16	Public consumption-to-output ratio
$P_{IM} IM/P_Y Y$	0.18	0.13	Imports-to-output ratio
$P_{IM} IM^C/P_Y Y$	0.05	0.06	Private consumption good
$P_{IM} IM^I/P_Y Y$	0.13	0.07	Private investment good
$M/P_C C$	1.34	0.42	Money-to-consumption ratio
$B/P_Y Y$	2.40	2.40	Government debt-to-output ratio
$D/P_Y Y$	0.00	0.00	Dividend income-to-output ratio

Note: This table reports the steady-state ratios of the main expenditure categories over nominal output, as obtained from the national accounts. The money-to-consumption ratios are computed as the ratio of the narrow monetary aggregate M1 held by the household sector over nominal consumption expenditure. The ratio for the euro area has been calibrated using monetary data for the 1999-2004 period, while the ratio for the United States is taken from Schmitt-Grohé and Uribe (2005).

Table B.2: Parameter Values

Parameter	Value: Euro Area		Value: United States		Description
A. Households					
s	0.42		0.58		Population size
β	$1.03^{-0.25}$		$1.03^{-0.25}$		Subjective discount factor
σ	2.00		2.00		Inverse of the intertemporal elasticity of substitution
κ	0.60		0.60		Degree of habit persistence
ζ	2.00		2.00		Inverse of the Frisch elasticity of labour supply
δ	0.025		0.025		Depreciation rate
ω	0.25		0.25		Size of household J
ξ_I, ξ_J	0.75		0.75		Fraction of household members not setting wages optimally each quarter
χ_I, χ_J	0.75		0.75		Degree of wage indexation
B. Intermediate-Good Firms					
α	$0.285^{\star}$		$0.285^{\star}$		Share of capital income in value added
ψ	$0.20^{\star}$		$0.20^{\star}$		Share of fixed cost in production
z, ρ_z	1.00	0.90	1.00	0.90	Parameters governing total factor productivity
η	6.00		6.00		Price elasticity of demand for labour bundles
η_I, η_J	6.00	6.00	6.00	6.00	Price elasticity of demand for a specific labour variety
ξ_H, ξ_X	0.90	0.30	0.90	0.30	Fraction of firms not setting prices optimally each quarter
χ_H, χ_X	0.50	0.50	0.50	0.50	Degree of price indexation
C. Final-Good Firms					
ν_C, ν_I	$0.920^{\star}$	$0.419^{\star}$	$0.900^{\star}$	$0.673^{\star}$	Home bias in the production of final goods
μ_C, μ_I	1.50	1.50	1.50	1.50	Price elasticity of demand for intermediate-good bundles
θ	6.00	6.00	6.00	6.00	Price elasticity of demand for a specific intermediate-good variety

Note: The superscript '$\star$' indicates that the parameter value is implicitly obtained by calibrating the steady-state ratios reported in Table B-1.

Table B.2: Parameter Values (cont.)

Parameter	Value: Euro Area		Value: United States		Description
D. Fiscal Authority					
B_Y	2.40		2.40		Government debt-to-output ratio
ϕ_{B_Y}	0.10		0.10		Sensitivity of lump-sum taxes to debt-to-output ratio
g, ρ_g	0.18	0.90	0.16	0.90	Parameters governing public consumption
tr, ρ_{tr}	$0.185^\star$	0.90	$0.069^\star$	0.90	Parameters governing public transfers
τ^c	0.183		0.077		Consumption tax rate
τ^d	0.00		0.00		Dividend tax rate
τ^k	0.00		0.00		Capital income tax rate
τ^n	0.122		0.154		Labour income tax rate
τ^{w_h}	0.118		0.071		Rate of social security contributions by households
τ^{w_f}	0.219		0.071		Rate of social security contributions by firms
E. Monetary Authority					
Π	1.02		1.02		Inflation target
ϕ_R	0.95		0.95		Degree of interest-rate inertia
ϕ_Π	2.00		2.00		Interest-rate sensitivity to inflation gap
ϕ_{g_Y}	0.10		0.10		Interest-rate sensitivity to output-growth gap
F. Adjustment and Transaction Costs					
$\gamma_{v,1}$, $\gamma_{v,2}$	$0.289^\star$	$0.150^\dagger$	$0.029^\star$	$0.150^\dagger$	Parameters of transaction cost function
$\gamma_{u,1}$, $\gamma_{u,2}$	$0.031^\star$	$0.007^\#$	$0.033^\star$	$0.007^\#$	Parameters of capital utilisation cost function
γ_I	$3.00^\#$		$3.00^\#$		Parameter of investment adjustment cost function
γ_{IM^C}, γ_{IM^I}	5.00	0.00	5.00	0.00	Parameters of import adjustment cost functions
γ_{B^F}	-0.01		-0.01		Parameter of intermediation cost function

Note: See above. The superscript '$\dagger$' indicates that the transaction cost parameter $\gamma_{v,2}$ is calibrated such that the implicit interest semi-elasticity of money demand (see Schmitt-Grohé and Uribe, 2005, for details) is equal to -0.75, while the superscript '$\#$' indicates that the calibrated parameter values differ from the values in Smets and Wouters (2003) by the scaling factors $1/R_K$ and 2, respectively.