IMF Working Paper

Assessing the Impact of a Change in the Composition of Public Spending: A DSGE Approach

Roland Straub and Ivan Tchakarov

INTERNATIONAL MONETARY FUND

IMF Working Paper

Asia Pacific Department

Assessing the Impact of a Change in the Composition of Public Spending: A DSGE Approach

Prepared by Roland Straub and Ivan Tchakarov[1]

Authorized for distribution by Nissanke Weerasinghe

July 2007

Abstract

Despite intense calls for safeguarding public investment in Europe, public investment expenditure, when measured in relation to GDP, has steadily fallen in the last three decades, evoking fears that economic activity may be correspondingly negatively affected. At the same time, however, public consumption in the EU-12 countries has trended up. In this paper, we provide a macroeconomic assessment of the observed change in the composition of public spending in the euro area in a medium-scale two-country dynamic stochastic general equilibrium (DSGE) model.
First, we identify the channels through which both temporary and permanent public investment shocks generate larger fiscal multipliers than exogenous increases in public consumption. Second, we quantify the negative impact of a change in fiscal stance, characterized by a permanent rise in public consumption and a permanent fall in public investment, keeping the overall level of public spending constant. The key message of the paper is that calls for reversing the observed trend in the composition of public spending are well justified.

---

[1] The authors are Economists at the European Central Bank and the IMF's Asia Pacific Department, respectively. The paper was prepared for the conference on "Fiscal Stabilisation Policies in a Monetary Union: What Can We Learn from DSGE Models?", European Commission, Brussels, 12—13 October 2006. We appreciate comments and suggestions from Günter Coenen, Matthias Mohr, Matthias Trabandt, Alessandro Turrini, and Harald Uhlig. The views expressed here do not necessarily reflect those of the ECB or the IMF.

Contents   Page

I. INTRODUCTION

While fiscal policy is one of the two main policy tools used by governments to affect macroeconomic conditions within countries, it is generally believed that nowadays authorities remain less engaged in fiscal activism compared to the golden days of Keynesian policy in the 1950s and 1960s. Nevertheless, it is also accepted that quite often policy makers seem sympathetic to the view of stimulating aggregate demand through increased spending. Policy makers in Europe also actively participate in this debate, which is evidenced by the recent study undertaken by the European Commission (2003) related to the determinants of public investment and the relative effectiveness of public consumption versus public investment as demand management tools.

The above captioned study reveals that, at the policy level in Europe, it is almost an article of faith that, abstracting from distributional issues, public investment is a more superior type of spending than public consumption. For example, the recent official review of public finances in Europe by the European Commission (see European Commission (2003), p.28) clearly suggests that any "...budgetary consolidation strategy, based on expenditure restraint, should not be achieved at the expense of the most 'productive' components of public spending (such as public investment, education, and research expenditures)." As a result, proposals to shield public investment from the rules of the Stability and Growth Pact have gained considerable currency.

Such proposals seem to be well justified in the face of the observed temporal evolution of public investment in the EU-12 countries. When measured in relation to GDP, average public investment has steadily fallen in the last three decades evoking fears that economic activity may be correspondingly negatively affected by this phenomenon. At the same time, however, public consumption in the EU-12 countries has trended up. Therefore, policy makers in Europe might be interested in finding out what could be the policy implications of the diverse temporal evolution of the two main elements of public spending. In this sense, the main purpose of our study is to provide a comparative qualitative and quantitative analysis of the relative strength of public consumption and public investment expenditures in influencing macroeconomic conditions in the short- and long-term, and to analyze a policy scenario which accounts for the observed paths of public consumption and public investment over the last thirty years. To this end, we employ a version of the New Area-Wide Model (NAWM) as discussed in Coenen, McAdam and Straub (2007), augmented to include separate and distinctive roles for public consumption and public investment, to investigate the economic effects of temporary and permanent shocks to the share of public consumption and public investment in GDP.

The NAWM is particularly suited to studying the effects of fiscal policy as it departs from a central tenet of most DSGE models. It breaks down the Ricardian equivalence by introducing

two types of households—one that can fully participate in assets markets and another that is limited in its ability to smooth consumption intertemporally[1]. This, along with the presence of distortionary taxes, allows for a more realistic treatment of fiscal policy in the model. Moreover, crucially for the analysis in the paper, we distinguish in the model between public consumption spending and public investment spending. In particular, we assume that public capital is an essential ingredient in the production function of the individual private firm. In contrast, spending on public consumption affects aggregate demand without enhancing the productivity of the private production sector.

The main result of the paper is that both temporary and permanent increases in public investment generate larger fiscal multipliers than those from increases in public consumption. Public investment not only increases aggregate demand, but it also raises aggregate supply by enhancing aggregate production and the marginal productivity of labor and private capital. As a result, the negative wealth effect associated with increases in public spending is ameliorated in the case of public investment. This leads to a smaller decrease or even increase in private consumption, depending on the productivity of public capital. The same logic applies to private investment and output—as public capital builds up, the productivity of private capital improves, causing a rise in private investment and output.

Furthermore, our results show that recent change in composition in public spending has potentially deleterious effects on economic activity in the euro area. In particular, keeping the overall level of public spending in Europe constant, the results indicate that a permanent rise in public consumption is not sufficient to unwind the adverse effects of a permanent fall in public investment. In this sense, the key message of the paper is that the calls for safeguarding public investment in Europe are not without merit.

The remainder of the paper is as follows: Section 2 briefly reviews the evolution of public investment and public consumption in the EU-12. Section 3 summarizes the literature on the effects of public investment on economic activity. Section 4 provides a short description of the model and the calibration. Section 5 explains the results from the temporary shocks. Section 6 analyzes the results from the policy scenario and the permanent shocks. Section 7 concludes.

II. PUBLIC INVESTMENT AND PUBLIC CONSUMPTION IN THE EURO AREA

This section reviews the temporal evolution of public investment and public consumption in the EU-12 countries and provides some explanations for the observed downward trend.

Figure 1 traces out the trend in public investment in the EU-12 countries since the 1970s. It is evident that public investment fell from about 4.2 percent of GDP in the beginning of the 1970s to below 3 percent of GDP in 2005[2]. While the general trend does point out to reduced rates

---

[1] See Galí, López-Salido, and Valles (2007) and Bilbiie and Straub (2005) for an analysis of the interaction of rule-of-thumb agents and the effects of fiscal policy.

[2] Public investment is computed as unweighted average of government fixed capital formation

of accumulation of public capital, there is a considerable variation across individual countries. Austria, Belgium and Germany have experienced the largest declines, with the share of public investment in GDP falling from about 5 to slightly above 1 percent. The fall in public investment has been less pronounced in Finland, France, Greece, Ireland, Italy, Netherlands and Portugal. In contrast, in Luxembourg[3] and Spain the share of public investment in GDP has in fact increased.

In addition, there are interesting developments within individual countries. For example, while public investment in Ireland dropped from about 6 percent of GDP in 1974 to 1.8 percent of GDP at the end of the 1980s, it subsequently rose to about 4 percent of GDP at the turn of the century. Similar, but less pronounced, evolution can be observed in Italy, where public investment fell to 2.1 percent of GDP in 1995, but later on accelerated to its long-term average of 3 percent of GDP.

It would also be useful to see what implications, if any, the decrease in public investment has had on public capital. Kamps (2004) provides new estimates of public capital stock in 22 OECD countries[4]. He shows that since the 1970s public capital stock has grown almost fivefold in Portugal, fourfold in Spain, threefold in Belgium and Finland, more than doubled in Greece and Ireland, doubled in Austria, France, Germany and Italy, and less than doubled in the Netherlands. The downtrend in public investment-to-GDP ratio has, therefore, not been large enough to force public investment below the level of depreciation. While the level of accumulation of public capital has slowed down in line with the decline in public investment, the stock of public capital in the EU-12 countries has continued to grow.

The above description of the evolution of public investment flows raises two important questions. First, what created the observed patterns, especially the long-term downtrend in public investment. Second, what are the consequences of this pattern, especially in terms of economic growth. We address the latter question in the next section, and focus on the former below.

There have been a number of explanations as to what might account for the observed decline in public investment in the EU-12 countries. The most commonly advanced are the extensive privatization and the drive toward a smaller economic role for the state in the past three decades; the emergence of alternative ways to finance infrastructure investment, such as the public-private partnerships; the impact of EMU's fiscal rules; and a decreasing need for additional infrastructure.

There are only few studies[5] devoted to the testing of these hypotheses and, moreover, they do not offer comprehensive and concluding evidence of why public investment has trended down for so long. In a recent econometric study, however, Valila and Mehrotra (2005) evaluate the above competing hypotheses and reach the conclusion that the long-term downtrend in public investment is associated with drawn-out episodes of fiscal consolidation, unrelated to EMU. In

---

across the EU-12 countries. Euro area data shows that public investment was 2.5 percent in GDP in 2005.

[3]   For Luxembourg, data is available only from 1990.

[4]   These include all EU-12 countries, but Luxembourg.

[5]   See, for example, De Haan, et al (1996), Sturm (1998), Galí and Perotti (2003), and Turrini (2004).

other words, public investment is one of the many fiscal policy tools used to curtail budgetary deficits. Specifically, the authors find no evidence that the fiscal rules embodied in the EMU could have accounted for the downtrend, nor do they find support for the hypothesis that the demand for public capital has reached a saturation point. In addition, they argue that it is unlikely that any political drive toward a smaller economic role for the state can account for the decline in public investment as, if measured in terms of tax revenue to GDP, governments have not become less significant in recent decades. Finally, public-private partnerships are a relatively recent phenomenon and, moreover, they have become significant only in a few EU-12 countries[6].

The temporal evolution of public consumption over the last three decades differs from that of public investment. Figure 2 shows the average public consumption increased from 14.8 percent in GDP in 1970 to 20 percent of GDP in 2005. Public consumption accelerated significantly relative to GDP in the 1970s and the 1980s when the bulk of this increase took place. The growth differential between public consumption and GDP was smaller in the 1990s and the beginning of the century, when the share of public consumption in GDP grew only modestly. This pattern is relatively uniform across Euro Area countries, with the notable exception of Ireland, where the share of public consumption in GDP was on a downward path in the 1990s.

This combined behavior of public investment and public consumption in the EU-12 countries motivates the policy scenario that we investigate using the NAWM.

III. Is Public Investment Beneficial for Economic Activity?

In this section we go on to review the empirical literature with a view to analyzing whether the decline in public investment has a detrimental impact on economic growth at the aggregate level.

The possibility that a declining share of public investment in GDP could have deleterious consequences for economic growth over the long term is a legitimate cause for concern, although the empirical evidence in this area remains mixed[7]. There are a number of reasons why the many studies on this topic fail to uncover a conclusive positive impact of public investment on growth. These include: (i) the difficulty in controlling for all the factors, in addition to public investment, that affect growth over the long term; (ii) the fact that a sizable portion of public investment is directed to supporting broad functions of government, including redistribution and the provision of public services, maintaining law and order, and administration, which do not directly boost productive potential; (iii) the lumpy nature of infrastructure investment which implies that the full impact of investment in roads, telecommunications, and other infrastructure on growth can only be realized with considerable lags, once effective networks have been established.

The precursor of these studies is Aschauer, who in a series of papers published in 1989, suggested that falling public investment in the United States can help explain the post-1970 slowdown in U.S. productivity growth. A number of subsequent studies reached similar conclusions, although

---

[6] For example, Portugal.

[7] For a detailed overview of the literature, see IMF (2004), and Romp and de Haan (2005).

the strength and robustness of such results turn out to be sensitive to the methodology and data employed.

There are four methodologies that have traditionally been used: (i) aggregate production functions, which relate output to public capital stock; (ii) cost or profit functions, to assess whether public capital lowers business costs; (iii) research focused on growth rather than the level of output, examining whether public investment helps explain differences in cross-country or cross-regional growth; (iv) VARs, which are suited to exploiting the time-series properties of public investment.

Considering the links between public capital and output, many studies–but not all–find a positive association between these variables. However, pointing to a range of econometric problems arising with such studies, Gramlich (1994) and others have noted that the implied rates of return of public capital in many of these studies appear to be implausibly high. Interestingly, while the work of Aschauer and others was originally motivated by the post-1970 slowdown in U.S. productivity growth, the latter picked up significantly during the 1990s while public investment continued to decline.

Most of the studies using cost or profit functions find that public capital does lower business costs or increases profits, although the magnitude of these affects is relatively small.

In a number of studies focusing on the level and growth of output, empirical support for a positive impact of public capital has been obtained using a particular component of investment–notably infrastructure. For example, Calderon and Serven (2003) show that quantitative measures of road and rail lines have a positive and significant impact on output per worker. Growth regressions also emphasize the role of infrastructure. Easterly and Rebelo (1993) find that aggregate public investment does not appear to be a significant determinant of per capital growth, but they do find a strong positive impact associated with public investment in transportation and communication.

Since empirical studies can be distorted by reverse causation, VAR studies attempt to establish the direction of causation. The results produced by this strain of literature are inconclusive. Perotti (2004) explicitly compares public consumption and public investment multipliers and finds that the latter are not more effective than the former in boosting GDP both in the short- and long-run. In addition, he does not find evidence that public investment pays for itself in the long run as the proponents of the "Golden Rule" have argued.

In general, the lack of clear-cut results may not be surprising. Empirical work is complicated by data issues that have to be borne in mind. First, the usual definition of public investment–government gross fixed capital formation–is somewhat narrow in the sense that it does not cover all public spending that adds to a country's productive potential. Current spending on education and health which clearly enhances human capital is a notable missing element. Second, net public investment is the proper indicator of additions to the public capital stock, but data on gross data are more readily available. Third, the data on public capital stock, either in financial or physical terms, would be better for analytical purposes, but they are used only in few studies (although those that produce the strongest positive results).

In this paper we address the issue of public investment in a theoretical model. There are very few papers that explicitly analyze the impact of government investment on macoreconomic dynamics in a micro-founded DSGE model. Notable exceptions are Pappa (2004) and Kumhof and Laxton (2007). However, while in the former the focus is the transmission of fiscal shocks to labor markets, the latter investigates the relationship between government investment and monetary policy.

IV. THE FRAMEWORK

In the following sections, we outline the features of the baseline NAWM model, as discussed in Coenen, McAdam, and Straub (2007), and highlight the changes we have introduced to conducting our analysis[8]. Finally, we also present the calibration of the model.

A. The Model

The NAWM builds on recent advances in developing micro-founded Dynamic Stochastic General Equilibrium (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 a relatively large number of nominal and real frictions in an effort to improve its empirical fit regarding both the domestic and the international dimension.

The baseline version of the NAWM consists of two symmetric countries of different size: the euro area and the United States, the latter representing the rest of the industrialized world. International linkages arise from the trade of goods and international assets, allowing for imperfect exchange-rate pass-through and imperfect risk sharing. In each country, there are four types of economic agents: households, firms, a fiscal and a monetary authority. Extending the setup in Coenen and Straub (2005), the NAWM features two distinct types of households which differ with respect to their ability to participate in asset markets, with one type of household only holding money as opposed to also trading bonds and accumulating physical capital. As a result, also households with limited ability to access asset markets can intertemporally smooth consumption by adjusting their holdings of money. Due to the existence of these two types of households, fiscal policies other than government spending—notably transfers—also have real effects even though both types of households are optimizing subject to intertemporal budget constraints. Further, 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 characterized by sticky nominal wages and indexation, eventually resulting in two separate wage Phillips curves.

In calibrating the behavior of the two types of households, we set the size of the group of households with limited ability to participate in asset markets to one-fourth, in line with the

---

[8] We describe the model in full in Appendix A.

estimates reported in Coenen and Straub (2005), while all other structural parameters are assumed to be identical across households. Moreover, in order to establish a more pronounced 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 constrained households with limited asset-market participation over the unconstrained ones in a proportion of three to one. This also helps to guarantee that the levels of consumption and hours worked are not too dissimilar across households.

Regarding firms, the NAWM distinguishes 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. The intermediate-good producers sell their differentiated outputs in both domestic and foreign markets under monopolistic competition, while the final-good producers operate under perfect competition and take prices as given. It is assumed that the intermediate-good producers set different prices in domestic and foreign markets, by charging a markup over marginal cost but pricing in local currency. In both markets, there is sluggish price adjustment due to staggered price contracts and indexation, yielding two separate price Phillips curves.

The fiscal authority purchases units of the public consumption good and makes transfer payments to the two types of households, in unevenly distributed amounts. These expenses are financed by different types of distortionary taxes, including taxes on consumption spending, labour and capital income, as well as profits. A simple feedback rule is assumed to stabilize the government debt-to-output ratio by appropriately adjusting a suitable fiscal instrument.

Finally, the monetary authority is assumed to follow an inertial Taylor-type interest-rate rule with interest-rate smoothing, which is specified in terms of annual consumer-price inflation and quarterly output growth.

B. Changes to the Baseline Model

Here we briefly outline only those equations of the model that differ from the set up discussed in Coenen, McAdam and Straub (2007). As we discussed earlier, we augment the original model by separating overall public spending into public consumption and public investment. The difference between these two components of public spending lies in the assumption that public investment is productive, in the sense that it constitutes an important factor in the production function of the individual private firm. In contrast, spending on public consumption affects aggregate demand without enhancing the productivity of the private production sector. In particular, each intermediate-good firm f produces its differentiated output using an increasing-returns-to-scale Cobb-Douglas technology,

$$Y_{f,t} = \max \left[z_t\, K_{f,t}^{\alpha_1}\, N_{f,t}^{(1-\alpha_1-\alpha_2)} GK_t^{\alpha_2} - \psi,\, 0 \right],$$

utilizing as inputs homogenous private capital services, $K_{f,t}$, that are rent from the members of household I in fully competitive markets, an index of differentiated labour services, $N_{f,t}$, which

combines household-specific varieties of labour supplied in monopolistically competitive markets, and public capital services GK_t that affect the production of each individual firm in the same way. Public capital increases over time, if public investment is larger than public capital's depreciation rate and the associated investment adjustment costs. We assume that the parametrization of the public investment adjustment costs function and the rate of depreciation are equivalent to the one assumed in Coenen, McAdam and Straub (2007) for the private sector.

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

$$MC_t = \frac{R_{K,t}K_t}{\alpha z_t\, K_t^{\alpha_1}\, N_t^{(1-\alpha_1-\alpha_2)}GK_t^{\alpha_2}}.$$

Relative to Coenen, McAdam and Straub (2007), non-tradable final public goods are divided into two groups–a public consumption good Q_t^{GC} and a public investment good Q_t^{GI}. It is assumed that the final public consumption good is a composite made only of domestic intermediate goods; that is, $Q_t^{GC} = H_t^{GC}$ with

$$H_t^{GC} = \left(\int_0^1 \left(H_{f,t}^{GC} \right)^{1-\frac{1}{\theta}} df \right)^{\frac{\theta}{\theta-1}}.$$

Hence, the optimal demand for each domestic intermediate good f is given by

$$H_{f,t}^{GC} = \left(\frac{P_{H,f,t}}{P_{H,t}} \right)^{-\theta} H_t^{GC},$$

and the price of a unit of the public consumption good is $P_{GC,t} = P_{H,t}$.

Similarly, the non-tradable final public investment good Q_t^{GI} is assumed to be a composite made only of domestic intermediate goods; that is, $Q_t^{GI} = H_t^{GI}$ with

$$H_t^{GI} = \left(\int_0^1 \left(H_{f,t}^{GI} \right)^{1-\frac{1}{\theta}} df \right)^{\frac{\theta}{\theta-1}}.$$

Hence, the optimal demand for each domestic intermediate good f is given by

$$H_{f,t}^{GI} = \left(\frac{P_{H,f,t}}{P_{H,t}} \right)^{-\theta} H_t^{GI},$$

and the price of a unit of the public investment good is $P_{GI,t} = P_{H,t}$.

Aggregating across the three final-good firms, we obtain the following demand for domestic and

foreign intermediate goods f, respectively:

$$H_{f,t} = H_{f,t}^C + H_{f,t}^I + H_{f,t}^{GC} + H_{f,t}^{GI} = \left(\frac{P_{H,f,t}}{P_{H,t}} \right)^{-\theta} H_t,$$

where $H_t = H_t^C + H_t^I + H_t^{GC} + H_t^{GI}$.

Market clearing condition implies that the supply of government consumption goods Q_t^{GC} equals to the demand for government consumption goods GC_t. A similar condition equating $Q_t^{GI} = GI_t$ holds also for government investment. The budget constraint of the fiscal authority will, therefore, distinguish between purchases of the final public consumption good, GC_t, and the final investment good GI_t. In addition, the fiscal authority makes transfer payments TR_t, issues bonds to finance its debt, $R_t^{-1} B_{t+1} - B_t$, earns seigniorage on money holdings, $M_t - M_{t-1}$, and raises taxes with details on the latter given above. The fiscal authority's period-by-period budget constraint then has the following form:

$$P_{GC,t}\, GC_t + P_{GI,t}\, GI_t + TR_t + B_t + M_{t-1}$$

$$= \tau_t^c\, P_{C,t}\, C_t + (\tau_t^n + \tau_t^{wh}) \left(\int_0^{1-\omega} W_{i,t}\, N_{i,t}\, di + \int_{1-\omega}^1 W_{j,t}\, N_{j,t}\, dj \right) + \tau_t^{wf}\, W_t\, N_t$$

$$+ \tau_t^k\, (R_{K,t}\, u_t - (\Gamma_u(u_t) + \delta)\, P_{I,t}\,)\, K_t + \tau_t^d\, D_t + T_t + R_t^{-1} B_{t+1} + M_t,$$

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

The fiscal authority's purchases of the final public consumption good are specified as a fraction of steady-state nominal output, $g_t^C = P_{GC,t} GC_t / P_Y Y$, and are assumed to follow a serially correlated process with mean g^C,

$$g_t^C = (1 - \rho_{gC})\, g^C + \rho_{gC}\, g_{t-1}^C + \varepsilon_{gC,t}.$$

In the same fashion, the fiscal authority's purchases of the final public investment good are specified as a fraction of steady-state nominal output, $g_t^I = P_{GI,t} GI_t / P_Y Y$, and are assumed to follow a serially correlated process with mean g^I,

$$g_t^I = (1 - \rho_{gI})\, g^I + \rho_{gI}\, g_{t-1}^I + \varepsilon_{gI,t}.$$

The imposed market-clearing condition will also change to include both final public goods, implying the following aggregate resource constraint:

$$P_{Y,t}\, Y_t = P_{C,t}\, (C_t + \Gamma_{v,t}) + P_{I,t}\, (I_t + \Gamma_u(u_t)\, K_t) + P_{GC,t}\, GC_t + P_{GI,t}\, GI_t$$

$$+ S_t\, P_{X,t}\, X_t - P_{IM,t} \left(IM_t^C\, \frac{1 - \Gamma_{IM^C}(IM_t^C / Q_t^C)}{\Gamma_{IM^C}^\dagger(IM_t^C / Q_t^C)} + IM_t^I\, \frac{1 - \Gamma_{IM^I}(IM_t^I / Q_t^I)}{\Gamma_{IM^I}^\dagger(IM_t^I / Q_t^I)} \right),$$

where $X_t, P_{xt}, IM_t^C, IM_t^I, P_{IM,t}$ are exports and imports of consumption and investment and their corresponding prices indices. $\Gamma_{v,t}, \Gamma_u(u_t), \Gamma_{IM^C}$ are adjustment costs of transaction, utilization and imports respectively, all defined in the appendix. In the next section, we describe the calibration of the model.

C.   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.[9] For example, the ratios of public consumption to output in the euro area and the United States are set to 0.155 and 0.128, respectively. The ratios of public investment to output in both countries are calibrated to 0.025 and 0.032. 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. 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.[10] Finally, the steady-state ratios of government debt over output are uniformly set equal to 2.40 per quarter, while the dividend income-to-output ratios are assumed to be zero in steady state.

While the calibration of the steady-state ratios has been based on observed data, we proceed by choosing 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), henceforth referred to as SW (2003). Thus, broadly similar values are assigned to those parameters that are common to both models.[11] A notable exception is the inverse of the intertemporal elasticity of substitution, which is raised to a value of 2.00, compared with a value of 1.35 in SW (2003). This modification helps to partly offset the effects induced by the ability of household I to borrow from abroad, which, unless dampened, would lead to excess interest-rate sensitivity of consumption relative to investment.

In calibrating the behavior of the two types of households, we set the size of household J equal to 0.25, in line with the estimates reported in Coenen and Straub (2005). The parameters governing the wage-setting decisions on the part of the two types of 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 SW (2003). Similarly, the markup power of the two households is assumed to be symmetric and equal to 20 percent, reflecting a uniform price elasticity of demand of 6.00 on

---

[9]   The calibrated steady-state ratios are summarized in Table 1.

[10]   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.

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

the part of the intermediate-good producing firms for different varieties as well as for different bundles of labour. Notwithstanding, the profile of wages and hours worked can differ across the two types households because of differences in the households' marginal rate of substitution.

In the baseline calibration of the model the labor share of income is set at 70 percent, the private capital share of income is calibrated at 28.5 percent, and the public capital share of income is calibrated at 1.5 percent.

As regards parameters characterizing the pricing behavior of intermediate-good firms selling their differentiated outputs in domestic markets, we again assign values broadly similar to those reported in SW (2003), with the degree of stickiness and the degree of indexation set 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. In this context, the price elasticity of demand for the differentiated outputs is set equal to 6.00, implying a 20 percent markup over marginal cost in steady state. The fixed cost in production is chosen to ensure zero profits in steady state, and the steady-state productivity level is normalized 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 changes in the terms of trade. 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 closed-economy model of SW (2003).

In calibrating the tax rates we use the data on the tax wedges reported in Coenen, McAdam and Straub (2007). Also, 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 public consumption and the public investment ratios 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.[12]

V. Temporary Shocks to Public Spending

In this section, we are interested in uncovering the differences in the response of macroeconomic aggregates following both, temporary changes in public consumption and public investment, and the corresponding short and long-term spending multipliers. Although, our main objective is to identify the macroeconomic effects of changes in the composition of public spending that are presumingly permanent, the response of macroeconomic aggregates following temporary shocks provide an intuitive starting point for our analysis. Furthermore, the literature is relatively scarce in comparing the macro effects of public investment and public consumption shocks in a DSGE framework (see Perotti, 2004), so the following discussion can also provide a useful benchmark for future analysis.

A. Public Consumption

Figure 3 and 4 depict selected dynamic response functions following a temporary public consumption shock equal to a one-percentage point increase in steady state output. All dynamic responses are shown as percentage-point deviations from steady state.

The behavior of the impulse response functions following a public spending shock are in line with our expectations. An increase in non-productive public spending, and the corresponding expected increase in future taxes generate a negative wealth effect, inducing unconstrained households to reduce consumption and increase labor supply on impact. On the other hand, the rise in aggregate demand triggers an increase in labor demand and real wages, allowing constrained households to increase their consumption on impact, and preventing aggregate consumption from falling.

A central theme in the recent literature on the effects of government spending shock has been indeed the ability of New-Keynesian DSGE models, augmented with a fraction of liquidity-constrained households, to generate a crowding-in in private consumption. Galí and others (2007) demonstrate that if a substantial fraction of households are choosing their consumption path in a "rule-of-thumb" fashion, an increase in government spending can give rise to higher private consumption. Coenen and Straub (2005) estimate, however, that the share of "rule-of-thumb" households in the euro area is lower than the necessary threshold identified in Galí and others (2007). As already suggested by Coenen, McAdam, and Straub (2007), however, the assumption that the unconstrained household can now borrow from abroad provide another

---

[12] 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.

channel which mitigates the negative wealth effect of government spending[13]. Indeed, imports rise strongly following a government spending shock. The rise in imports is partly triggered by the significant improvement in the terms of trade which induces protracted expenditure switching away from domestic towards foreign goods. Thus, the negative wealth effect generated by the government spending shock is partly mitigated by the substitution and wealth effect implied by the improvement in the terms of trade.

The behavior of the rest of the impulse response functions also accord well with intuition. The increase in output following the government consumption shock and the induced increase in both aggregate wage rate and the rental rate of capital feeds into an expansion of marginal cost and inflation. Monetary policy reacts to the build-up of inflationary pressures and output growth by raising the policy rate.

To evaluate rigorously the dynamic properties of alternative public spending the responses of output is suggestive but not enough. What really matters is the response of output per unit of public spending, in other words, the multipliers of government spending. Consequently, we calculate the public consumption multiplier[14], presented in Table 2, at different points of time and find that the short-term public consumption multiplier is higher than one, although it stabilizes at 0.81 in the long-term. These results mirror closely the quantitative estimates, albeit not the dynamic path, of the government consumption multipliers obtained by Perotti (2004), who conducts an empirical investigation of the effects of government spending in five countries–the USA, Germany, England, Canada, and Australia. Perotti estimates that in all countries except the USA, the government consumption multiplier is always positive and quite similar across individual countries—the multiplier ranges from 0.6 to 0.8 one year after the shock, increasing to 0.9 to 1.0 three years following the shock, with maximum achieved around 3–5 years after the shock and ranging between 0.9 and 1.3. In the case of the USA, the multiplier is about twice larger than the rest of the countries at each time horizon.

B.   Public Investment

Figure 3 and 4 also depicts the selected dynamic response functions to a temporary public investment shock equal to a one-percentage point increase in steady-state output. Again, all dynamic responses of variables are shown as percentage-point deviations from steady state.

It is immediately seen that the introduction of public capital in the firm's production function does change the dynamic pattern of the impulse response functions. The increase in public investment yields a pronounced rise in public capital and this has important qualitatively and quantitative implications for the behavior of the rest of the variables in the model. Private consumption now increases immediately after the shock and stays positive for a sustained period of time. The

---

[13]   Of course, increasing the relative share of constrained agents will tilt the results in favor of a more pronounced expansion of overall private consumption.

[14]   The multiplier is defined as the ratio of the cummulative impulse response functions of output and government spending.

negative wealth effect is still operational for the members of household I at the outset of the shock, but this effect wanes later on as it is offset by the increase in private firms' productivity associated with the expansion of public capital. Similarly, while private investment and private capital fall initially just as in the case of a government consumption shock, they expand in the long-term along with the accumulation of public capital and the related increase in the production possibility frontier.

The short-run public investment multiplier is analogous to the short-run public consumption multiplier—it is greater than one. However, in the long-run, the government investment multiplier grows substantially and reaches 2. This model-based finding runs somewhat counter to Perotti (2004), who finds that although the public investment multiplier starts out higher than the public consumption multiplier in the USA, Germany and Canada, it subsequently declines in all countries except Australia. As a result, except in Germany, the public investment multiplier is smaller than the public consumption multiplier at all horizons after the initial impact[15].

What is the economics behind these results and what accounts for the differential effects of public consumption and public investment shocks? Broadly speaking, as government consumption increases, the intertemporal government budget constraint dictates that taxes must increase by the same amount, leading to a fall in private wealth and, consequently, in the consumption of forward-looking economic agents. In contrast, public investment not only increases aggregate demand, but it also raises aggregate supply by enhancing aggregate production and the marginal productivity of labor and private capital. Intuitively, the public investment shock renders the wealth effect less negative or even positive, if the productivity of public capital is high enough. This leads to a smaller decrease or even increase in private consumption. The same logic applies to private investment—as public capital builds up, the productivity of private capital improves, causing a rise in private investment.

Furthermore, productive government spending has also a cost-alleviating effect resulting after a few periods in subdued response of marginal costs. In general, there are two competing forces that influence marginal cost. First, the increased demand for labor and higher real wage resulting from any given rise in aggregate demand generated by a positive shock to government spending will push up firms' marginal cost. However, the addition of productive public investment in firms' production function implies that marginal cost will increase less for any given increase in aggregate demand, as public investment will enter with a negative sign in the equation for marginal cost[16]. This positive aggregate supply effect may, therefore, reduce or, if strong enough, even overturn the aggregate demand effect. The impulse response functions for marginal cost reflect these considerations. While initially its response is quite similar following both shocks,

---

[15]   Note that we focus on the study by Perotti (2004) mainly because he claims that his empirical approach is capable of doing away with a number of problem with existing approaches. However, there is a huge body of empirical literature, including one that uses the production function aproach, which finds significantly positive effects of public investment on economic activity.

[16]   In other words, productive public investment can ultimately be viewed and interpreted as a technology shock to firms' production process.

the gradual build up of public capital forces marginal cost to fall more than in the case of public consumption shock.

The cost alleviating effects of productive public investment are naturally reflected in the more muted response of inflation and the nominal interest rate. The latter implies—given the negative correlation between the real interest rate and consumption growth—that to the extent that higher inflation leads to a higher real interest rate, current consumption must fall[17]. However, as productive public investment induces lower inflation and a less aggressive response of monetary authorities, the resulting rise in the real interest rate is smaller as compared with the case of non-productive government spending. This mechanism further amplifies the positive supply side effects of public investment shock, generating higher private consumption, private investment, output, and public investment multipliers.

C.   Sensitivity Analysis

In this section, we consider the sensitivity of our results to changes in some model parameters of interest. We focus, thereby on the comparison of public consumption and public investment multipliers. The results are reported in Table 2.

First, we test the sensitivity of our results to an increase in labor supply elasticity (the inverse of ζ) from 0.5 to 2.5. There are several channels through an increase in labor supply elasticity is affecting long run multipliers. First, the stronger response in labor supply triggers a rise in the marginal product of capital, making investment more attractive for unconstrained households. Accordingly, the stronger response in hours worked and capital leads to a more pronounced rise in output, generating higher public spending multipliers in both cases. Second, the increase in labour supply elasticity also has dampening effect on the increase in real wages. While this effect has a negative impact on the consumption of constrained households, it also has a cost-alleviating effect on the marginal cost of firms. The latter results in suppressed inflationary pressures in the economy. The moderating effect on inflation—and the resulting less aggressive monetary policy stance—leads, through its impact on unconstrained households, to higher private absorption and stronger spending multipliers than in the baseline scenario.

Second, we exploit the abilities of the model to generate different responses based on the way transfers are distributed among households in the economy. In the baseline, we assumed that transfers are disproportionately (with ratio 3 to 1) paid to household J. Here we reverse somewhat this distributional pattern by assuming that now both household I and household J receive equal payments by the fiscal authorities. This scenario raises the disposable income of household I and dampens the negative wealth effects of public spending on their consumption. Consequently, the consumption of household I is higher than in the baseline case. Of course, there is a countervailing effect on the consumption of household J induced by negative wealth effect due to the decrease in transfer payments. However, owing to the limited ability of constrained agents to smooth consumption, the relative increase in labor supply of constrained households is higher than the

---

[17]   This assumes that the Taylor principle holds.

relative decrease of labor supply of unconstrained households. Accordingly, this experiment is associated with higher public spending multipliers compared to the baseline case.

Third, we study how the increase in asset market participation affects our results. To this end, we calibrate the model by assuming that the share of non-Ricardian agents is reduced from 25 percent to 10 percent. In line with the expectations, the average household in the economy is becoming less prone to consume a certain fraction of its disposable income, which enhances the negative wealth effect of public spending. The resulting lower private absorption is reflected in the smaller multipliers.

Finally, we explore the sensitivity of the multipliers to changes in the policy parameters. In the forth experiment, we assume that the fiscal authorities are more aggressive in their response to public debt in the fiscal rule. Accordingly, output reacts less strongly to the positive aggregate demand shocks, resulting in smaller multipliers. Similarly, in the fifth scenario, more aggressive monetary policy reaction to inflation raises the real interest rate more than in the baseline case, further diminishing the consumption of household I and private investment. The resulting smaller increase in output is also evidenced in the multipliers.

VI. WHAT IS THE IMPACT OF A CHANGE IN THE COMPOSITION OF PUBLIC SPENDING?

In this section, we evaluate the possible implication of a change in the composition of public spending on macroeconomic aggregates in the euro area. As we discussed in the previous sections, the scenario is motivated by the gradual decline of public investment-to-GDP ratio in the euro area, and the corresponding rise of the share of public consumption in aggregate output. Consequently, in what follows, we investigate the macroeconomic impact of a one percentage point increase in public consumption to GDP ratio together with a one percentage point decline in the share of public investment-to-GDP, by holding the share of overall public spending-to-GDP constant. In order to facilitate the intuition behind the results, we also present the macroeconomic impact of separate, permanent changes in the public consumption and public investment share of GDP.

A. Policy Scenario

We present the dynamic path of the selected macro variables in Figure 5 and 6, while the public spending multipliers are depicted in Table 3.

Based on our DSGE model simulations, a change in the composition of public spending in the euro area has a significant negative impact on economic activity. The results are presented in Figure 5. The impact response of the public spending multiplier is around -0.2 percent of steady-state output, while the long-run multiplier is around -0.74 percent. Interestingly, while private investment is increasing on impact, the long-run response is clearly negative in the long-run. Furthermore, we observe a significant and substantial decrease in private consumption, while the initial fall in hours worked is followed by a gradual increase. In a similar vein, the deterioration of the terms of trade is followed by a long-run improvement.

What are the main factors behind these results? To facilitate the intuition, we present in what follows the outcome of the two separate, individual permanent public spending shocks in Figure 6. To ensure the comparison of the two individual public spending shocks, we present in both cases, that is also in the case of public investment shock, the results following a permanent one percentage point *increase* in public spending.[18]

In the scenario presented in Figure 6, a permanent, one percentage point permanent increase in the public consumption to GDP ratio leads on impact to an increase of output by 1.24 percentage points[19]. The main trigger of the output response is again the negative wealth effect induced by the permanent increase in public spending. Obviously, as the shock is permanent, the impact increase in labor supply, and the decrease in consumption are substantial. Furthermore, the increase in labor supply has a permanent, negative effect on real wages. Investment falls initially, but as the increase in labor supply has a positive impact on the marginal product of capital, investment picks up and the long-run response of investment becomes positive. Another interesting result is the u-shaped behavior of the output multiplier following the shock shown in Table 3. This reflects the negative response of investment, and the sharp rise of hours worked on impact. As both private and public capital are state variables, the increase in aggregate demand causes a sharp rise in hours worked. Notice that due to habit persistence, the crowding-out effect of public spending on private consumption is less pronounced on impact and the negative response of consumption peaks after 2 years. Therefore, as the negative response of private consumption starts to kick in, subdued aggregate demand is constraining the rise in hours worked (also reflected by the decline in real wages, although the initial impact is positive). As a result, the output multiplier declines and starts to rise again when investment recovers.

Now turning to the response following a permanent, 1 percentage point increase (decrease) in the public investment to GDP ratio, we observe a remarkable, 1.39 percentage point increase (decrease) in output on impact. Notice that while the increase in public investment pushes aggregate demand up in the economy, it also has a persistent, positive impact on the marginal productivity of labor and private capital. The negative wealth effect induced by the expected future tax increases has, as before, a negative impact on consumption and a positive effect on labor supply. However, the increased productivity of labor has a positive effect on labor demand, causing in equilibrium a persistent increase in real wages. Interestingly, the impact response of investment is even more negative than in the case of a public consumption. This can be explained by the fact that as public capital increases on its transition to the new steady-state, the marginal productivity of private capital rises steadily and gradually, inducing asset holders to postpone investment to the future. This channel is absent following an increase in public consumption, leading private investment fall less on impact, but increase more in the long run.

The latter can also explain the puzzling behavior of private investment following the change

---

[18]   Impulse response functions are approximately symmetric in our analysis, so a negative shock will change the sign but not the magnitude of the response.

[19]   Note that the long-run public consumption multiplier is above one following a permanent public consumption shock as has already been demonstrated by Baxter and King (1993) in the neoclassical model.

in composition of public spending. Owing to the permanent decline in public investment, and the corresponding expected decrease in the marginal productivity in the future, unconstrained households bring forward their investment, which leads to the substantial increase of private investment in the short-run. In the long-run, however, the reduction of the public investment has also a negative long-run impact on private investment.

To summarize, the previous results demonstrate that the observed change in composition of public spending has a significant negative impact on aggregate economic activity. The results are mainly triggered by the long-run decrease in marginal productivity owing to the fall in public investment and through its corresponding effect on private investment and real wages. Although the decline in public investment is partly mitigated by the rise in public consumption, mainly through the positive effect of the latter on labor supply, a fall in long-run output is nevertheless substantial and can reach about 0.74 percent of steady state output. Furthermore, the results indicate, without providing a formal proof in what follows, that as both, consumption and leisure decline, the change in the composition of public spending is not welfare optimal.

VII. Conclusion

Abstracting from distributional effects, there is a broad consensus between policy makers in Europe that public investment is the superior type of spending instrument generally available for the government. Nevertheless, data on public spending indicate a significant and gradual decline in the public investment share of GDP in the recent years, while at the same time in most countries, the public consumption share of GDP has increased or has remained constant. Although, there is a substantial empirical literature that attempt to identify the sources of these developments, there is still a lack of understanding of the nature and the impact of a change in the composition of public spending. To shed some light on these issues from a DSGE perspective, we examined the macroeconomic effects of a change in composition of public spending using a modified version of the NAWM.

To facilitate the discussion, we also discussed the channels through public investment affects macroeconomic aggregates, following both temporary and permanent shocks, and demonstrated the differences to the impact of non-productive public consumption on real activity.

The results indicate that the described changes in fiscal stance can have a significant long-run impact on economic activity. In particular, the long-run response of output, consumption, and real wages are negative. We have further shown that, while investment might experience a boom in the short-run, it will gradually decline in the long-run.

In this sense, the key message of the paper is that the calls for safeguarding public investment in Europe are not without merit, and the recent change in the composition of public spending is deleterious for long-run growth.

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

$$\Gamma_v(v_{h,t}) \;=\; \gamma_{v,1}\, v_{h,t} + \gamma_{v,2}\, v_{ht}^{-1} - 2\,\sqrt{\gamma_{v,1}\,\gamma_{v,2}}, \tag{1}$$

where $\gamma_{v,1}, \gamma_{v,2} > 0$ (cf. Schmitt-Grohé and Uribe, 2006).

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

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

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

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

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

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

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,

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

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: THE NEW-AREA WIDE MODEL

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, '*'.[20]

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.[21]

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 $B_{i,t+1}^F$,

---

[20]   See Coenen, McAdam, and Straub (2005) for a more detailed description of the model.

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

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

$$E_t \left[\sum_{k=0}^{\infty} \beta^k \left(\frac{1}{1-\sigma} \left(C_{i,t+k} - \kappa \, C_{I,t+k-1} \right)^{1-\sigma} - \frac{1}{1+\zeta} \left(N_{i,t+k} \right)^{1+\zeta} \right) \right], \tag{5}$$

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:

$$\left(1 + \tau_t^C + \Gamma_v(v_{i,t}) \right) P_{C,t} \, C_{i,t} + P_{I,t} \, I_{i,t} \tag{6}$$

$$+ R_t^{-1} B_{i,t+1} + \left((1 - \Gamma_{BF}(B_t^F)) R_{F,t} \right)^{-1} S_t \, B_{i,t+1}^F + M_{i,t} + \Xi_{i,t} + \Phi_{i,t}$$

$$= \left(1 - \tau_t^N - \tau_t^{Wh} \right) W_{i,t} \, N_{i,t} + \left(1 - \tau_t^K \right) \left(R_{K,t} \, u_{i,t} - \Gamma_u(u_{i,t}) P_{I,t} \right) K_{i,t}$$

$$+ \tau_t^K \, \delta \, P_{I,t} \, K_{i,t} + \left(1 - \tau_t^D \right) D_{i,t} + TR_{i,t} - T_{i,t} + B_{i,t} + S_t \, B_{i,t}^F + M_{i,t-1},$$

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, $\Gamma_v(v_{i,t})$, which depends on consumption-based velocity, $v_{i,t} = (1 + \tau_t^C) P_{C,t} C_{i,t} / M_{i,t}$; that is, the inverse of the household member's money-to-consumption ratio. Similarly, $\Gamma_{BF}(B_t^F)$ 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 $\Xi_{i,t}$.[22] As regards the provision of effective capital services, varying the intensity of capital utilisation is subject to a proportional cost $\Gamma_u(u_{i,t})$.

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 $D_{i,t}$.[23] Here, for simplicity, we assume that the utilisation cost of physical capital and physical capital depreciation are exempted from taxation. τ_t^{Wh} is the additional pay-roll tax rate levied on

---

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

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

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.[24] As a result, all household members will choose identical allocations in equilibrium.[25]

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

$$K_{i,t+1} = (1-\delta)\,K_{i,t} + (1 - \Gamma_I(I_{i,t}/I_{i,t-1}))\,I_{i,t}, \tag{7}$$

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.

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 (6) and the capital accumulation equation (7), respectively, the first-order conditions for maximising the household member's lifetime utility function (5) with respect to $C_{i,t}$, $I_{i,t}$, $K_{i,t+1}$, $u_{i,t}$, $B_{i,t+1}$, $B^F_{i,t+1}$ and $M_{i,t}$, are given by:

$$\Lambda_{i,t} = \frac{(C_{i,t} - \kappa\,C_{I,t-1})^{-\sigma}}{1 + \tau^C_t + \Gamma_v(v_{i,t}) + \Gamma'_v(v_{i,t})\,v_{i,t}}, \tag{8}$$

$$\frac{P_{I,t}}{P_{C,t}} = Q_{i,t}\left(1 - \Gamma_I(I_{i,t}/I_{i,t-1}) - \Gamma'_I(I_{i,t}/I_{i,t-1})\,I_{i,t}\right) \tag{9}$$

$$+ \beta\,E_t\left[\frac{\Lambda_{i,t+1}}{\Lambda_{i,t}}\,Q_{i,t+1}\,\Gamma'_I(I_{i,t+1}/I_{i,t})\,\frac{I^2_{i,t+1}}{I_{i,t}}\right],$$

$$Q_{i,t} = \beta\,E_t\left[\frac{\Lambda_{i,t+1}}{\Lambda_{i,t}}\left((1-\delta)\,Q_{i,t+1}\right.\right. \tag{10}$$

$$\left.\left. + (1 - \tau^K_{t+1})\,\frac{R_{K,t+1}}{P_{C,t+1}}\,u_{i,t+1} + \left(\tau^K_{t+1}\,\delta - (1 - \tau^K_{t+1})\,\Gamma_u(u_{i,t+1})\right)\frac{P_{I,t+1}}{P_{C,t+1}}\right)\right],$$

$$R_{K,t} = \Gamma'_u(u_{i,t})\,P_{I,t}, \tag{11}$$

$$\beta\,R_t\,E_t\left[\frac{\Lambda_{i,t+1}}{\Lambda_{i,t}}\,\frac{P_{C,t}}{P_{C,t+1}}\right] = 1, \tag{12}$$

---

[24] The existence of state-contingent securities is assumed for analytical convenience and renders the model tractable under staggered wage setting with household members supplying differentiated labour services.

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

$$\beta \left(1 - \Gamma_{B^F}(B_t^F)\right) R_{F,t} \, \mathrm{E}_t \left[\frac{\Lambda_{i,t+1}}{\Lambda_{i,t}} \frac{P_{C,t}}{P_{C,t+1}} \frac{S_{t+1}}{S_t}\right] = 1, \tag{13}$$

$$\beta \, \mathrm{E}_t \left[\frac{\Lambda_{i,t+1}}{\Lambda_{i,t}} \frac{P_{C,t}}{P_{C,t+1}}\right] = 1 - \Gamma'_v(v_{i,t}) \, v_{i,t}^2. \tag{14}$$

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.[26]

Combining the first-order conditions with respect to the holdings of domestic and internationally traded bonds, (12) and (13), 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 $N_{i,t}$ in monopolistically competitive markets. We assume that the wages for the differentiated labour services, $W_{i,t}$, 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 $\tilde{W}_{I,t} = \tilde{W}_{i,t}$. Those members that do not receive permission are allowed to adjust it according to the following scheme:

$$W_{i,t} = \left(\frac{P_{C,t-1}}{P_{C,t-2}}\right)^{\chi_I} \pi_C^{1-\chi_I} W_{i,t-1}, \tag{15}$$

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 (5), taking into account the indexation scheme (15) 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

---

[26] Notice that the first-order condition (11) implies that the intensity of capital utilisation is identical across household members; that is, $u_{i,t} = u_t$.

period t:

$$E_t \left[\sum_{k=0}^{\infty} (\xi_I \beta)^k \left(\Lambda_{i,t+k} \left(1 - \tau_{t+k}^N - \tau_{t+k}^{W_h} \right) \frac{\tilde{W}_{I,t}}{P_{C,t+k}} \left(\frac{P_{C,t+k-1}}{P_{C,t-1}} \right)^{\chi_I} \pi_C^{(1-\chi_I)k} \right. \right. \tag{16}$$

$$\left. \left. - \frac{\eta_I}{\eta_I - 1} (N_{i,t+k})^\zeta \right) N_{i,t+k} \right] = 0.$$

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,[27] reflecting the degree of monopoly power on the part of the household members; that is,

$$(1 - \tau_t^N - \tau_t^{W_h}) \frac{\tilde{W}_{I,t}}{P_{C,t}} = -\frac{\eta_I}{\eta_I - 1} \frac{\Delta_{i,t}}{\Lambda_{i,t}}. \tag{17}$$

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.

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:

$$(1 + \tau_t^C + \Gamma_v(v_{j,t})) P_{C,t} C_{j,t} + M_{j,t} \tag{18}$$
$$= (1 - \tau_t^N - \tau_t^{W_h}) W_{j,t} N_{j,t} + TR_{j,t} - T_{j,t} + M_{j,t-1} + \Phi_{j,t}$$

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

Defining $\Lambda_{j,t}/P_{C,t}$ as the Lagrange multiplier associated with the budget constraint (18), the first-order conditions for maximising the household members' lifetime utility with respect to $C_{j,t}$

---

[27] 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.

and $M_{j,t}$ are given by:

$$\Lambda_{j,t} = \frac{(C_{j,t} - \kappa\, C_{J,t-1})^{-\sigma}}{1 + \tau_t^C + \Gamma_v(v_{j,t}) + \Gamma_v'(v_{j,t})\, v_{j,t}}, \tag{19}$$

$$\beta\, \mathrm{E}_t \left[\frac{\Lambda_{j,t+1}}{\Lambda_{j,t}} \frac{P_{C,t}}{P_{C,t+1}} \right] = 1 - \Gamma_v'(v_{j,t})\, v_{j,t}^2, \tag{20}$$

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.

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.

Intermediate-Good Firms

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

$$Y_{f,t} = \max \left[z_t\, K_{f,t}^\alpha\, N_{f,t}^{1-\alpha} - \psi,\, 0 \right], \tag{21}$$

utilising as inputs homogenous capital services, $K_{f,t}$, that are rented 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.[28]

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

---

[28]   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.

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 (21). Here, $\tau_t^{W_f}$ denotes the payroll tax rate levied on wage payments (representing the firm's contribution to social security).

Defining as $MC_{f,t}$ the Lagrange multiplier associated with the technology constraint (21), 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

$$MC_t = \frac{1}{z_t \alpha^\alpha (1 - \alpha)^{1-\alpha}} (R_{K,t})^\alpha ((1 + \tau_t^{W_f}) W_t)^{1-\alpha}. \tag{22}$$

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,

$$N_{f,t} = \left((1 - \omega)^{\frac{1}{\eta}} \left(N_{f,t}^I \right)^{1-\frac{1}{\eta}} + \omega^{\frac{1}{\eta}} \left(N_{f,t}^J \right)^{1-\frac{1}{\eta}} \right)^{\frac{\eta}{\eta-1}}, \tag{23}$$

where the parameter $\eta > 1$ denotes the intratemporal elasticity of substitution between the two household-specific bundles of labour services.[29]

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:

$$N_{f,t}^I = \left(\left(\frac{1}{1-\omega} \right)^{\frac{1}{\eta_I}} \int_0^{1-\omega} \left(N_{f,t}^i \right)^{1-\frac{1}{\eta_I}} di \right)^{\frac{\eta_I}{\eta_I-1}}, \qquad N_{f,t}^J = \left(\left(\frac{1}{\omega} \right)^{\frac{1}{\eta_J}} \int_{1-\omega}^1 \left(N_{f,t}^j \right)^{1-\frac{1}{\eta_J}} dj \right)^{\frac{\eta_J}{\eta_J-1}}, \tag{24}$$

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 (24). This yields the following demand functions

---

[29] In principle, the two household-specific bundles of labour services could be distinguished by differences in skill levels across households, resulting in a larger dispersion of wage income which may ultimately provide a rationale for the existence of liquidity constraints on the part of the low-income household.

for labour varieties i and j:

$$N_{f,t}^i = \frac{1}{1-\omega}\left(\frac{W_{i,t}}{W_{I,t}}\right)^{-\eta_I} N_{f,t}^I, \qquad N_{f,t}^j = \frac{1}{\omega}\left(\frac{W_{j,t}}{W_{J,t}}\right)^{-\eta_J} N_{f,t}^J, \qquad (25)$$

where $W_{I,t}$ and $W_{J,t}$ are the associated 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 $N_{f,t}^I$ and $N_{f,t}^J$ that minimise $W_{I,t} N_{f,t}^I + W_{J,t} N_{f,t}^J$ subject to aggregation constraint (23). This yields the following demand functions for the household-specific labour bundles:

$$N_{f,t}^I = (1-\omega)\left(\frac{W_{I,t}}{W_t}\right)^{-\eta} N_{f,t}, \qquad N_{f,t}^J = \omega\left(\frac{W_{J,t}}{W_t}\right)^{-\eta} N_{f,t}, \qquad (26)$$

where W_t is the associated aggregate 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:

$$N_t^i = \int_0^1 N_{f,t}^i df = \frac{1}{1-\omega}\left(\frac{W_{i,t}}{W_{I,t}}\right)^{-\eta_I} N_t^I, \qquad N_t^j = \int_0^1 N_{f,t}^j df = \frac{1}{\omega}\left(\frac{W_{j,t}}{W_{J,t}}\right)^{-\eta_J} N_t^J. \quad (27)$$

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 $\tilde{P}_{H,t} = \tilde{P}_{H,f,t}$ and $\tilde{P}_{X,t} = \tilde{P}_{X,f,t}$, depending on the market of destination. Those firms which do not receive permission are allowed to adjust their prices according to the following schemes:

$$P_{H,f,t} = \left(\frac{P_{H,t-1}}{P_{H,t-2}}\right)^{\chi_H} \pi_H^{1-\chi_H} P_{H,f,t-1}, \qquad P_{X,f,t} = \left(\frac{P_{X,t-1}}{P_{X,t-2}}\right)^{\chi_X} \pi_X^{1-\chi_X} P_{X,f,t-1}, \qquad (28)$$

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,

$$\mathrm{E}_t \left[\sum_{k=0}^{\infty} \Lambda_{I,t,t+k} \left(\xi_H^k \, D_{H,f,t+k} + \xi_X^k \, D_{X,f,t+k} \right) \right], \qquad (29)$$

subject to the price-indexation schemes (28) 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 $D_{H,f,t} = P_{H,f,t} \, H_{f,t} - MC_t \, H_{f,t}$ and $D_{X,f,t} = S_t \, P_{X,f,t} \, X_{f,t} - MC_t \, X_{f,t}$ are period-t nominal profits (net of fixed cost) yielded in domestic and foreign markets, 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:

$$\mathrm{E}_t \left[\sum_{k=0}^{\infty} \xi_H^k \, \Lambda_{I,t,t+k} \left(\tilde{P}_{H,t} \left(\frac{P_{H,t+k-1}}{P_{H,t-1}} \right)^{\chi_H} \pi_H^{(1-\chi_H)k} - \frac{\theta}{\theta-1} \, MC_{t+k} \right) H_{f,t+k} \right] = 0. \qquad (30)$$

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.[30]

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

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,

$$Q_t^C = \left(\nu_C^{\frac{1}{\mu_C}} \left(H_t^C \right)^{1-\frac{1}{\mu_C}} + (1-\nu_C)^{\frac{1}{\mu_C}} \left((1 - \Gamma_{IM^C}(IM_t^C/Q_t^C)) \, IM_t^C \right)^{1-\frac{1}{\mu_C}} \right)^{\frac{\mu_C}{\mu_C-1}}, \qquad (31)$$

where the parameter $\mu_C > 1$ denotes the intratemporal elasticity of substitution between the

---

[30] 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.

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, $\Gamma_{IM^C}(IM_t^C/Q_t^C)$, 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.[31]

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

$$H_t^C = \left(\int_0^1 \left(H_{f,t}^C \right)^{1-\frac{1}{\theta}} df \right)^{\frac{\theta}{\theta-1}}, \qquad IM_t^C = \left(\int_0^1 \left(IM_{f*,t}^C \right)^{1-\frac{1}{\theta^*}} df^* \right)^{\frac{\theta^*}{\theta^*-1}}, \qquad (32)$$

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 (32). This yields the following demand functions for the domestic and foreign intermediate goods f and f^*:

$$H_{f,t}^C = \left(\frac{P_{H,f,t}}{P_{H,t}} \right)^{-\theta} H_t^C, \qquad IM_{f*,t}^C = \left(\frac{P_{IM,f*,t}}{P_{IM,t}} \right)^{-\theta^*} IM_t^C, \qquad (33)$$

where $P_{H,t}$ and $P_{IM,t}$ are the aggregate price indexes for the bundles of domestic and foreign intermediate goods, 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 (31). This yields the following demand functions for the intermediate-good bundles:

$$H_t^C = \nu_C \left(\frac{P_{H,t}}{P_{C,t}} \right)^{-\mu_C} Q_t^C, \qquad (34)$$

$$IM_t^C = (1 - \nu_C) \left(\frac{P_{IM,t}}{P_{C,t} \Gamma_{IM^C,t}^\dagger} \right)^{-\mu_C} \frac{Q_t^C}{1 - \Gamma_{IM^C}(IM_t^C/Q_t^C)}, \qquad (35)$$

---

[31] While our treatment of the adjustment cost as being external to the firm would formally involve assuming the existence of a large number of firms with appropriate adjustments in notation (see, e.g., Bayoumi, Laxton and Pesenti, 2004), we abstract from these adjustments for ease of exposition.

where

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

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,

$$Q_t^I = \left(\nu_I^{\frac{1}{\mu_I}} \left(H_t^I \right)^{1-\frac{1}{\mu_I}} + (1 - \nu_I)^{\frac{1}{\mu_I}} \left((1 - \Gamma_{IM^I}(IM_t^I/Q_t^I)) IM_t^I \right)^{1-\frac{1}{\mu_I}} \right)^{\frac{\mu_I}{\mu_I-1}}, \qquad (36)$$

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.[32]

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 $H_{f,t}^G = \left(P_{H,f,t}/P_{H,t} \right)^{-\theta} H_t^G$ 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:

$$H_{f,t} = H_{f,t}^C + H_{f,t}^I + H_{f,t}^G = \left(\frac{P_{H,f,t}}{P_{H,t}} \right)^{-\theta} H_t, \qquad (37)$$

$$IM_{f*,t} = IM_{f*,t}^C + IM_{f*,t}^I = \left(\frac{P_{IM,f*,t}}{P_{IM,t}} \right)^{-\theta^*} IM_t, \qquad (38)$$

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

---

[32] 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.

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, $P_{IM,f*,t} = P^*_{X,f*,t}$ ($P_{IM,t} = P^*_{X,t}$).

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:

$$P_{G,t} G_t + TR_t + B_t + M_{t-1} \tag{39}$$
$$= \tau_t^C P_{C,t} C_t + (\tau_t^N + \tau_t^{W_h}) \left(\int_0^{1-\omega} W_{i,t} N_{i,t} \, di + \int_{1-\omega}^1 W_{j,t} N_{j,t} \, dj \right) + \tau_t^{W_f} W_t N_t$$
$$+ \tau_t^K \left(R_{K,t} u_t - (\Gamma_u(u_t) + \delta) P_{I,t} \right) K_t + \tau_t^D D_t + T_t + R_t^{-1} B_{t+1} + M_t,$$

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 $tr_t = (1 - \rho_{tr}) tr + \rho_{tr} tr_{t-1} + \varepsilon_{tr,t}$.

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 are constant, $\tau_t^X = \tau^X$, unless otherwise stated. The fiscal rule applied in the paper, which ensures equilibrium determinacy of the model is described in the main text.

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,

$$R_t^4 = \phi_R R_{t-1}^4 + (1 - \phi_R) \left[R^4 + \phi_\Pi \left(\frac{P_{C,t}}{P_{C,t-4}} - \Pi \right) \right] + \phi_{g_Y} \left(\frac{Y_t}{Y_{t-1}} - g_Y \right) + \varepsilon_{R,t}, \tag{40}$$

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.

Aggregation and Aggregate Resource Constraint

The model is closed by imposing market-clearing conditions, formulating the aggregate resource constraint and stating the law of motion for the domestic holdings of international assets.

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 (15) and equation (16), respectively, the wage index $W_{I,t}$ evolves according to

$$W_{I,t} = \left((1 - \xi_I)(\tilde{W}_{I,t})^{1-\eta_I} + \xi_I \left(\left(\frac{P_{C,t-1}}{P_{C,t-2}} \right)^{\chi_I} \pi_C^{1-\chi_I} W_{I,t-1} \right)^{1-\eta_I} \right)^{\frac{1}{1-\eta_I}}. \quad (41)$$

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 (28) and equation (30), respectively, the aggregate price index $P_{H,t}$ evolves according to

$$P_{H,t} = \left((1 - \xi_H)(\tilde{P}_{H,t})^{1-\theta} + \xi_H \left(\left(\frac{P_{H,t-1}}{P_{H,t-2}} \right)^{\chi_H} \pi_H^{1-\chi_H} P_{H,t-1} \right)^{1-\theta} \right)^{\frac{1}{1-\theta}}. \quad (42)$$

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

Aggregate Resource Constraint and Net Foreign Assets

Imposing market-clearing conditions[33] implies the following aggregate resource constraint:

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

$$- P_{IM,t} \left(IM_t^C \frac{1 - \Gamma_{IM^C}(IM_t^C/Q_t^C)}{\Gamma_{IM^C}^\dagger(IM_t^C/Q_t^C)} + IM_t^I \frac{1 - \Gamma_{IM^I}(IM_t^I/Q_t^I)}{\Gamma_{IM^I}^\dagger(IM_t^I/Q_t^I)} \right), \quad (43)$$

where $\Gamma_{v,t} = \int_0^{1-\omega} \Gamma_v(v_{i,t}) C_{i,t} \, di + \int_{1-\omega}^1 \Gamma_v(v_{j,t}) C_{j,t} \, dj$ measures the aggregate transaction costs

---

[33] See Coenen, McAdam and Straub (2005) for details.

of households.

The domestic holdings of internationally traded bonds (that is, the home country's (net) foreign assets, denominated in foreign currency)[34] evolve according to

$$R_{F,t}^{-1} B_{t+1}^F \;=\; B_t^F + \frac{TB_t}{S_t}, \tag{44}$$

where $TB_t = S_t\, P_{X,t}\, X_t - P_{IM,t}\, IM_t$ is the home country's trade balance, and $ToT_t = P_{IM,t}/S_t\, P_{X,t}$ denotes the domestic terms of trade.

---

[34] 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.

Figure 1. Public Investment in EU-12 and United States, 1970-2005
(In percent of GDP)
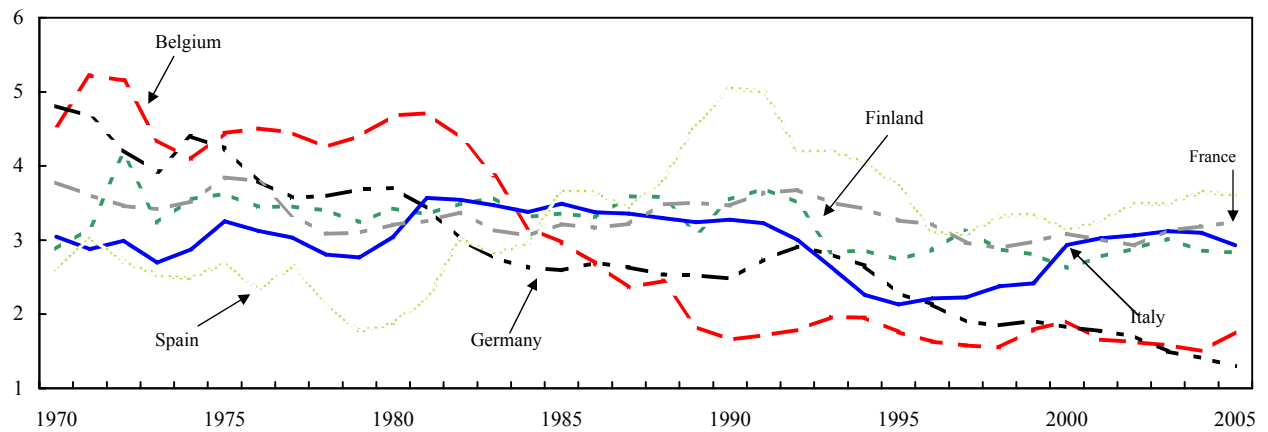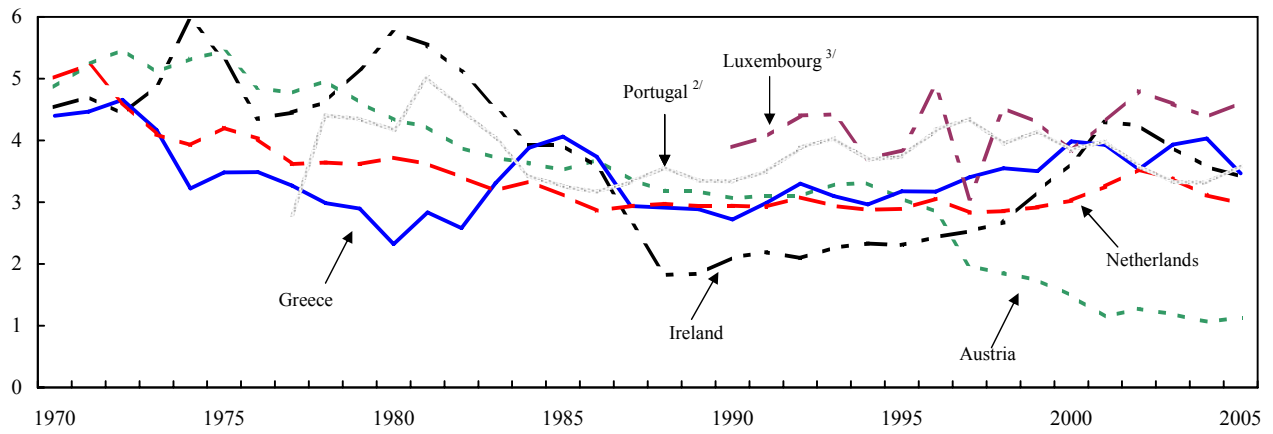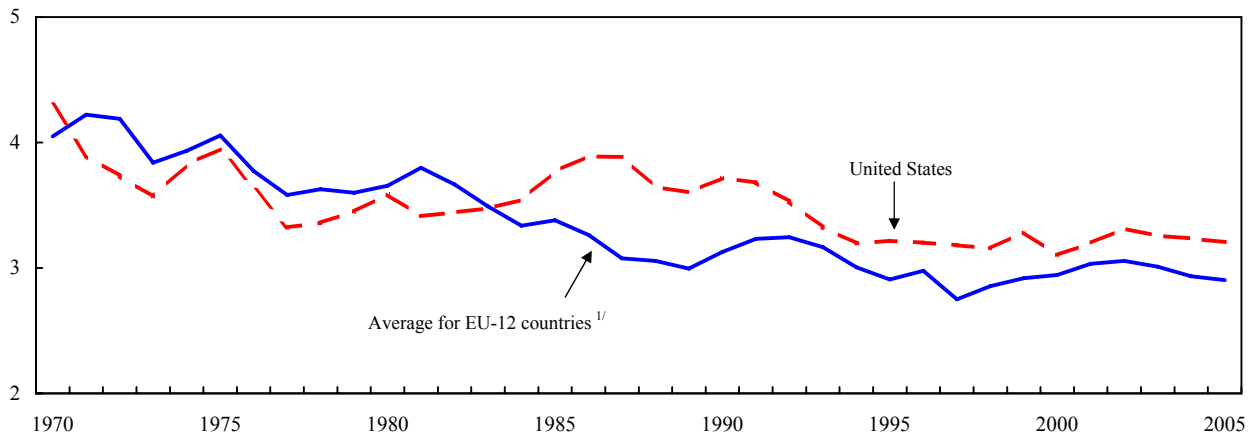
Note: Public investment is computed as government fixed capital formation from the OECD database.
1/ Unweighted average for Austria, Belgium, Greece, Finland, France, Germany, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain.
2/ Data for Portugal is available only from 1990.
3/ Data for Luxembourg is available only from 1977.

Figure 2. Public Consumption in EU-12 and United States, 1970-2005
(In percent of GDP)

Average for EU-12 countries [1]

United States

Netherlands

Austria

Ireland

Portugal

Greece

Luxembourg

France

Belgium

Finland

Italy
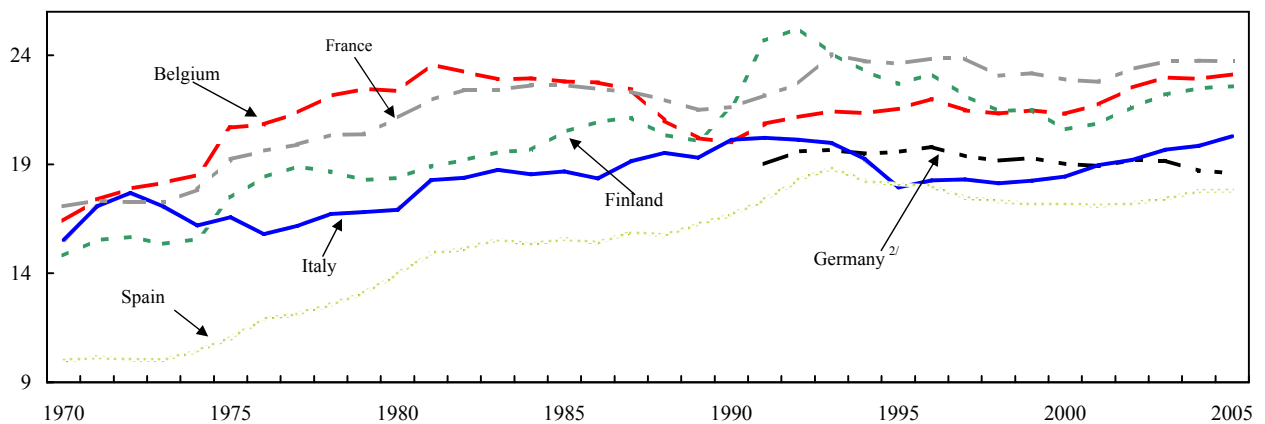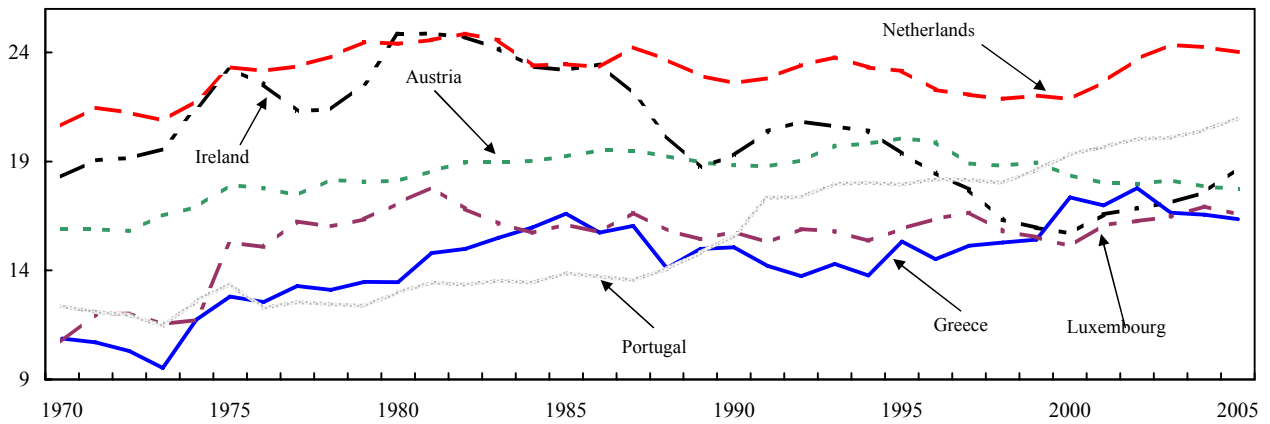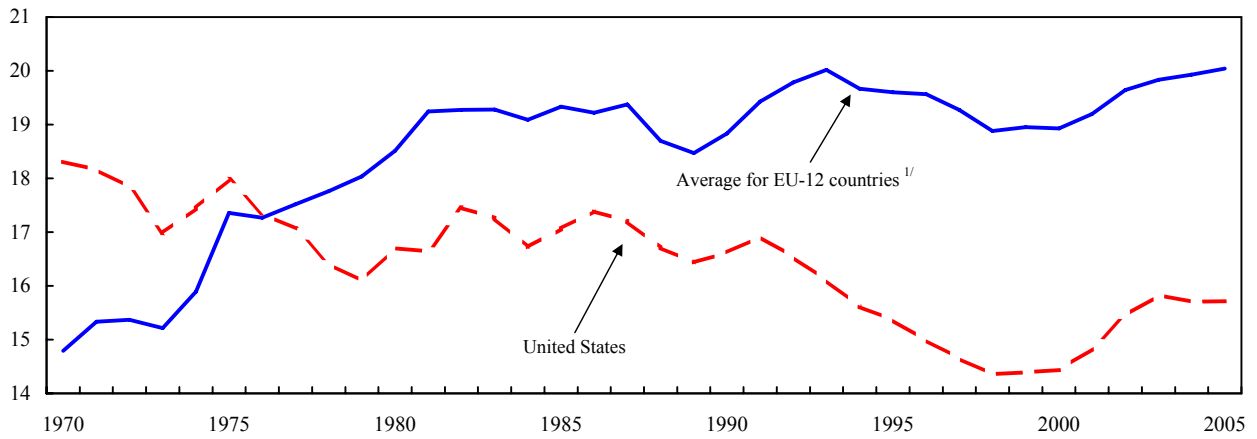
Germany [2]

Spain

Note: Public consumption is computed as government final consumption expenditure from the OECD database.
1/ Unweighted average for Austria, Belgium, Greece, Finland, France, Germany, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain.
2/ Data for Germany is available only from 1990.

Figure 3. Dynamic Responses to Transitory Public Consumption and Public Investment Shocks
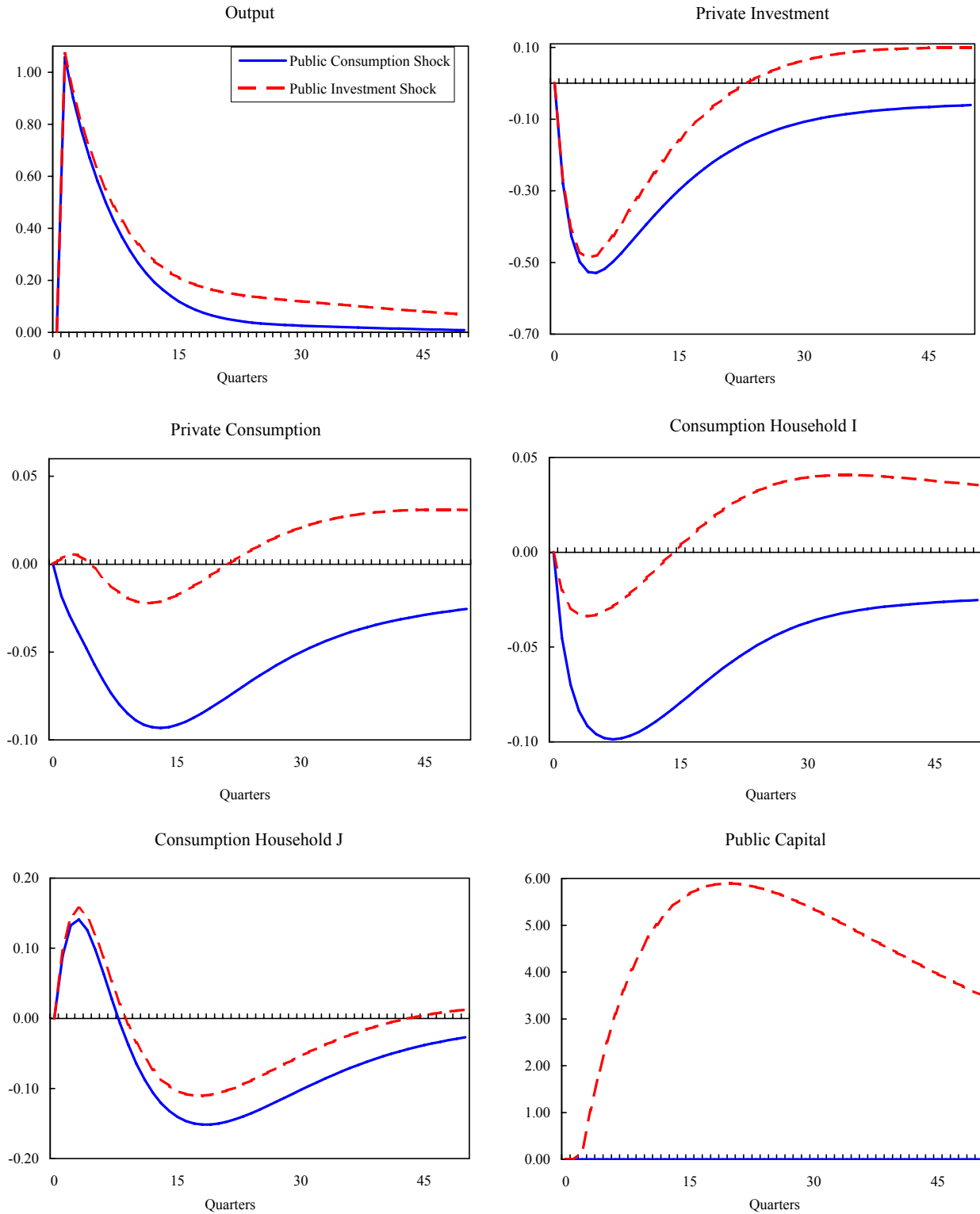
Source: Authors' calculations.
Note: For the baseline version of the model, this figure depicts the dynamic responses of selected variables to persistent government investment and government consumption shocks equal to an one-percent increase in steady-state output. All dynamic responses are reported as percentage-point deviations from steady state.

Figure 4. Dynamic Responses to Transitory Public Consumption and Public Investment Shocks

Source: Authors' calculations.
Note: For the baseline version of the model, this figure depicts the dynamic responses of selected variables to persistent government investment and government consumption shocks equal to an one-percent increase in steady-state output. All dynamic responses are reported as percentage-point deviations from steady state.

Figure 5. Dynamic Responses to Joint Permanent Public Consumption and Public Investment Shocks
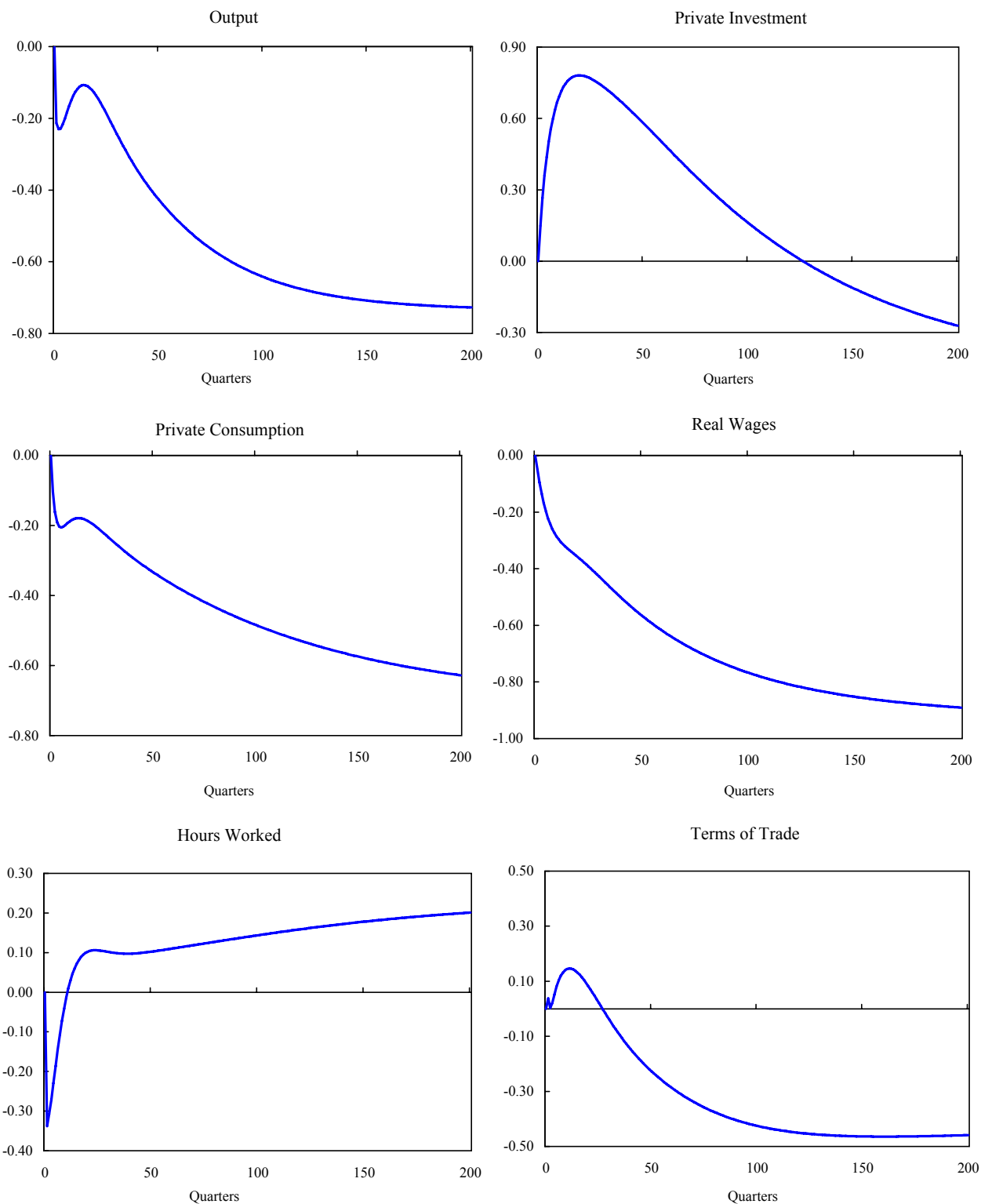
Output

Private Investment

Private Consumption

Real Wages

Hours Worked

Terms of Trade

Source: Authors' calculations.

Note: For the baseline version of the model, this figure depicts the dynamic responses of selected variables to joint permanent government investment and government consumotion shocks equal to an one-percent increase in steady-state output. All dynamic responses are reported as percentage-point deviations from steady state.

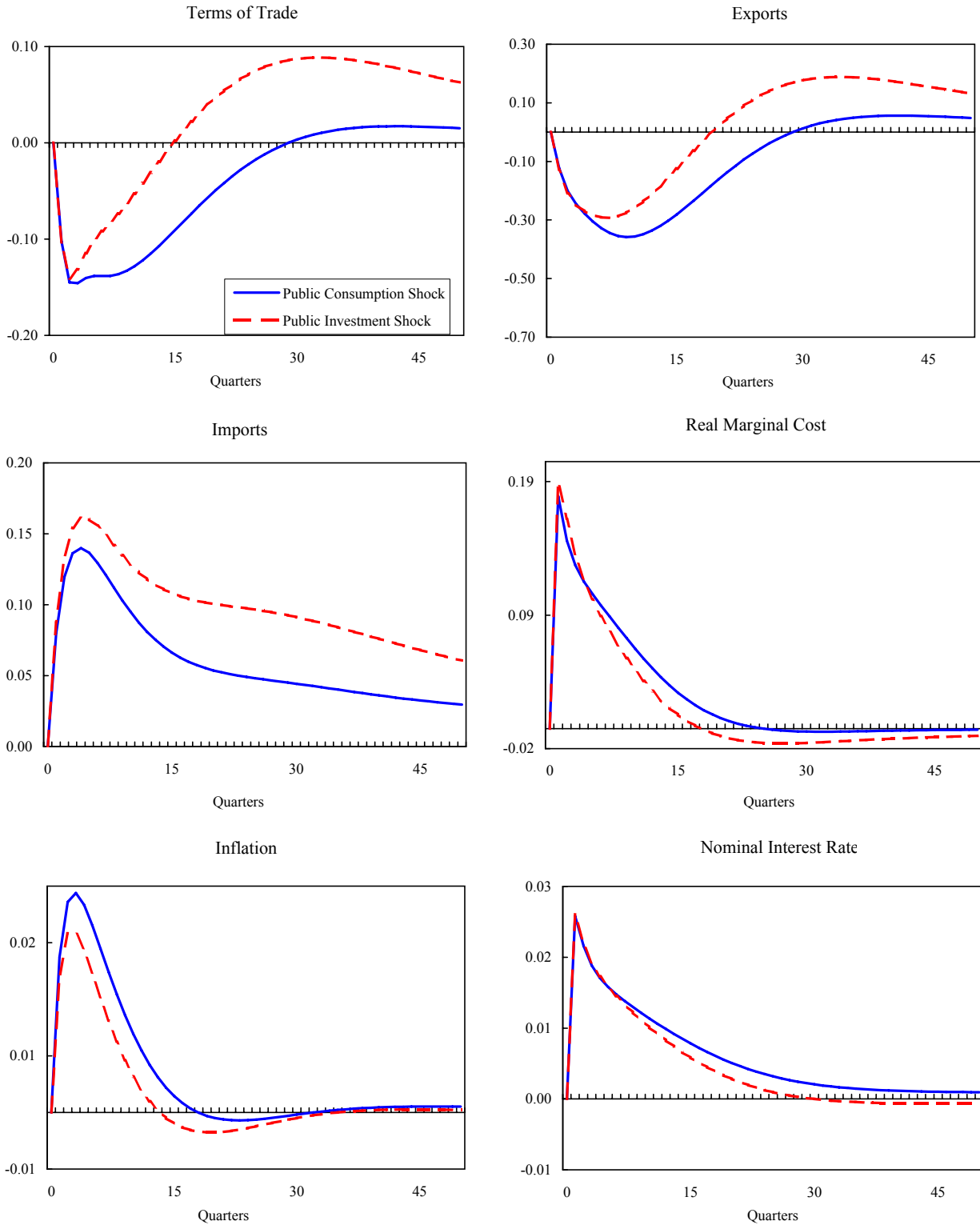## Figure 6. Dynamic Responses to Permanent Public Consumption and Public Investment Shocks

Source: Authors' calculations.
Note: For the baseline version of the model, this figure depicts the dynamic responses of selected variables to permanent government investment and government consumption shocks equal to an one-percent increase in steady-state output. All dynamic responses are reported as percentage-point deviations from steady state.
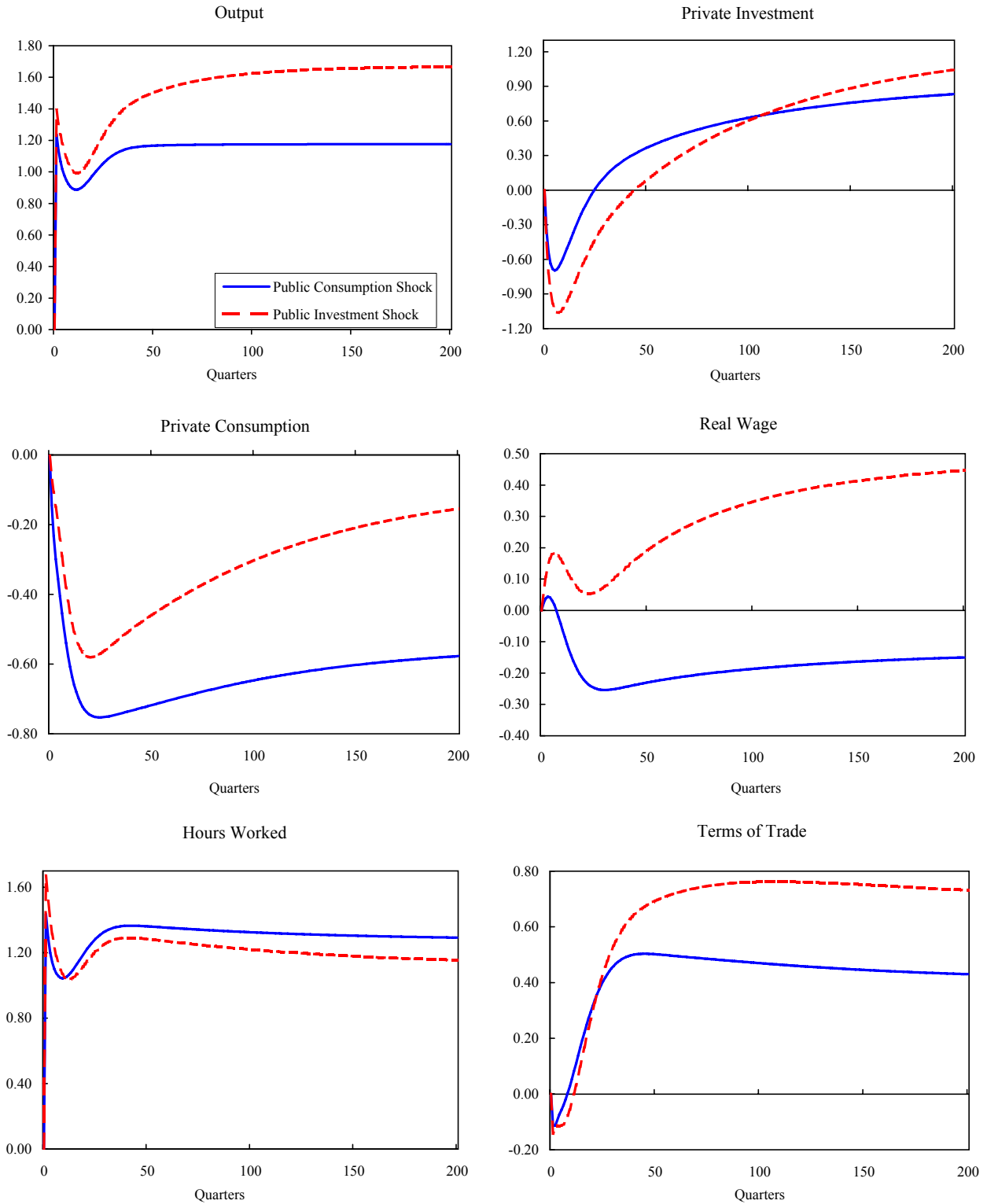
Table 1. Steady-State Ratios

Ratios	Value		Description
	Euro Area	USA	
$P_C C/P_Y Y$	0.60	0.62	Private consumption-to-output ratio
$P_I C/P_Y Y$	0.22	0.22	Private investment-to-output ratio
$P_G G^C/P_Y Y$	0.155	0.128	Public consumption-to-output ratio
$P_G G^I/P_Y Y$	0.025	0.032	Public investment-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/PC_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	Divident 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 ratios of the narrow monetary agregate 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 Scmidt-Grohe and Uribe (2005).

Table 2: Sensitivity Analysis of the Public Consumption and Public Investment
Multipliers (periods after the temporary shock)

A. Baseline

	2	4	8	20	Long-run
Public Consumption Multiplier	1.058	1.010	0.940	0.810	0.790
Public Investment Multiplier	1.072	1.036	0.990	0.960	1.430

B. Labor Supply Elasticity equal to 2.5 (0.5 in baseline)

	2	4	8	20	Long-run
Public Consumption Multiplier	1.068	1.030	0.990	0.950	1.050
Public Investment Multiplier	1.073	1.037	0.993	0.966	1.437

C. Equal Transfer Distribution (in baseline 3 to 1 in favor of H/H J)

	2	4	8	20	Long-run
Public Consumption Multiplier	1.059	1.012	0.944	0.821	0.820
Public Investment Multiplier	1.073	1.037	0.992	0.968	1.436

D. Share of Households J equal to 0.1 (0.25 in baseline)

	2	4	8	20	Long-run
Public Consumption Multiplier	1.048	0.995	0.926	0.800	0.770
Public Investment Multiplier	1.063	1.022	0.976	0.950	1.410

E. More Aggressive Fiscal Rule

	2	4	8	20	Long-run
Public Consumption Multiplier	1.052	1.000	0.929	0.805	0.750
Public Investment Multiplier	1.066	1.026	0.978	0.951	1.387

F. More Aggressive Monetary Rule

	2	4	8	20	Long-run
Public Consumption Multiplier	1.034	0.972	0.891	0.760	0.749
Public Investment Multiplier	1.055	1.008	0.954	0.922	1.398

Table 3: Public Consumption and Public Investment Multipliers
(periods after the permanent shock)

A. Baseline

	2	4	8	20	Long-run
Public Consumption Multiplier	1.239	1.066	0.924	0.973	1.177
Public Investment Multiplier	1.393	1.236	1.055	1.102	1.670

B. Policy Scenario

	2	4	8	20	Long-run
Public Spending Multiplier	-0.214	-0.229	-0.166	-0.128	-0.736

References

Aschauer, D., 1989a, "Is Public Expenditure Productive?" *Journal of Monetary Economics*, Vol. 23 (March), pp. 177-200.

Aschauer, D., 1989b, "Public Investment and Productivity Growth in the Group of Seven," *Economic Perspectives*, Vol. 13 (September/October), pp. 17-25.

Baxter, M. and R. King, 1993, "Fiscal Policy in a General Equilibrium", *American Economic Review,* Vol. 83 (June), pp. 313-334.

Calderon, C. and L. Serven, 2003, "The Output Cost of Latin America's Infrastructure Gap," in *The Limits of Stabilization-Infarstructure, Public Deficits, and Growth in Latin America*, ed. by William Easterly and Serven, Washington, World Bank.

Coenen, G. and Roland Straub, 2005, "Does Government Spending Crowd in Private Consumption? Theory and Empirical Evidence for the Euro Area", *International Finance*, 8, pp. 435-70.

Coenen, G., P. McAdam and R. Straub, 2007, "Tax Reform and Labour-Market Performance in the Euro Area: A Simulation-Based Analysis Using the New Area-Wide Model", *Journal of Economic Dynamics and Control*, forthcoming.

De Haan, J., J. Sturm and B. Sikken, 1996," Government Capital Formation: Explaining the Decline",*Weltwirrtschaftliches Archiv*, 132:1, pp.55-74.

De Haan, J. and W. Romp, 2005, "Public Capital and Economic Growth: a Critical Survey", EIB, Volume 10/1.

Easterly, W. and S. Rebelo, 1993, "Fiscal Policy and Economic Growth," J*ournal of Monetary Economics*, Vol. 32 (December), pp. 417-58.

European Commission, 2003, Public Finances in EMU, European Commission, DG for Economic and Financial Affairs Publication (Brussels, Belgium).

Galí, J., J. López-Salido and J. Valles, 2007, "Understanding the Effects of Government Spending on Consumption", *JEEA,* forthcoming.

Galí, J. and R.Perotti, 2003, "Fiscal Policy and Monetary Integration in Europe", *Economic Policy*, 18:37, pp. 533-572.

Gramlich, E., 1994, "Infrastructure Investment: A Review Essay," *Journal of Economic Literature*, Vol. 32 (September), pp. 1176-96.

IMF, 2004, " Public Investment and Fiscal Policy", IMF Board Paper SM/04/93.

Kamps, C., 2004, "New Estimates of Government Net Capital Stocks for 22 OECD Countries 1996-2001", IMF Working Paper WP/04/67.

Kumhof, M., and D. Laxton, 2007, "A Party without a Hangover", IMF Working Paper, forthcoming.

Pappa. E., 2004, "New Keynesian or RBC Transmission? The Effects of Fiscal Policy in Labor Markets," Working Papers 293, IGIER (Innocenzo Gasparini Institute for Economic Research), Bocconi University.

Perotti, R., 2004, "Public Investment: Another (Different) Look", Working Papers 2977, IGIER (Innocenzo Gasparini Institute for Economic Research), Bocconi University.

Sturm, J., Public Capital Expenditure in OECD Countries: the Causes and Consequences of the Decline in Public Capital Spending, Edward Elgar, Cheltenham, UK.

Turrini, A., 2004, " Public Investment and the EU Fiscal Framework", European Commission, DG for Economic and Financial Affairs, Economic Paper 202, (Brussels, Belgium).

Valila, T. and A. Mehrotra, 2005, " Evolution and Determinants of Public Investment in Europe",EIB, Economic and Financial Report 2005-01.