Fiscal Policy, the Trade Balance, and the Real Exchange Rate: Implications for International Risk Sharing

Tommaso Monacelli* Roberto Perotti†

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Abstract

We employ structural VAR techniques to estimate, for a series of OECD countries, the effects of government spending shocks on the real exchange rate, the trade balance and their comovements with GDP and private consumption. First, we find that in all countries a rise in government spending induces a real exchange rate depreciation and a trade balance deficit. In the US, however, the effect on the trade balance is small. We show how recent empirical evidence that points to a *decline* in the trade deficit after a budget deficit shock can be traced to an alternative (and, in our view, questionable) method to recover the fiscal shocks. Second, in all countries private consumption rises in response to a government spending shock, and therefore comoves positively with the real exchange rate. This result is in stark contrast to virtually all models with complete asset markets and separable utility, including an open economy New Keynesian model with price stickiness and capital accumulation. But an extension of the model to include non-separable preferences in consumption and leisure is able to replicate (at least qualitatively) the responses of consumption and the real exchange rate that we find in the data. Furthermore, if the elasticity of substitution between domestic and imported goods is sufficiently small, the model is also successful in delivering the right comovement between the real exchange rate and the trade balance.

Keywords: fiscal shocks, trade balance, nominal and real exchange rate, twin deficits, imports, exports.

JEL Classification Number: E52, F41, *E62.*

*IGIER, Università Bocconi and CEPR. Correspondence to: IGIER, Via Salasco 5, 20136, Milan, Italy. URL: http://www.igier.uni-bocconi.it/monacelli.

†IGIER, Università Bocconi, NBER and CEPR. Correspondence to: IGIER, Via Salasco 5, 20136, Milan, Italy. URL: http://www.igier.uni-bocconi.it/perotti.

1 Introduction

In this paper we use a Structural Vector Auto Regression methodology to study the effects of fiscal policy, and in particular government spending, on the real exchange rate and the trade balance in four OECD countries. Ranging from the traditional apparatus of the Mundell-Fleming model to the more recent New Open Economy Macroeconomics (henceforth NOEM), the issue of how changes in fiscal policy affect the competitiveness of a country and its external balance remains a classical textbook question in macroeconomics. At the policy level, the recent nearly contemporaneous increase in both the US trade balance and government budget deficits has revived a long debate on the "twin deficits" hypothesis. Yet, with the few exceptions we note below, this issue has received a surprisingly limited attention in the empirical literature.

Our empirical analysis delivers two main results. First, in all four countries we find that a rise in government spending tends to induce a real exchange rate depreciation and a trade balance deficit. The magnitude of these effects varies somewhat with the specification, but in general we find rather consistently that in the US the effect on the trade balance is small and barely significant. Second, in all countries we observe private consumption to rise in response to a government spending shock, and therefore to comove positively with the real exchange rate.

Two important implications follow from these results. Our evidence provides support for a traditional "twin deficit" hypothesis, in stark contrast with a recent study by Kim and Roubini (2003). However, the US stands out as a partial exception in this respect, since in this country the trade balance effect of a fiscal expansion is estimated to be rather small. A second implication concerns the consistency of facts and theory. Both the response of the real exchange rate and its comovement with private consumption and the trade balance are at odds with a benchmark general equilibrium model of the NOEM generation featuring imperfect competition, price stickiness and complete financial markets. This reference model is sufficiently general in that it is able, in its version comprising investment and capital accumulation, to nest a frictionless international real business cycle framework similar, for instance, to that of Backus et al. (1994).

While the model is successful in replicating the negative response of the trade balance to a government spending shock that we observe in the data, and also in linking the magnitude of that response to the degree of openness, it has counterfactual predictions on the response of the real exchange rate and of private consumption. We argue that the key failure of the model lies in the equilibrium behavior of private consumption: in the model, as a result of a typical wealth effect on labor supply, private consumption falls in response to a rise in government spending, whereas the opposite is true in the data. This in turn explains the behavior of the real exchange rate in the reference model: with complete asset markets, a risk-sharing arbitrage condition ties the ratio of the marginal utilities of consumption across countries to the real exchange rate. Via this condition, the fall in consumption is accompanied by an equilibrium appreciation of the real exchange rate.

To address these theoretical issues, we study an extension of the benchmark model featuring non-separable preferences in consumption and leisure (and yet consistent with a balanced growth path, as in the classic real business cycle study of King et al. (1988)). Linnemann (2005) argues that the employment-consumption complementarity implied by this form of utility specification is able to generate a positive response of private consumption to an innovation in government spending. We show that our baseline open economy model extended to include non-separable preferences is able to reproduce the right comovement between consumption and real exchange rate. Furthermore, when the elasticity of substitution between domestic and imported goods is sufficiently small, the extended model is also successful in delivering the right comovement between the real exchange rate and the trade balance.

Ours is not the first paper to use VAR techniques to study the effects of fiscal policy on the trade balance. Kim and Roubini (2003) show that in the US a budget deficit shock causes an improvement in the trade balance. We argue below that this finding is the result of a methodology to identify fiscal shocks that we believe has several undesirable and counterfactual features. In addition to the Kim and Roubini study, Corsetti and Müller (2006) also apply a methodology close to ours - essentially an extension of Blanchard and Perotti (2002) to include the real exchange rate and the trade balance. Their focus is mainly on explaining differences across countries in the response of the trade balance, while ours is mostly on the joint response of trade balance, consumption and real exchange rate, and their implications for models with complete asset markets. In sections 3 and 4 we expand on a comparison of our methodology and results with those of Kim and Roubini and Corsetti and Müller.

The outline of the paper is as follows. Section 2 describes the methodology we use to identify the fiscal shocks. Section 3 presents the main results, with an important robustness analysis. Section 4 presents a comparison with the results of Kim and Roubini (2003), and shows how the differences in the results can be ascribed to important differences in the specification. Section 5 presents an analysis of government spending shocks in a baseline NOEM model with complete asset markets, separable preferences and no capital, and under three alternative specifications of the monetary policy reaction function. Section 6 adds investment and capital accumulation to this basic framework. Section 7 compares our empirical results with the main predictions of these benchmark models, and identifies three empirical puzzles from the point of view of the theory. Section 8 shows that a model with non-separable preferences can reconcile facts and theory while preserving the assumption of complete asset markets. Section 9 concludes.

2 Methodology

Our method to identify fiscal shocks is an extension of Blanchard and Perotti (2002) and Perotti (2004). Corsetti and Müller (2006) also apply the same method to study the effects of fiscal policy on the trade balance, with some important differences that we discuss below. As we mentioned, their interest is different from the study of the joint responses of private consumption, the trade balance, and the real exchange rate, on which we focus.

We illustrate the methodology using a trivariate example. Consider the vector $X_t \equiv [g_t \quad t_t \quad y_t]'$, where g_t, t_t and y_t are the log of real government spending on goods and services ("government spending" for short), the log of real net taxes (the difference between revenues and spending other than on goods and services), and the log of real GDP, respectively, all in per capita terms. Consider the reduced form VAR

$$X_t = A(L)X_{t-1} + U_t, \tag{1}$$

where $A(L)$ is a polynomial of order 4 and $U_t \equiv [u_t^g \quad u_t^t \quad u_t^y]'$ is the vector of reduced form residuals.

The terms u_t^g and u_t^t capture three effects. First, the *automatic response* of tax revenues and government spending to output innovations; second, the *systematic discretionary response* of policymakers to output innovations (for example, systematic cuts to tax rates when output falls, and viceversa when output increases); third, the true *structural shocks* to government spending and taxes. By definition, structural shocks are uncorrelated with each other, hence this last component is what one would like to uncover in order to estimate impulse responses to fiscal policy shocks.

Formally, one can write:

$$u_t^t = \alpha_{ty} u_t^y + \beta_{tg} e_t^g + e_t^t \tag{2}$$

$$u_t^g = \alpha_{gy} u_t^y + \beta_{gt} e_t^t + e_t^g \tag{3}$$

$$u_t^y = \gamma_{yt} u_t^t + \gamma_{yg} u_t^g + e_t^y \tag{4}$$

where the coefficients α_{jk} in (2) and (3) capture the first two components and e_t^g and e_t^t are the structural fiscal shocks such that $cov(e_t^g, e_t^t) = 0$. Clearly, e_t^g and e_t^t are correlated with the reduced form residuals, hence they cannot be obtained by an OLS estimation of (2) and (3).

However, because it takes longer than a quarter for discretionary fiscal policy to respond to, say, an output shock, the *systematic discretionary response* is absent in quarterly data. Thus, the coefficients α_{jk} in (2) and (3) capture only the *automatic response* of fiscal variables to economic activity: one can then use available external information on the elasticity of taxes and spending to GDP to compute the appropriate values of the coefficients α_{jk} (see Perotti (2004) for a detailed description); with these, one can then construct the cyclically adjusted fiscal shocks:

$$u_t^{t,CA} \equiv u_t^t - \alpha_{ty} u_t^y = \beta_{tg} e_t^g + e_t^t \tag{5}$$

$$u_t^{g,CA} \equiv u_t^g - \alpha_{gy} u_t^y = \beta_{gt} e_t^t + e_t^g \tag{6}$$

Since there is no theoretical guidance on the values of β_{gt} and β_{tg}, we start with one orthogonalization, in which we assume $\beta_{gt} = 0$ and estimate β_{tg} by OLS. Because the correlation between the two cyclically adjusted residuals is quite low, the ordering of the two shocks is immaterial to the results.

The two structural shocks e_t^g and e_t^t thus estimated are orthogonal to the other structural shocks of the economy, hence they can be used as instruments for u_t^t and u_t^g in (4). Once the structural shocks are thus identified, one can then proceed to estimate the impulse responses. In what follows, we will focus on the impulse responses to the government spending shocks.

3 Results

In this section we illustrate our empirical strategy and the main results. We begin by describing our data set.

3.1 The Data and the Benchmark Specification

Our sample includes four countries: United States, United Kingdom, Canada and Australia. Since the method of identification described above relies crucially on the existence of data of high enough frequency, the choice of the countries is dictated by the availability of non interpolated quarterly government budget data for the general government. In the benchmark specification, the estimation period starts in the first quarter of 1975, to encompass the onset of the flexible exchange rate regime but, at the same time, to avoid the turbulent years 1973-74. Our sample ends between 2001:2 and 2001:4, depending on the country.

Our benchmark VAR specification includes the following variables: (i) the log of *real government spending*, (ii) the log of *net taxes* (tax revenues less transfers), (iii) the log of *GDP*, (iv) the log of *private consumption* of non-durables and services, (v) the log of *net exports* of goods and services as a share of GDP, (vi) the log of the CPI-based *real effective exchange rate* (an increase is a depreciation) and (vii) the nominal *3-month interest rate*. When we investigate the effects of government spending shocks on private investment, we replace private consumption with the latter variable. The VAR also includes quarterly dummies, a linear trend, and a quadratic trend. The first three variables are expressed in real, per capita terms using the GDP deflator; private consumption and private investment are deflated by their own deflators.[1] We will see that the deflator used for government spending has some impact on the trade balance response to a government spending shock.[2]

All data, except the interest rate and the real exchange rate, are from the National Income Accounts, and are seasonally adjusted by the original sources. Government spending is defined

[1] Over the entire sample period, the deflator of consumption of nondurables and services is available only for Australia; hence, we use the deflator of total private consumption.

[2] This specification of the reduced form is similar to that of Corsetti and Müller (2006), with a few differences: their list of variables includes both government spending and the budget deficit as a share of GDP, but not net taxes; they include the inflation rate; they have the terms of trade instead of the real exchange rate; and they deflate government spending by its own deflator. Implicitly, we will discuss some of these differences in the next sections.

as current spending on goods and services, i.e., government consumption; in the US, these include also defense investment, whose items in the other countries are already included under government consumption. Government consumption is net of depreciation allowances. All government budget variables refer to the general government. Perotti (2004) provides the full details on the construction of the government budget variables.

The elasticity of net taxes to GDP (the coefficient α_{ty} in (5)) is constructed from the elasticities of the individual components (personal and business income taxes, social security taxes, indirect taxes, unemployment benefits) which in turn are computed from data provided by the OECD, using the methodology illustrated in Perotti (2004). We assume that, in quarterly data, the contemporaneous elasticity of government purchases to output, α_{gy}, is 0.

Figure 1 displays the results of the baseline model. Each column corresponds to a country; each row displays the response of a different variable to a government spending shock equal to 1 percent of GDP. The variables are, from top to bottom: government spending, the budget deficit, GDP, private consumption, private investment, the trade balance, and the log of the real exchange rate. The responses of government spending, private investment and private consumption are expressed as shares of GDP, by multiplying the response from the VAR (which is expressed in logs) by the sample average share of that variable in GDP (the trade balance is already expressed as a share of GDP). The response of the budget deficit is constructed as the difference between the responses of government spending and net taxes thus transformed, hence it is also expressed as a share of GDP.

For each variable, Figure 1 displays the impulse response and the 68 percent confidence bands, corresponding to the 16th and 32th percentile of 500 simulations (assuming normality), at each horizon.

Notice, first, that the government spending shock is not very persistent: after 4 quarters, in all countries government spending is only between .3 and .4 percentage points of GDP above trend; after 8 quarters, it ranges from .1 percentage point in the UK to .4 percentage points in the US. As a consequence, the budget deficit also falls quite rapidly back to trend. In Australia, the budget turns into a surplus after 2 years: but this is largely endogenous, a consequence of the positive GDP response.

The response of GDP is positive in all countries. It is largest in the US, where it takes a while to build up, with a peak of 1.8 after 2 years. In the other countries the peak responses range from .7 in Australia to 1.4 in the UK, and are reached after three years in the UK, one in Canada, and on impact in Australia.

The response of private consumption mimics everywhere that of GDP, hence it is positive everywhere. The timing of the maximum responses and their ranking are also very close to those of GDP.

Private investment always falls initially, then it recovers everywhere, and after between 2 and 3 years it rises slightly above trend, with positive maxima that range from .2 in Canada to .7 in Australia.

The trade balance always deteriorates initially, by between .4 and .9 percentage points of GDP. In the UK and Canada this deterioration lasts the whole horizon; in the US the trade balance goes back immediately to trend or slightly below, and in the long run, after 3 years and beyond, it shows a significant improvement above trend, with a peak of .5 percentage points. Thus, in contrast to Kim and Roubini (2003), in the US we do not find evidence of crowding in of net exports by the budget deficit in the short or medium run; but neither do we find much evidence of substantial crowding out.

Finally, the real exchange rate basically does not move in Canada; but in the other countries it depreciates, and by substantial amounts - about 4 percentage points by year 2. In the US it keeps depreciating afterwards, reaching a peak of 8.2 percentage points after 4 years.

Figure 2 displays the same impulse responses as Figure 1, but from the model estimated over the 1980-2001 period, the same sample period used by Corsetti and Müller (2006). The results are similar, but we now find a weaker response of GDP in all countries except Australia. In particular, the GDP response turns negative in the UK and Canada after about $2\frac{1}{2}$ years: this is consistent with the findings in Perotti (2004). Correspondingly, in the UK the trade balance turns positive when GDP turns negative; conversely, the trade balance response is now uniformly negative in the US. The real exchange rate still depreciates, except for an initial, and largely insignificant, appreciation in the US.

3.2 The Role of Deflators

Instead of the GDP deflator, one could have used government spending's own deflator to express government spending in real terms. Consider a purely nominal shock to government spending: for instance, an increase in the wage of government employees, without any change in their number or productivity. Most models predict that this action should have a positive effect on employment and output: in a neoclassical model, this happens via a negative wealth effect on the private sector, whereas in a Keynesian model, via a higher demand. Yet, if we used government spending's own deflator, real government spending would not change and we would not be able to capture the effects of this type of fiscal shock. Only by employing the GDP deflator will we be able to capture the positive effect of the shock on output. This is the rationale for our use of the GDP deflator in the benchmark model.

Still, one could be interested in estimating the effects of changes in the quantities of goods and services purchased by the government. Thus, in our second specification government spending is deflated by its own deflator. The results are displayed in Figure 3. The basic conclusions remain broadly in line with our baseline specification, with two exceptions. First, there is now evidence of a negative GDP response in the UK, where government spending exhibits a large decline in persistence relative to Figure 1; GDP falls also initially in the US and in the long run in Canada. Second, just as the GDP and private consumption responses reverse sign in the UK, so does the trade balance response, which becomes positive. In the US and Australia as well there is evidence of an improvement in the trade balance. Note that in Corsetti and Müller (2006) government spending is deflated by its own deflator, as in this section; like us, they find more positive, or less negative, effects of a government spending shock on the trade balance than we find in Figure 1, where we used instead the GDP deflator.

3.3 An Alternative Approach

Figure 4 displays the results from an alternative approach to estimating the effects of government spending. It is an application of the "Narrative Approach" originally developed by Romer and Romer (1989) for the analysis of monetary policy, extended by Ramey and Shapiro (1998) to the study of fiscal policy, and further elaborated by Edelberg, Eichenbaum and Fisher (1999) and Burnside, Eichenbaum and Fisher (2004). It consists of estimating the same reduced form (1), with the addition of the contemporaneous value and several lags of three dummy variables, taking the value of 1 on 1950:3, 1965:1, and 1980:1. Ramey and Shapiro (1998) argue that these three dates capture the onset of as many episodes of fiscal expansion, the Korean War, the Vietnam War, and the Carter-Reagan military buildup, which were largely caused by military and foreign policy events. On the basis of an extensive reading of contemporary accounts, they conclude that these events were largely exogenous and unexpected; hence, these three dummy variables identify, in an econometric sense, three shocks to fiscal policy: the dynamic effects of the "Ramey and Shapiro" fiscal episodes can then be traced by the responses of the endogenous variables to unit shocks to the dummy variables.

Because we have data on the real exchange rate only from 1975, we can only study the response to the Carter-Reagan military buildup. Figure 4 displays the responses to a unit shock to the 1980:1 dummy variable. Contrary to what is generally believed, government spending during the early eighties was below trend: the increase in military spending was more than compensated by the fall in civilian spending; hence, the first panel shows that government spending fell in response to a shock to the 1980:1 dummy. Most other responses are qualitatively consistent with those of our baseline model using our Structural Vector Autoregression approach, with the opposite sign given that we are looking at a *decline* in government spending. Private consumption and (initially) GDP fall, and the trade balance improves. However, the real exchange rate depreciates initially and then appreciates only in the long run. In evaluating these results, one should consider that we are trying to estimate the response of the real exchange rate in an exceptionally turbulent period, characterized by a large dollar depreciation in 1980-81 followed by an even larger dollar appreciation. Thus, we find the qualitative coincidence of our results with those from the Structural Vector Autoregression Approach quite encouraging.

3.4 Summary of the Empirical Results

Despite their minor differences, all specifications display a few robust features which will be important later in evaluating alternative models: the response of the trade balance to a government spending shock tends to have the opposite sign to the response of GDP and private consumption, while the response of the real exchange rate tends to have the same sign.

For the purpose of evaluating the theoretical models that we study next, our empirical analysis can be summarized in terms of four main conclusions that have a reasonable degree of generality. In response to a positive innovation in government consumption:

1. GDP and private consumption both *rise* in the short and medium run; the only exception is the UK under an alternative specification, based on a different deflating methodology.

2. The trade balance *deteriorates* in the short to medium run under the benchmark specification. But the response of the trade balance is somewhat sensitive to the method of deflation of government spending: when government spending's own deflator is used, the trade balance tends to improve, except in Canada. On the other hand, under the same specification the GDP response also tends to be much weaker.

3. The real exchange rate tends to *depreciate*, except in Canada where it is flat. Thus, the responses of private consumption and of the real exchange rate tend to exhibit the same sign. Because the trade balance moves in opposite direction to GDP and private consumption, typically the trade balance moves in opposite direction to the real exchange rate (i.e., it worsens when the exchange rate depreciates).

4. Private investment *falls*. In some cases, the impact elasticity of investment is quite large.

4 Comparison with Kim and Roubini (2003)

Using a different specification and identification, Kim and Roubini (2003) and Corsetti and Müller (2006) find that in the US a shock to the budget deficit / GDP ratio typically causes a significant and (in the case of Kim and Roubini) large improvement in the current account / GDP ratio. As we have shown above, we do not find much support for this "twin divergence" result. These differences can largely be traced to the differences in the specification and identification methods.

We first show that, when we apply the Kim and Roubini (2003) specification and identification approach, we can easily replicate their results. Consider a VAR in five variables: the log of *real GDP*, the *primary budget deficit / GDP ratio*, the *trade balance / GDP ratio*, the *three-months interest rate*, and the log of the *real exchange rate*.[3] The shocks are identified via a simple Choleski orthogonalization, with the variables in the order listed above. This identification approach has an important consequence: when there is a positive shock to the deficit, real GDP on impact is not allowed to change.

Figure 5 illustrates the responses of the main variables to a government deficit shock normalized to 1 percent of GDP. A consistent pattern emerges: this approach tends to find a negative initial effect of a deficit shock on GDP, followed in some cases by a small increase above trend in the medium run, and a non-negligible *positive* effect on the trade balance, even in the short run. In the US, GDP decreases, while the trade balance improves, by about .2 percentage points of GDP after 4 quarters. The real exchange rate depreciates, by a maximum of 4 percent after 2 years and a half. All these results are qualitatively and even quantitatively consistent with those of Kim and Roubini. The results in the other countries (not included in the Kim and Roubini study, but included in the Corsetti and Müller study) are broadly consistent with those of the US. The response of GDP is persistently smaller than the response we found by applying our methodology, and it is significantly negative in the medium to long run except in Australia. The trade balance response is also algebraically larger than in our previous results: it improves everywhere except in Canada, where it is insignificantly different from 0. Importantly, the real exchange rate depreciates in all countries.

Thus, the key difference with the results based on our specification is that a positive budget deficit shock tends to generate a negative response of GDP, and a positive response of the trade balance. It is easy to see that there are two reasons for this: Kim and Roubini specify the budget deficit as a share of GDP; in addition, in identifying the budget deficit shock they ignore the automatic effect of GDP on the budget deficit itself. For both reasons, the identification method generates a confusion between a negative GDP shock and a positive deficit shock.

To see this, suppose the true model is a version of our equations (2) to (4), where for comparability with Kim and Roubini we have collapsed government spending and net taxes in

[3] Our specification differs slightly from Kim and Roubini in that we include the trade balance - while Kim and Roubini have the current account -, and we include the nominal interest rate while they have the *ex-ante* real interest rate. These small modifications do not have significant effects on the results.

a single variable:

$$u_d = \beta u_y + \varepsilon_d \quad (7)$$

$$u_y = \gamma u_d + \varepsilon_y \quad (8)$$

where d is the budget deficit / GDP ratio and u_d and u_y are the reduced form deficit and GDP innovations. $\beta < 0$ because of the automatic effects of GDP on tax revenues and of the positive effect on the denominator, and $\gamma > 0$ as posited by most models (provided at least that taxes are not too distortionary). Kim and Roubini orthogonalize the reduced form innovations via a Choleski ordering:

$$\widetilde{\varepsilon}_y = u_y \quad (9)$$

$$u_d = \widetilde{\beta} u_y + \widetilde{\varepsilon}_d \quad (10)$$

where a tilde denotes a coefficient, or a variable, as estimated with the Kim and Roubini identification approach.

Parameter $\widetilde{\beta}$ is estimated by OLS; however, note that in the data the true deficit shock ε_d is correlated positively with u_y: in fact, from (7) and (8)

$$u_y = \frac{\gamma}{1-\beta\gamma}\varepsilon_d + \frac{1}{1-\beta\gamma}\varepsilon_y \quad (11)$$

Hence, forcing $\widetilde{\varepsilon}_d$ in (10) to be uncorrelated with u_y implies that $\widetilde{\varepsilon}_d$ must be correlated negatively with the true GDP shock ε_y. If the trade balance is also correlated negatively with the true GDP shock, this also builds in a positive spurious correlation between the budget deficit and the trade balance. This explains both the weak response of GDP and the positive response of the trade balance to the estimated deficit shock.[4]

Intuitively, suppose there is a negative realization of the true GDP shock: the deficit/GDP ratio will increase for two reasons: because the denominator falls, and because at the numerator tax revenues fall. This creates a spurious negative correlation between the deficit and the GDP innovations. Furthermore, as GDP falls, the trade balance improves, thus also creating a spurious positive correlation between the deficit and the trade balance innovations.

[4]More formally, note that, because of the positive correlation between u_y and ε_d, the OLS estimate of $\widetilde{\beta}$ exceeds the true β. Also, from (7) and (9) , $\widetilde{\varepsilon}_d = \varepsilon_d - (\widetilde{\beta} - \beta)u_y$ and, from (11), $cov(\widetilde{\varepsilon}_d, \varepsilon_y) = -(\widetilde{\beta} - \beta)\sigma^2_{\varepsilon_y}/(1-\beta\gamma)^2 < 0$.

Note that, if d represented the log of government spending instead of the deficit/GDP ratio as the fiscal variable, by our discussion in section 2, with quarterly data $\beta = 0$; yet, a Choleski ordering in which output comes first, as in (9) and (10), would still impose a negative correlation between $\widetilde{\varepsilon}_d$ and ε_y as long as $\gamma > 0$. This type of Choleski ordering also implies that a shock to government spending has no impact effect on total output, hence it must crowd out private output *exactly* one for one on impact.

These observations call for a different specification and identification strategy. First, it is important to separate government spending and taxation. Second, in general Choleski ordering is not suitable to identify the structural fiscal shocks, and certainly not a Choleski ordering in which output comes first. Third, the current GDP is an endogenous variable and should not appear at the denominator of the fiscal variables whose shocks we are studying.

5 An Analysis of Government Spending Shocks in the Open Economy

In this section we introduce a theoretical discussion of the channels through which shocks to government spending affect the dynamics of the real exchange rate and the trade balance. We build a small open economy model that shares many features of the recent New Keynesian literature: explicit microfoundations with endogenous labor supply, nominal price rigidity, monopolistic competition, forward-looking price setting, and complete asset markets.

We proceed in three steps. First, we describe a baseline version of our model featuring separable preferences in consumption and leisure and no capital accumulation. Second, we extend the baseline model by adding an investment decision and capital accumulation. Third, we generalize household preferences to be non-separable in consumption and leisure. We show that the latter extension is important for the model to conform to a series of stylized facts that have emerged from our empirical analysis.

5.1 The Baseline Model: Separable Preferences and No Capital

To economize on space we lay out the model already in its log-linearized form (with all variables expressed in percent deviations from their respective steady-state values) and in a more compact format relative to its primitive structural elements. In the Appendix we lay out the details of the underlying structural model.

Let y_t denote output of domestic goods, c_t private consumption, g_t government consumption of domestic goods, and s_t the (effective) terms of trade, i.e., the relative price of imports $p_{F,t} - p_{H,t}$, where $p_{F,t}$ is the price of a differentiated bundle of goods imported from the rest of the world, and $p_{H,t}$ is the price of domestically produced goods (both expressed in units of domestic currency). We assume that (exogenous) government spending is financed by means of lump-sum taxes; in line with a long tradition, and with empirical observation, we also assume that government spending has a higher content of domestic goods than the rest of the economy; in fact, for simplicity we go all the way and assume that it falls exclusively on domestic goods.

The first component of the model is a market clearing condition for domestic goods:

$$y_t = (1-\gamma_g)\ \left(c_t + \frac{\alpha\omega}{\sigma} s_t\right)\ + \gamma_g g_t \quad , \quad \omega \equiv \sigma\eta + (1-\alpha)(\sigma\eta - 1) \tag{12}$$

where $\gamma_g \equiv \frac{G}{Y}$ is the steady-state share of government consumption in output, $\sigma > 0$ is the *intertemporal* elasticity of substitution in consumption, $\eta > 0$ is the *intratemporal* elasticity of substitution between domestic and foreign goods, and $\alpha \geq 0$ is the share of imported goods in the consumption index. Thus, α is a natural index of openness: in the special case of $\alpha = 0$ the above condition reduces to a standard market clearing condition for a closed economy. Notice that, given consumption, a terms of trade depreciation, by inducing an expenditure switching effect towards domestic goods, increases domestic output.

The real exchange rate is the ratio of the World CPI to the Home CPI: $q_t \equiv e_t + p_t^* - p_t$. Since the law of one price holds, the terms of trade s_t defined above are linearly related to the real exchange rate q_t. To see this, notice that in our framework the World economy is by construction a closed economy, hence CPI and domestic goods price level coincide in the World economy. As a result, we have $e_t + p_t^* = e_t + p_{F,t}^* = p_{F,t}$. In addition, the Home CPI can be written as

$$p_t \equiv (1-\alpha)p_{H,t} + \alpha p_{F,t} \tag{13}$$

$$= p_{H,t} + \alpha s_t \tag{14}$$

Combining these expressions, the real effective exchange rate reads

$$q_t \equiv e_t + p_t^* - p_t \quad (15)$$

$$= (1-\alpha)s_t, \quad (16)$$

Given an appropriate normalization of the initial conditions, international risk-sharing entails that the marginal rate of substitution between domestic and world consumption should be a function of the real effective exchange rate[5]

$$c_t = y_t^* + \sigma^{-1} q_t \quad (17)$$

In this expression, we have used the fact that World consumption coincides with World output.

As in all neo-keynesian models, a key equation on the supply side describes the evolution of the real marginal cost. Let mc_t denote the deviation of the real marginal cost from a desired constant value consistent with flexible prices. Under the assumption of linear production function $y_t = n_t$, the marginal cost equals the real product wage $w_t - p_{H,t}$, hence from (14)

$$mc_t = w_t - p_t + \alpha s_t \quad (18)$$

$$= \sigma c_t + \varphi y_t + \alpha s_t \quad (19)$$

where $\varphi > 0$ is the inverse elasticity of labor supply. The second equality derives from the first order condition of the representative agent's problem, according to which the marginal rate of substitution between leisure and consumption must equal the real consumption wage $w_t - p_t$. Hence, in an open economy the real marginal cost depends also on the evolution of the terms of trade. In particular, a real depreciation (i.e., a rise in s_t), by increasing the product wage for any given level of consumption and output, induces a higher real marginal cost.

Under a standard Calvo-type price setting, the forward-looking expression for inflation in domestic goods prices parallels the familiar expression from closed-economy models[6]:

$$\pi_{H,t} = \beta E_t\{\pi_{H,t+1}\} + \kappa \; mc_t \quad (20)$$

[5] See the Appendix for a discussion. A condition of this kind is common to all models with complete international asset markets.

[6] See Gali and Monacelli (2005) for an explicit derivation.

where $\kappa \equiv \frac{(1-\beta\vartheta)(1-\vartheta)}{\vartheta} > 0$, β is the discount factor and ϑ is the probability of not resetting prices in any given period (hence an index of nominal stickiness in domestic prices).

Finally, let nx_t denote the deviation of the net export / GDP share from its steady-state level; because the trade balance is the difference between output and absorption, we have

$$nx_t = y_t - (1-\gamma_g)(c_t + \alpha s_t) - \gamma_g g_t \tag{21}$$

Combining this with (12), and using (16), we obtain the following relationship between net exports and the real exchange rate

$$nx_t = (1-\gamma_g)\frac{\alpha}{1-\alpha}\left(\frac{\omega}{\sigma} - 1\right) q_t, \quad \omega \equiv \sigma\eta + (1-\alpha)(\sigma\eta - 1) \tag{22}$$

The model is closed by a specification of the monetary authority behavior (see sections (5.3) to (5.5)).

5.2 Intuition

The key for an intuitive understanding of the working of this model is the negative wealth effect caused by government spending. The rise in government consumption, by implying a rise in future taxes, raises the shadow value of wealth, and therefore induces a fall in private consumption. In turn, for any given level of world output, international risk-sharing, via equation (17), requires an appreciation of the real exchange. Thus, the model predicts that the responses of private consumption and the real exchange rate have the same sign.

Next consider the effects on the trade balance. In general, there are two competing forces at work. On the one hand, the decline in private consumption tends to cause an improvement of the trade balance (the absorption effect); but the real exchange rate appreciation causes a switch towards foreign goods and therefore a worsening of the trade balance (the switching effect). From equation (22), this effect depends on the sign of $\Omega \equiv (1-\gamma_g)\frac{\alpha}{1-\alpha}\left(\frac{\omega}{\sigma} - 1\right)$, which in turn depends on the values of σ, α and η. Without loss of generality, we will consider the case $\sigma = 1$ (log-consumption utility) so that, in (22), $\Omega = (1-\gamma_g)\frac{\alpha}{1-\alpha}(2-\alpha)(\eta - 1)$: if the elasticity of substitution η exceeds 1, the switching effect dominates and the trade balance worsens; if η is below 1, the absorption effect dominates and the trade balance improves. In the knife-edge case $\eta = 1$, the trade balance is always zero.

The relationship between the trade balance and the real exchange rate is also affected by the degree of openness (see also Corsetti and Müller (2006) for an analysis that emphasizes the role of openness in the transmission of fiscal shocks). Under log consumption utility we have

$$\frac{\partial\Omega}{\partial\alpha}=(1-\gamma_g)(\eta-1)\left[1+\frac{1}{(1-\alpha)^2}\right]$$

Hence, for any given appreciation of the real exchange rate, if $\eta > 1$ a higher degree of openness α induces a larger trade deficit, while if $\eta < 1$ a larger α induces a larger trade surplus. Thus, the effect of higher openness is in both cases to amplify the equilibrium response of the trade balance.

In general, it is not possible to sign analytically the effects on total output and the conditional correlations involving this variable. Equation (12) illustrates why. On one hand, higher government spending raises output. On the other hand, the decline in private consumption and the real appreciation (that causes a switch to foreign goods) both reduce output. The net effect cannot be signed analytically, except in some cases, one of which we study below. However, it is easy to see (at least in the baseline model without investment) why output should increase (the result we find in all our numerical simulations): private consumption and leisure are both normal goods, hence they both fall as a result of the the wealth effect; then the associated increase in employment raises output.

We now turn to study the solution of the model under three alternative specifications of the monetary authority reaction function. We first assume that the monetary authority stabilizes strictly one of two measures of inflation, (i) CPI-inflation π_t (*CPI targeting*) or (ii) domestic (producer-price) inflation $\pi_{H,t}$ (*PPI targeting*). We show that in these cases it is possible to derive a range of analytical results on the effects of government expenditure shocks, starting from the decline in private consumption. We then show that these results also holds for more general Taylor-type rules, for which numerical solutions are needed.

5.3 CPI Targeting

Strict stabilization of CPI inflation can be formalized as $p_t = 0$ for all t. In this case, the terms of trade and the domestic price level are related via (14) as follows:

$$s_t = -\frac{1}{\alpha}p_{H,t} \tag{23}$$

Assume, without loss of generality, that $y_t^* = 0$. Substituting (17) into (12) and in turn into (19) gives the following expression linking the real marginal cost to the price level for any given level of government spending:

$$mc_t = -\frac{1}{\alpha}\left(1 + \frac{\varphi\omega_\alpha}{\sigma}\right) p_{H,t} + \ \gamma_g \varphi g_t \tag{24}$$

where $\omega_\alpha \equiv (1-\gamma_g)(1+\alpha(\omega-1))$. Substituting (24) into (20) gives the following second order difference equation for the domestic price level:

$$\Gamma p_{H,t} = \ \beta E_t\{p_{H,t+1}\} + p_{H,t-1} + \lambda\gamma_g\varphi g_t \tag{25}$$

where $\Gamma \equiv 1+\beta+\frac{\lambda}{\alpha}\left(1+\frac{\varphi\omega_\alpha}{\sigma}\right)$. The above equation has a stable solution of the following form:

$$p_{H,t} = \psi_1 \ p_{H,t-1} + \lambda\gamma_g\varphi \ \psi_1 \sum_{j=0}^{\infty} (\beta\psi_1)^j \ \ E_t\{g_{t+j}\} \tag{26}$$

where $\psi_1 \equiv \frac{\Gamma\left(1-\sqrt{1-\frac{4\beta}{\Gamma^2}}\right)}{2\beta} \in (0,1)$ is the stable root of the characteristic equation associated with (25). As a result, under CPI targeting, current and expected movements in government consumption necessarily induce a *rise* in the domestic price level. In turn, via (23), this unambiguously induces an *appreciation* of the terms of trade and the real exchange rate[7], and, from the risk-sharing condition (17), a fall in private consumption.

5.4 PPI Targeting

This case allows us to determine analytically the effects on output. Full stabilization of domestic inflation can be formalized as $p_{H,t} = 0$ for all t. To sustain a constant producer price level, equation (19) requires $mc_t = 0$: this implies the same allocation that would prevail under fully flexible producer prices (recall that mc_t is defined as the percentage deviation of the marginal cost from its constant flexible price value). Imposing $mc_t = 0$ in (19), and using (17), entails a negative relationship between output and the terms of trade (once again under the simplifying assumption $y_t^* = 0$):

$$s_t = -\varphi y_t \tag{27}$$

[7]Notice that the effect on the price level of a rise in government spending is generally ambiguous in a corresponding sticky-price closed economy, depending on the assumed behavior of the monetary authority (see Linnemann and Schabert (2004)).

Substituting (17) and (27) into (12) gives:

$$y_t = \Omega_{yg} \; g_t \tag{28}$$

where $\Omega_{yg} \equiv \frac{\gamma_g}{\left(1+\frac{\varphi(1-\gamma_g)\,\omega\alpha}{\sigma}\right)} > 0$. Hence under PPI targeting output unambiguously increases and therefore, via (27), the terms of trade appreciate after a positive government spending shock.

In conclusion, we can state a few analytical results from these two cases. A positive government spending shock generates:

1. a decline in private consumption
2. a real exchange rate (terms of trade) appreciation
3. a decline in the trade balance if $\eta > 1$, and an improvement if $\eta < 1$.

5.5 Dynamics Under Simple Taylor Rules

We now consider more general monetary policy rules, in the form of Taylor-type interest rate rules in which the monetary authority sets the short-term nominal interest rate in response to deviations of an appropriate inflation index from some target (assumed here to be zero for simplicity):

$$r_t = \overline{r} + \phi_\pi \; \widetilde{\pi}_t \tag{29}$$

where $\overline{r}$ is a target for the nominal interest rate and $\widetilde{\pi}_t$ is an inflation index. The latter corresponds either to $\pi_{H,t}$, if the target is in terms of the PPI, or to π_t if the target is in terms of CPI. Thus, the case of strict PPI (CPI) targeting discussed above can be interpreted as the result of a Taylor rule with $\widetilde{\pi}_t = \pi_{H,t}$ $(\widetilde{\pi}_t = \pi_t)$ and $\phi_\pi \to \infty$.

An analytical solution is not readily available in the case of a generic Taylor rule. Hence we resort to numerical simulations. In the baseline simulation, we set the steady state share of government spending in output to $\gamma_g = 0.25$, and the degree of openness α to 0.4. In the calibration of the interest rate rules we follow the original Taylor estimate and set ϕ_π to 1.5. As we have discussed, the parameters η and σ are of particular importance for our purposes, since their values determine the sign of the response of the trade balance to a government spending shock.

Under our baseline case of $\sigma = 1$ (log utility), we have seen that $\eta = 1$ (Cobb-Douglas consumption index) implies that the trade balance is zero at all times, while if $\eta > 1$ the trade balance worsens in response to a government spending shock. In our baseline calibration we concentrate, as in Backus et al (1994), on values of η strictly greater than 1; specifically, our baseline value is $\eta = 1.5$. Yet, since the literature lacks a consensus on the value of this parameter, we also conduct sensitivity experiments and defer a discussion on this point to a later stage of the paper.[8]

Finally, we assume an AR(1) process for (log) government spending, with an autoregressive parameter of 0.85 in quarterly data. This is close to the average of our VAR estimates, that typically find that about half of the initial shock to government spending is dissipated after about 1 year.

Figure 6 displays the effects on output, consumption, the trade balance, the terms of trade, PPI and CPI inflation of a one percent rise in government spending. All variables are measured in percent deviations from steady state values. For each variable, the implied equilibrium dynamics under a PPI Taylor rule is compared to the one under a CPI Taylor rule.

The results based on a Taylor-type specification of monetary policy are in line with our discussion above. A rise in government spending produces a partial crowding out of consumption (via the wealth effect), an appreciation of the real exchange rate, and a positive effect on output. As expected, given that $\sigma = 1$ and $\eta > 1$, the trade balance deteriorates.

In Figure 7 we experiment with alternative values of the elasticity η. As we know, the trade balance worsens if $\eta > 1$ and improves if $\eta < 1$. In addition, the figure shows that private consumption falls more (hence the real exchange rate appreciates more) the smaller is η. The reason is straightforward: when government spending rises, private wealth falls and the terms of trade appreciate; if η is low, the representative agent cannot easily substitute the less expensive foreign good for the more expensive domestic good, and total consumption falls more.

[8] The remaining parameters are chosen as follows: ϑ is set to a benchmark value of 0.75 (a value consistent with an average period of 4 quarters between price adjustments), β is set to 0.99, which implies a riskless annual return of about 4 percent in the steady state.

6 Adding Investment and Capital Accumulation

We now extend our benchmark model to include a role for capital and investment. We assume that the domestic households hold the capital stock and derive income from renting capital to domestic firms. Also, we assume that investment, like consumption, is a composite index of domestic and imported foreign goods. Once again, more details on the primitives of the model are provided in the Appendix.

Under the above assumptions, the log-linearized market clearing condition must be modified as follows

$$y_t = \gamma_c \, c_t + (1 - \gamma_c - \gamma_g) i_t + \frac{(1 - \gamma_g) \; \alpha\omega}{\sigma} s_t \; + \gamma_g g_t \tag{30}$$

where γ_c is the share of consumption in steady-state output and i_t denotes investment.

Under adjustment costs, capital accumulation evolves according to (in log-linearized form):

$$k_{t+1} = (1 - \delta) k_t + \delta i_t \tag{31}$$

where k_t is the beginning of period t capital stock and δ is the physical depreciation rate of capital.

The household's efficiency conditions for the choice of investment imply the following equations

$$\lambda_{q,t} = -\xi\delta(i_t - k_t) \tag{32}$$

$$\lambda_{q,t} + rr_t = (1 - \beta(1 - \delta)) \; E_t \{z_{t+1}\} + \beta(1 - \delta)) \; E_t \{\lambda_{q,t+1}\} - \beta\delta^2\xi(i_{t+1} - k_{t+1}) \tag{33}$$

where $\lambda_{q,t}$ is the real shadow price of an additional unit of investment (or Tobin's q), $\xi \equiv \Phi'' \left(\frac{I}{K}\right) < 0$ is the curvature of a concave investment adjustment cost function $\Phi\left(\frac{I}{K}\right)$ which is increasing in the investment-capital ratio, and which satisfies $\Phi\left(\frac{I}{K}\right) = \delta$ and $\Phi'\left(\frac{I}{K}\right) = \Phi'(\delta) = 1$. In addition, $rr_t \equiv r_t - E_t \{\pi_{t+1}\}$ is the CPI-based real interest rate and z_t is the (CPI-based) real rental cost of capital. Equation (32) indicates that, under adjustment costs, the shadow price of capital rises with the investment-capital ratio. Equation (33) is a typical asset-price condition (derived from the log-linearization of an intertemporal Euler equation on capital) which relates the current marginal price of capital to the future marginal price (as a consequence of the presence of adjustment costs), the real interest rate and the rental cost.

Notice that (32) and (33) can be combined to yield:

$$\lambda_{q,t} = (1 - \beta(1-\delta))E_t\{z_{t+1}\} \; + \; \beta E_t\{\lambda_{q,t+1}\} \; - (r_t - E_t\{\pi_{H,t+1} + \alpha \Delta s_{t+1}\}) \tag{34}$$

Hence, by integrating forward, one can easily see that Tobin's q depends on current and expected future movements of the rental cost (with positive sign) and of the real interest rate (with negative sign).

On the firm's side, the log-linearized efficiency conditions for capital and labor demand read:

$$\sigma c_t + (1+\varphi)n_t + \alpha s_t = mc_t + y_t \tag{35}$$

$$z_t + \alpha s_t = mc_t + y_t - k_t \tag{36}$$

where ψ is the capital share in a Cobb-Douglas production function including capital and labor. Notice that, unlike a closed a economy, movements in the terms of trade affect the CPI-based real rental cost of capital. Thus, for any given level of output and real marginal cost, a terms of trade appreciation tends to *increase* the rental cost of capital. This, *ceteris paribus*, tends to increase the shadow value of investment $\lambda_{q,t}$, providing a boost to investment which is absent in the closed economy counterpart of our model.

Finally, in the presence of investment, the trade balance equation must be modified as follows

$$nx_t = y_t - \left(\gamma_c c_t + (1-\gamma_c-\gamma_g)i_t + (1-\gamma_g)\alpha s_t \; + \; \gamma_g g_t\right)$$

Figure 8 displays the response of selected variables to a one percent rise in government consumption in the model comprising investment and capital accumulation. In these simulations parameter η is set at its baseline value of 1.5. Since the responses under a PPI Taylor rule are almost identical to the ones under a CPI Taylor rule, we report the results under the former rule only.

There are three main findings that are worth noticing at this stage. First, the real appreciation is a robust feature also of the economy with capital accumulation. Second, a rise in government spending produces a fall in investment. This is the result of a fall in Tobin's q, which depends (via the asset price condition (34)) on current and expected future movements in the rental cost and the real interest rate. The real interest rate, both current and future, rises to support a lower level of consumption, thus depressing $\lambda_{q,t}$. On the other hand, the rental cost rises initially, exerting an upward pressure on $\lambda_{q,t}$, but then reverts quickly back to steady state. The net effect is a fall in Tobin's q, which drives investment down.

Finally, notice that the fall in investment is not sufficient to turn the trade balance deficit into a surplus: as in the model without investment, the trade balance falls.

Given the impact of a real appreciation on the dynamics of the rental cost (via both equation (36) and (34)), it is worth exploring the sensitivity of the response of investment and of the trade balance to alternative degrees of openness of the economy. Figure 9 displays the results. Higher values of openness induce, as expected, a stronger response of the rental cost; in fact, for a value of $\alpha = 0.8$, the positive response of the rental cost is strong enough to induce a rise in Tobin's q and a subsequent rise in investment. In all cases, the negative response of the trade balance is amplified. Thus, and similarly to the baseline case without investment, the prediction of the model is once again that a higher degree of openness induces an amplified response of the trade balance.[9]

7 Comparing Facts and Theory: Some New Puzzles?

Our evidence suggests that the "twin deficits" hypothesis is broadly consistent with the data. The US stands out somewhat as an exception, in that the effect on the trade balance is small and positive in the long run. However, the US is less open to trade than the other countries in the sample, and we have seen that trade openness amplifies the response of the trade deficit to a government spending shock. Hence, the trade balance response in the US can be explained by the low value of α, assuming $\eta > 1$.

However, a series of important anomalies still emerge in other respects. We identify at least *three* main potential puzzles from our comparison of facts and theory. All of them stem from a basic discrepancy between the model and the data: in the model, the key force driving all other results is the negative wealth effect of government spending that depresses private consumption; but in the data private consumption rises. In fact, the conditional correlation

[9] To economize on space, we do not report here the results for alternative values of η, since they are qualitatively in line with the baseline economy without investment. Hence, for values of $\eta < 1$, we once again observe a rise in the trade balance, with higher openness amplifying the positive response.

between private consumption and GDP is stubbornly positive, contrary to the predictions of the model (see Table 1). Interestingly, the response of private consumption to a government spending shock is a key issue in the recent empirical literature on the macroeconomic effects of government spending (see, e.g., Blanchard and Perotti (2002), Galí et al. (2006), Perotti (2006) on one hand, and Edelberg, Eichenbaum and Fisher (1999) or Burnside, Eichenbaum and Fisher (2004) on the other).

Table 1: **Conditional Correlations**

	USA	GBR	CAN	AUS	USA	GBR	CAN	AUS
	corr(C,Y)				corr(C,E)			
benchmark	.95*	.44*	.92*	.01	-.17	.87*	.76*	-83*
G/PG	.87*	.61*	.86*	.07*	.47*	-.28	-.64*	-.68*

Note: C is consumption, Y is output, E is real exchange rate (a higher value represents a depreciation). "Benchmark": government spending is deflated by the GDP deflator; "G/PG": government spending is deflated by its own deflator.

The real exchange rate puzzle. While in the data we observe a real exchange rate *depreciation* following a positive government spending shock, a real *appreciation* is a robust feature of the theoretical framework, regardless of the presence of investment and/or of the assumed degree of price stickiness.

The reason is straightforward: the wealth effect drives private consumption down, and the international risk-sharing condition implies that the real exchange rate *must* appreciate. In fact, this result holds in virtually any model displaying complete asset markets, like the standard international real business cycle model of Backus et al. (1994): in fact, one can view our model with capital accumulation as a generalization of their model to the case of price stickiness. It also holds in models with different frictions like local currency pricing, pricing to market and trade costs (Engel (2002)), and in models with traded and non traded goods. A strong positive correlation between (relative) consumption and the real exchange rate continues to hold even if residents do not have access to state contingent assets and, for instance, can buy only riskless bonds (see Chari et al. (2003)).

In addition, the observed real depreciation in response to a rise in government spending lies in stark contrast with a traditional Mundell-Fleming model. In that model, represented by an open economy extension of the traditional IS-LM apparatus, a rise in government purchases, by boosting domestic aggregate demand, entails a rise in the domestic interest rate. This causes a nominal (and real) appreciation and in turn a deterioration of the trade balance.

Interestingly, a "modern variant" of the Mundell-Fleming model, namely the model by Obstfeld-Rogoff (1995), predicts exactly the opposite. In that framework, where PPP holds throughout, the behavior of the nominal exchange rate tracks the one of the price level closely and is in some sense residual. The critical effect (shared with a benchmark neoclassical model) is that, under the assumption that the fiscal authority follows a balanced budget rule, a rise in government consumption generates a fall in private consumption via a typical wealth effect on employment. This induces a fall in the demand for money which, for a given supply of money, requires a rise in the price level to restore the equilibrium in the money market. Because of PPP, a relative rise in the domestic price level entails, unlike the Mundell-Fleming model, a one-to-one nominal depreciation. Hence the Obstfeld-Rogoff model predicts the observed nominal depreciation and the rise in the price level. Yet this happens for the "wrong" reason, since in the model the main channel operates through a *fall* in private consumption, in stark contrast with the estimated response of the latter emerging from our empirical analysis.

The consumption-real exchange rate comovement puzzle. The same mechanism explains the second, related puzzle. Because the very reason for the real exchange rate appreciation is the decline in private consumption, in all the models with complete asset markets reviewed above the real exchange rate and private consumption responses have negative signs. In the data, we do find that the signs of the private consumption and real exchange rate responses are the same, but they are both *positive.*

Models with complete asset markets also predict a positive correlation between the real exchange rate and private consumption conditional on a government spending shock. We find that the conditional correlation between the two variables is sometimes positive, sometimes negative (see Table 1); but even in the former case this is not supporting evidence for the model, because it happens for the "wrong" reasons: both private consumption and the real exchange rate increase after a government spending shock.[10]

The trade balance-real exchange rate comovement puzzle. In the model, the trade balance worsens while the real exchange rate appreciates in response to a government spending shock. In the data, we do tend to find a deterioration of the trade balance, but we find the opposite sign for the response of the real exchange rate.

8 Government Spending, Consumption and the Real Exchange Rate: the Role of Non-Separable Utility

Clearly, as long as we maintain the assumption of international risk-sharing, we cannot hope to resolve the puzzles above unless we can generate a positive response of private consumption to a government spending shock. Generating that response requires eliminating or at least mitigating the negative wealth effect of government spending on private consumption. This can be achieved by limiting the ability of the private sector to smooth consumption via asset markets, as in the model by Galí, López-Salido and Vallés (2006) where rule of thumb consumers who do not borrow or save coexist with standard optimizing agents. An alternative option preserves the assumption of complete asset markets but allows for non-separability in preferences between consumption and leisure, as in the closed economy models of Basu and Kimball (2002) and Linnemann (2005). We now show that extending the latter approach to an open economy framework helps explain the three puzzles we have pointed out above.

8.1 A Model with Non-Separable Utility

Suppose momentary utility is specified as follows:

$$U(C_t, L_t) = \frac{1}{1-\sigma} C_t^{1-\sigma}\; V(L_t) \qquad \sigma > 1 \tag{37}$$

[10] Any statement on the correlation between *relative* consumption and the real exchange rate is well-defined in the case of the small open economies belonging to our sample. In fact, if, in response to an innovation in government spending, domestic consumption rises and the real *effective* exchange rate depreciates, *relative* consumption rises as well, for rest-of-the world consumption is exogenous to domestic government spending innovations. However, in the case of the US, we need to implicitly (and realistically) assume that consumption in the rest of the world rises by less than US consumption in response to a US increase in government spending. We devote to future research the analysis of the international transmission of fiscal shocks.

where $L_t = 1 - N_t$ is leisure. King et al. (1998) show that $V(L_t)$ must be decreasing and convex to guarantee a balanced-growth path (i.e., steady-state consumption growth at constant leisure). We specify $V(L_t)$ to take the form $(1 - L_t)^{1+\varphi}$, with $\varphi > 0$. Note that this specification implies $U_{cl} < 0$, i.e., that consumption and employment are complements. Linnemann (2005) shows that, if the complementarity is strong enough, preferences as in (37) can deliver a positive effect of a government spending shock on private consumption within a standard neoclassical model. We review the basic argument here, and then show its implications for the response of the real exchange rate and the trade balance.

The marginal utility of wealth λ_t is now

$$\lambda_t = \frac{N_t^{1+\varphi}}{C_t^{\sigma}} \tag{38}$$

The risk-sharing condition linking the real-exchange rate to the international ratio of the marginal utilities of consumption (see also the Appendix) now becomes (expressed in log-linearized form):

$$q_t = \sigma c_t - (1 + \varphi) n_t \tag{39}$$

As a result, the equilibrium effect on the real exchange rate will depend crucially on the relative strength of the consumption and employment responses, which in turn depend on the values of the elasticities σ and φ.

These two parameters are not independent. In the Appendix we show that the steady state implies the following restriction:

$$\varphi = \mu^{-1} \frac{(\sigma - 1)(1 - \psi)}{c_y} \tag{40}$$

where c_y is the steady state share of consumption, μ is the steady state markup and, as before, ψ is the capital share in production (the coefficient of capital in the Cobb-Douglas production function). Hence, all else equal, φ is increasing in σ.

To study the effects of a government spending shock in this model, Figure 10 displays the effects of a government spending shock on selected variables under alternative values of the elasticity σ (which implies corresponding values of φ via the restriction (40)). We set the markup $\mu = 1.12$, the capital share $\psi = 0.36$, the steady-state share of consumption in output

$c_y = 0.5$, the share of government spending in output $g_y = 0.25$, the degree of openness $\alpha = 0.4$, and the trade elasticity $\eta = 1.5$ (see also the Appendix for more details). Given these parameter values, we then choose values of σ such that $\varphi > 0$ in (40).

Figure 10 shows clearly that the complementarity between consumption and employment entails a positive response of private consumption to a government spending shock. The intuition is straightforward: by the usual wealth effect, leisure and consumption fall following the increase in government spending. Because of the complementarity between consumption and employment, the higher employment increases the marginal utility of consumption; this induces a higher consumption *ceteris paribus*, and if the complementarity is strong enough, consumption increases in general equilibrium.[11]

What are the roles of σ and φ?[12] Figures 11 shows the effects of changing σ, holding φ constant: the impact response of private consumption and employment is an increasing function of σ. The reason is that σ is inversely related to the intertemporal elasticity of substitution in consumption, and that the real interest rate increases following the shock, because of the rise in inflation combined with a monetary policy rule such as (29) (recall that we assume $\phi_\pi > 1$, hence we are in the case of an *active* monetary policy). When the real rate increases, the consumer is induced to tilt her consumption path upward, i.e. to reduce current consumption relative to future consumption. For any given increase in the real interest rate, she will be willing to tilt her consumption path more, the higher is the intertemporal elasticity of substitution in consumption, i.e., the lower is σ. Hence, a lower σ implies a smaller positive effect on private consumption; the complementarity between consumption and employment means that the response of employment also is an increasing function of σ.

On the other hand, Figure 12 shows that, holding constant σ, a higher φ causes a lower

[11] Notice that -somehow more artificially- a similar effect may be induced by assuming a direct complementarity between private and public consumption in the utility function (as in Bouakkez and Rebei (2003)). For instance, by assuming preferences of the form $U\left(\widetilde{C}_t, N_t\right)$ where effective consumption is

$$\widetilde{C}_t \equiv [(1-\gamma)^{\frac{1}{\eta_g}} C_t^{\frac{\eta_g-1}{\eta_g}} + \gamma^{\frac{1}{\eta_g}} G_t^{\frac{\eta_g-1}{\eta_g}}]^{\frac{\eta_g}{\eta_g-1}}$$

and where $\eta_g > 0$ is the elasticity of substitution between private and domestic consumption. In this specification, C_t and G_t are perfect complements when $\eta_g \to 0$ and perfect substitutes when $\eta_g \to \infty$. A possible disadvantage of this approach is that it crucially requires that government spending yields utility whereas most of the existing models in the business cycle literature abstract from this specific case.

[12] The analysis of the effects of changes in σ and φ is based on Linnemann (2005).

impact effect on consumption and employment. Intuitively, a consumer with a higher φ has a higher curvature of the utility function in leisure; hence, she will be unwilling to decrease leisure much in response to the negative wealth effect caused by the increase in government spending; the complementarity effect on private consumption will be smaller, and the latter will increase less.

Thus, individually σ and φ have opposite effects on the impact response of private consumption. But because of the steady state restriction between these two parameters, when σ increases, φ must increase. From Figure 10, the resulting effect on consumption and employment is always positive (although not monotonic in σ).

8.2 The Real Exchange Rate and Trade Balance Responses

The effect on the real exchange rate is described by (39). The effect of a higher σ is in principle ambiguous: as σ increases (and therefore φ also increases via equation (40)), the effect on the term σc_t is ambiguous, since the response of c_t is decreasing in σ; the effect on the term $(1 + \varphi)n_t$ is also ambiguous, since the response of n_t is a negative function of φ. Figure 10 shows that, for sufficiently low values of σ, the real exchange rate *depreciates* in response to the government spending shock, in line with our empirical results. The conditional correlation between consumption and the real exchange rate remains positive, but now this happens for the "right" reason: in fact, the sign of the two responses individually is the same in the data and in the model.

It is clear that the general equilibrium restriction linking σ and φ in (40) is important for our results. If φ is kept constant, we have seen that the impact response of c_t is increasing in σ, and the term σc_t is unambiguously increasing in σ. Hence, in this case, it would be only for sufficiently high values of σ that the model generates a positive response of the real exchange rate.

Notice, though, that the model continues to exhibit a comovement between the real exchange rate and the trade balance which appears to be inconsistent with the data: when we specify preferences in such a way that the real exchange rate depreciates, the trade balance improves, contrary to our findings. However, we know from the baseline model with separable utility that the sign of the response of the trade balance hinges crucially on the value of the elasticity of substitution η. Figure 13 depicts the effects on the real exchange rate and on the trade balance of a government spending shock in the model with non-separable utility for alternative values of η. Throughout we assume $\sigma = 2$, a value that has been observed to generate a positive comovement between consumption and the real exchange rate in our earlier experiment. The figure shows that a low elasticity of substitution η now induces a fall in the trade balance, while a high η induces an improvement, the opposite than in the model with separable utilities. Importantly, varying η has no effect on the sign of the comovement between consumption and the real exchange rate.

The reason why the effect of varying η on the response of the trade balance to a spending shock is opposite in the model with non-separable utility relative to the baseline case is simple. The assumption of non-separable utility changes the relationship of the real exchange rate with the marginal utility of consumption (leading to the modified risk-sharing condition (39)). However, the link between the trade balance and the real exchange rate can still be described by an equation such as (22). In the latter expression, a value of $\eta < 1$ has the effect of switching the response of the real exchange rate into a response of the trade balance of opposite sign. Hence, since the model with non-separable utility induces a depreciation (rise) in the real exchange rate, it is not surprising that a value of $\eta < 1$ now determines a deterioration of the trade balance (with the opposite effect in the case $\eta > 1$).

Thus, in the model with non-separable utility, the combination of sufficiently low σ (sufficiently high intertemporal elasticity of substitution in consumption) and sufficiently low elasticity of substitution η can generate not only the right comovement between consumption and the real exchange rate, but also the right comovement between the latter variables and the trade balance.

The fact that this version of the model requires a value of η smaller than unity to generate also the right comovement between trade balance and real exchange rate may appear problematic. In fact, a value of $\eta > 1$ was previously required in our baseline model to generate the twin deficit result. However, the existing literature lacks a consensus on the value of this parameter. For instance, Backus et al. (1994), Chari et al. (2002), among many others, set $\eta = 1.5$. A recent series of studies employing Bayesian estimations of fully structural DSGE open macro models seem to support a range for η between 1.5 and 2: see, for instance, Justiniano and Preston (2006), De Walque, Smets and Wouters (2005), Rabanal and Tuesta (2005). On the other hand, Obsteld and Rogoff (1995) and Corsetti and Pesenti (2001) work under the assumption $\eta = 1$ (Cobb-Douglas). More recently, Corsetti and Dedola (2004), Burnside et al. (2004), and Corsetti, Dedola and Leduc (2005) explore ranges of η between 0.5 and 1.5, and argue in favor of values in the low end of the range based on the emphasized role for international product market segmentation.

8.3 Non-Separability, Rule-of-Thumb Consumers and the Open Economy

The recent literature investigating the effect of government spending on private consumption has pointed out a quasi-isomorphism between a modelling approach based on the role of so-called rule-of-thumb (ROT henceforth) consumers (i.e, agents who are prevented from engaging in consumption-smoothing, as in Galí et al. (2006)) and an approach based on non-separable utility (as in Linnemann (2005)). The intuition for this quasi-isomorphism lies in the form of the (aggregate) Euler consumption equation, which in both frameworks features a dependence of expected consumption growth on expected employment growth.[13]

While in closed economy models the two approaches have been shown to deliver similar implications in terms of the effects of government spending on private consumption, the same does not hold true in the open economy. Recently Erceg et al. (2005) analyze the effects of fiscal shocks on the trade balance and the real exchange rate in a last-generation NOEM model. Their model is parameterized to the US economy and includes several market frictions that are considered important for the ability of prototypical DSGE models to provide an adequate fit to the data. In a version of their model, and with the explicit goal of replicating the observed behavior of private consumption, Erceg et al. also include a role for ROT consumers. However, while successful on the front of generating a positive response of consumption, the simulations reported in Erceg et al. continue to generate a "standard" result on the real exchange rate,

[13] Galí et al. (2006) show that the model with ROT consumers delivers the same Euler equation as the model with non-separable utility, except that the former includes a term in anticipated tax changes. This difference can be exploited empirically: in a Campbell-Mankiw consumption equation, predictable changes in taxes are significant. Galí et al. (2006) interpret this as evidence in favor of a Rule-of-Thumb specification against a non-separable utility specification.

namely the latter invariably *appreciates* in response to a government consumption shock. In contrast to Erceg et al., a real exchange rate *depreciation* (and therefore a negative comovement with consumption) is instead a key implication of our model featuring non-separable utility.

The intuition why the introduction of ROT consumers *per se* cannot solve the consumption-real exchange rate anomaly emphasized in this paper works as follows. Recall that the tight relation between (relative) consumption and the real exchange rate is a typical implication of general equilibrium models with complete international financial markets. In the models of Galí et al. and Erceg et al., the positive response of consumption by ROT agents is key in generating the result that total private consumption rises in response to a positive government spending shock. But ROT consumers are simply prevented from accessing financial markets (both internally and, a fortiori, internationally); only the optimizing agents are the ones who engage in consumption smoothing, hence it is their consumption behavior that determines the movement of the real exchange rate via the risk sharing condition. But optimizing agents are still subject to a typical wealth effect on employment, which drives their consumption down: thus, the real exchange rate must appreciate even in the Erceg et al. model. In contrast, in our model with non-separable preferences, optimizing agents respond by rising consumption, and this is the key for generating a real exchange rate depreciation in line with our empirical evidence.

9 Conclusions

Rather than repeating the main results, we conclude by pointing out what we regard as the main limitations of this study. As we have emphasized throughout the paper, a "standard" model with complete asset markets (and with or without nominal rigidities) faces a fundamental difficulty: for it to explain the depreciation of the real exchange rate following a positive government spending shock, private consumption should fall, but in the data it increases. We have shown how assuming non-separable references in consumption and leisure can help reconcile the theory with the data, while preserving the assumption of complete asset markets. An alternative consists in giving up this last assumption; however, this will need some thinking, as we have seen that a straightforward extension to an open economy of a model with liquidity constrained consumers may not work in this respect.

Another extension that will require some thinking concerns productivity shocks. As first observed by Backus and Smith (1993), in the data the unconditional correlation between the real exchange rate and consumption is virtually zero. We have shown that the same correlation, conditional on a government spending shock, is positive; using also a structural VAR approach, Corsetti, Dedola and Leduc (2005) show that, conditional on a productivity shock, that correlation is negative: productivity shocks typically induce a real exchange rate appreciation. These results on the two conditional correlations, combined, are consistent with a zero unconditional correlation. A standard model with separable utility would have problems explaining the zero unconditional correlation. We have seen that the correlation conditional on a government spending shock is positive in that model, like in the data, although for the "wrong" reasons, as consumption falls and the real exchange rate appreciates. The correlation conditional on a productivity shock is also positive for a simple reason: the increase in wealth following the productivity shock reduces the marginal utility of wealth; consumption increases, and from the risk sharing condition (see also (39)), the real exchange rate depreciates, a result inconsistent with the VAR evidence. In our model with non-separable utility, we generate a positive correlation conditional on a government spending shock, although now for the "right" reasons; but the correlation conditional on a productivity shock is still also positive, as the mechanism highlighted above applies also to this model. Thus, some modification, like international price discrimination leading to incomplete pass-through along the lines of Corsetti and Dedola (2004), will be necessary to generate an appreciation of the real exchange rate.

Our interest was mainly in uncovering the main qualitative comovements of the real exchange rate, the trade balance and private consumption, and in confronting these with the benchmark NOEM models. Thus, we have not tried to build a DSGE to confront with the data, but only a model that would be consistent with the signs of the main responses. For the same reason, we have not tried to explain the quantitative differences between the responses among the different countries. We believe at the present stage this would be a rather difficult exercise: for instance, in all models with forward-looking agents, complete asset markets, and separable utility, the response of private consumption is smaller (in an algebraic sense) the larger the wealth effect, hence the higher the persistence of the government spending shock. However, in our results, the

US tends to have the more persistent government spending process, but it also has the largest private consumption response. Clearly the wealth effect is not a good starting point to explain private consumption if the response of the latter is positive.

Thus, we believe it would be premature to try and fit a model to the several responses we have studied. Our goal was more limited: to point out what we regard as three important empirical puzzles from the point of view of the mainstream open economy models, and to indicate a direction that appears compatible with the solution of these puzzles, at least qualitatively.

Appendix: A Sticky Price Optimizing Open Economy Model

A.1 The model without capital

As in Galí and Monacelli (2005), the world is composed by a continuum of countries, each of measure zero, and indexed by a symmetric degree of home bias in consumption. Each country produces (and specializes in) a continuum of differentiated goods, represented by the unit interval. The household in the representative domestic economy seeks to maximize

$$E_0 \sum_{t=0}^{\infty} \beta^t \; U(C_t, N_t) \tag{A. 1}$$

where N_t denotes hours of labor, and C_t is a composite consumption index defined by

$$C_t \equiv \left[(1-\alpha)^{\frac{1}{\eta}} \; (C_{H,t})^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} \; (C_{F,t})^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \tag{A. 2}$$

where $C_{H,t}$ is an index of consumption of domestic goods given by the CES function $C_{H,t} \equiv \left(\int_0^1 C_{H,t}(j)^{\frac{\varepsilon-1}{\varepsilon}} \; dj \right)^{\frac{\varepsilon}{\varepsilon-1}}$, with $j \in [0,1]$ denoting the good variety, $C_{F,t}$ is an index of imported goods given by $C_{F,t} \equiv \left(\int_0^1 (C_{i,t})^{\frac{\eta-1}{\eta}} \; di \right)^{\frac{\eta}{\eta-1}}$ where $C_{i,t}$ denotes the quantity of goods *imported* from country i and consumed by domestic households. It is given by an analogous CES function $C_{i,t} \equiv \left(\int_0^1 C_{i,t}(j)^{\frac{\varepsilon-1}{\varepsilon}} \; dj \right)^{\frac{\varepsilon}{\varepsilon-1}}$ where $\varepsilon > 1$ denotes the elasticity of substitution between varieties (produced within any given country). Parameter $\alpha \in [0,1]$ is (inversely) related to the degree of home bias in preferences, and is thus a natural index of openness. Parameter $\eta > 0$ measures the substitutability between domestic and foreign goods, as well as the substitutability between goods produced in different foreign economies.

Demand for Each Variety The optimal allocation of any given expenditure within each category of goods yields the demand functions: $C_{H,t}(j) = \left(\frac{P_{H,t}(j)}{P_{H,t}} \right)^{-\varepsilon} C_{H,t}$ and $C_{i,t}(j) = \left(\frac{P_{i,t}(j)}{P_{i,t}} \right)^{-\varepsilon} C_{i,t}$ for all $i, j \in [0,1]$, where $P_{H,t} \equiv \left(\int_0^1 P_{H,t}(j)^{1-\varepsilon} \; dj \right)^{\frac{1}{1-\varepsilon}}$ is the *domestic* price index and $P_{i,t} \equiv \left(\int_0^1 P_{i,t}(j)^{1-\varepsilon} \; dj \right)^{\frac{1}{1-\varepsilon}}$ is a price index for goods imported from country i (expressed in domestic currency), for all $i \in [0,1]$.

Demand for Imports The optimal allocation of expenditures on imported goods by country of origin implies:

$$C_{i,t} = \left(\frac{P_{i,t}}{P_{F,t}}\right)^{-\eta} C_{F,t} \tag{A. 3}$$

for all $i \in [0,1]$, and where $P_{F,t} \equiv \left(\int_0^1 P_{i,t}{}^{1-\eta}\, di\right)^{\frac{1}{1-\eta}}$ is the price index for imported goods (expressed in domestic currency).

Allocation between Domestic and Foreign Goods The optimal allocation of expenditures between domestic and imported goods is given by:

$$C_{H,t} = (1-\alpha)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t \quad ; \quad C_{F,t} = \alpha\left(\frac{P_{F,t}}{P_t}\right)^{-\eta} C_t \tag{A. 4}$$

where $P_t \equiv [(1-\alpha)\ (P_{H,t})^{1-\eta} + \alpha\ (P_{F,t})^{1-\eta}]^{\frac{1}{1-\eta}}$ is the consumer price index (CPI).

Government Expenditure Home country's *public consumption* index is given by

$$G_{H,t} \equiv \left(\int_0^1 G_{H,t}(j)^{\frac{\epsilon-1}{\epsilon}} dj\right)^{\frac{\epsilon}{\epsilon-1}} \tag{A. 5}$$

here $G_{H,t}(j)$ is the quantity of domestic good j purchased by the government. Government purchases are fully allocated to domestically produced goods. For any given level of public consumption $G_{H,t}$, the government allocates expenditures across goods in order to minimize total cost. This yields the following set of government demand schedules, analogous to those associated with private consumption:

$$G_{H,t}(j) = \left(\frac{P_{H,t}(j)}{P_{H,t}}\right)^{-\epsilon} G_{H,t} \tag{A. 6}$$

Efficiency Conditions Under the assumption of a standard separable utility function $U(C,N) \equiv \frac{C^{1-\sigma}}{1-\sigma} - \frac{N^{1+\varphi}}{1+\varphi}$ the remaining optimality conditions for the household's problem as follows:

$$C_t^{\sigma}\ N_t^{\varphi} = \frac{W_t}{P_t} \tag{A. 7}$$

$$\beta \left(\frac{C_{t+1}}{C_t}\right)^{-\sigma} \left(\frac{P_t}{P_{t+1}}\right) = \nu_{t,t+1} \tag{A. 8}$$

where $\nu_{t,t+1}$ is the price of a state-contingent asset expressed in units of domestic currency. Taking conditional expectations on both sides of (A. 8) and rearranging terms we obtain:

$$\beta R_t \; E_t \left\{ \left(\frac{C_{t+1}}{C_t}\right)^{-\sigma} \left(\frac{P_t}{P_{t+1}}\right) \right\} = 1 \tag{A. 9}$$

where $R_t \equiv \frac{1}{E_t\{\nu_{t,t+1}\}}$ is the gross return on a riskless one-period discount bond which pays off one unit of domestic currency in $t+1$ and $E_t\{\nu_{t,t+1}\}$ is its price.

Risk Sharing With complete financial markets, a first order condition analogous to (A. 8) must also hold for the representative household in any country i

$$\beta \left(\frac{C^i_{t+1}}{C^i_t}\right)^{-\sigma} \left(\frac{P^i_t}{P^i_{t+1}}\right) \left(\frac{\mathcal{E}^i_t}{\mathcal{E}^i_{t+1}}\right) = \nu_{t,t+1} \tag{A. 10}$$

where $\mathcal{E}^i_t$ is the nominal exchange rate between Home and country i (i.e., the price of country i's currency expressed in units of Home currency). Combining (A. 8) and (A. 10), iterating and normalizing the initial distribution of wealth to be symmetric across each pair of countries, we obtain

$$\left(\frac{C_t}{C^i_t}\right)^{\sigma} = Q^i_t$$

where $Q^i_t \equiv \frac{\mathcal{E}^i_t P^i_t}{P_t}$ is the (CPI-based) real exchange rate between Home and country i. Integrating over i we obtain the following log-linear risk-sharing condition

$$c_t = c^*_t + \sigma^{-1} \, q_t$$

where $c^*_t \equiv \int_0^1 c^i_t \, di = y^*_t$ is world consumption (in log terms) and $q_t \equiv \int_0^1 q^i_t \, di = \log Q_t$ is the log real effective exchange rate, with $q^i_t \equiv \log Q^i_t$ and $Q_t \equiv \exp \int_0^1 q^i_t$. The above equation corresponds to (17) in the text.

Marginal Cost and Price Setting A typical firm j in the home economy produces a differentiated good with a linear technology represented by the production function $Y_t(j) =$

$N_t(j)$. The (log) real marginal cost (expressed in terms of domestic prices) is common across domestic firms and given by

$$mc_t = w_t - p_{H,t} \tag{A. 11}$$

We assume that firms set prices in a staggered fashion, as in Calvo (1983). The optimal price-setting strategy for the typical firm resetting its price in period t can be approximated by the (log-linear) rule:

$$\overline{p}_{H,t} = \mu + (1-\beta\vartheta)\sum_{k=0}^{\infty}(\beta\vartheta)^k\ E_t\{mc_{t+k} + p_{H,t}\} \tag{A. 12}$$

where $\overline{p}_{H,t}$ denotes the (log) of newly set domestic prices, and $\mu \equiv \log\left(\frac{\varepsilon}{\varepsilon-1}\right)$, which corresponds to the log of the (gross) markup in the steady state.[14]

Market Clearing Goods market clearing in the Home small open economy requires

$$\begin{aligned} Y_t(j) &= C_{H,t}(j) + \int_0^1 C^i_{H,t}(j)\ di \qquad \text{(A. 13)} \\ &= \left(\frac{P_{H,t}(j)}{P_{H,t}}\right)^{-\varepsilon}\left[(1-\alpha)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t + \alpha\int_0^1\left(\frac{P_{H,t}}{\mathcal{E}_{i,t}P^i_{F,t}}\right)^{-\eta}\left(\frac{P^i_{F,t}}{P^i_t}\right)^{-\eta} C^i_t\ di\right] + G_{H,t} \end{aligned}$$

for all $j \in [0,1]$ and all t, where $C^i_{H,t}(j)$ denotes country i's demand for good j produced in the home economy (i.e., domestic exports of variety j). The second equality has made use of (A. 4) and (A. 3) together with our assumption of symmetric preferences across countries, which implies $C^i_{H,t}(j) = \alpha\left(\frac{P_{H,t}(j)}{P_{H,t}}\right)^{-\varepsilon}\left(\frac{P_{H,t}}{\mathcal{E}^i_t P^i_{F,t}}\right)^{-\eta}\left(\frac{P^i_{F,t}}{P^i_t}\right)^{-\eta} C^i_t$.

Plugging (A. 13) into the definition of aggregate domestic output $Y_t \equiv \left[\int_0^1 Y_t(j)^{1-\frac{1}{\varepsilon}}\ dj\right]^{\frac{\varepsilon}{\varepsilon-1}}$ we obtain:

$$\begin{aligned} Y_t &= (1-\alpha)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t + \alpha\int_0^1\left(\frac{P_{H,t}}{\mathcal{E}_{i,t}P^i_{F,t}}\right)^{-\eta}\left(\frac{P^i_{F,t}}{P^i_t}\right)^{-\eta} C^i_t\ di + G_{H,t} \\ &= \left(\frac{P_{H,t}}{P_t}\right)^{-\eta}\left[(1-\alpha)\ C_t + \alpha\int_0^1 (Q^i_t)^{\eta}\ C^i_t\ di\right] + G_{H,t} \\ &= \left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t\ \left[(1-\alpha) + \alpha\int_0^1 (Q^i_t)^{\eta-\frac{1}{\sigma}}\ di\right] + G_{H,t} \qquad \text{(A. 14)} \end{aligned}$$

Log-linearizing equation (A. 14) around a zero inflation steady-state in which net exports are zero yields (12) in the text.

[14] See Gali and Monacelli (2005) for a derivation.

A.2 Adding Capital and Investment

We assume that households hold the capital stock and rent it to firms in a perfectly competitive rental market. The Home household budget constraint reads in this case

$$\int_0^1 P_{H,t}(j)C_{H,t}(j)\ dj + \int_0^1\int_0^1 P_{i,t}(j)C_{i,t}(j)\ dj\ di + E_t\{\nu_{t,t+1}D_{t+1}\} \leq D_t + W_tN_t + Z_tK_t + P_tT_t \tag{A. 15}$$

where Z_t is the nominal rental cost of capital and T_t are real net transfers/taxes rebated to consumers.

Capital accumulation is subject to adjustment costs and is driven by

$$K_{t+1} = (1-\delta)K_t + \Phi\left(\frac{I_t}{K_t}\right)I_t \tag{A. 16}$$

where $\Phi\left(\frac{I_t}{K_t}\right)$ is a function increasing and concave ($\Phi'' < 0$), which satisfies $\Phi\left(\frac{I}{K}\right) = \delta$ and $\Phi'\left(\frac{I}{K}\right) = 1$ in the deterministic steady state.

Let's define by $\beta^t\chi_t$ and $\beta^t\chi_t\Lambda_{q,t}$ the Lagrange multipliers on constraints (A. 15) and (A. 16) respectively. Households efficiency conditions will now include the following equations:

$$\Lambda_{q,t} = \left[\Phi'\left(\frac{I_t}{K_t}\right)\right]^{-1} \tag{A. 17}$$

$$\Lambda_{q,t} = \beta E_t\left\{\frac{\chi_{t+1}}{\chi_t}\left[\frac{Z_{t+1}}{P_{t+1}} + \Lambda_{q,t+1}\left((1-\delta) + \Phi\left(\frac{I_{t+1}}{K_{t+1}}\right) - \Phi'\left(\frac{I_{t+1}}{K_{t+1}}\right)\frac{I_{t+1}}{K_{t+1}}\right)\right]\right\} \tag{A. 18}$$

where $\Lambda_{q,t}$ has the interpretation of the real shadow price of capital (or Tobin's q).

Notice that efficiency also requires

$$1 = \beta E_t\left\{\frac{\chi_{t+1}}{\chi_t}\frac{R_t\ P_t}{P_{t+1}}\right\} \tag{A. 19}$$

Log-linearization of (A. 16), (A. 17), (A. 18), (A. 19) around the deterministic steady state leads to (31), (32) and (33) in the text.

On the firm's side, we assume that production is conducted by means of the Cobb-Douglas function $Y_t = K_t^{\psi}N_t^{1-\psi}$. Efficiency conditions therefore include expressions for cost minimizing demand of capital and labor

$$\frac{Z_t}{P_t}h(S_t) = mc_t\ \psi\left(\frac{N_t}{K_t}\right)^{1-\psi} \tag{A. 20}$$

$$\frac{W_t}{P_t} h(S_t) = mc_t \ (1-\psi) \left(\frac{K_t}{N_t}\right)^{\psi} \tag{A. 21}$$

where $h(S_t) \equiv \frac{P_t}{P_{H,t}} = [(1-\alpha) \ + \alpha \ (S_t)^{1-\eta}]^{\frac{1}{1-\eta}}$ with $h^{'}(S_t) > 0$. Notice, in particular, that up to first order, $h(S_t) \simeq \alpha \ s_t$, an approximation which is useful in deriving the log-linearized version of our model. Notice also that movements in the terms of trade affect both the demand of capital and labor.

A.3 The Steady-State under Non-Separable Utility

Consider the utility specification $\frac{1}{1-\sigma} C^{1-\sigma} \ N^{1+\varphi}$ and the production function $Y = K^{\psi} N^{1-\psi}$. Firm's efficiency conditions and the definition of the rental cost imply the output-capital ratio reads

$$\frac{Y}{K} = \frac{\beta^{-1} - 1 + \delta}{\mu^{-1}\psi} \tag{A. 22}$$

In turn, the production function implies that the capital-labor ratio is

$$\frac{K}{N} = \left(\frac{Y}{K}\right)^{\frac{1}{\psi-1}} = \left(\frac{\beta^{-1} - 1 + \delta}{\mu^{-1}\psi}\right)^{\frac{1}{\psi-1}} \tag{A. 23}$$

Using the intratemporal consumption/leisure condition $\frac{W}{P} = \frac{1+\varphi}{\sigma-1}\frac{C}{N}$, one can write the consumption-employment ratio as follows

$$\frac{C}{N} = \left(\frac{\sigma-1}{1+\varphi}\right) \mu^{-1}(1-\psi) \left(\frac{K}{N}\right)^{\psi} \tag{A. 24}$$

At the same time, market clearing (with investment) implies:

$$\left(\left(\frac{K}{N}\right)^{\psi} - \delta\frac{K}{N}\right) N - G = C \tag{A. 25}$$

Combining (A. 24) and (A. 25) we obtain the following expression for steady-state employment

$$N = \frac{G}{\left(\frac{K}{N}\right)^{\psi}\left[1 - \left(\frac{\sigma-1}{1+\varphi}\right)\mu^{-1}(1-\psi)\right] - \delta\frac{K}{N}} \tag{A. 26}$$

where $\frac{K}{N}$ is given from (A. 23).

Notice also that from (A. 24) we have that the consumption-output ratio reads

$$\gamma_c \equiv \frac{C}{Y} = \frac{\frac{C}{N}}{\left(\frac{K}{N}\right)^{\psi}} = \left(\frac{\sigma-1}{1+\varphi}\right) \mu^{-1}(1-\psi)$$

For any given value of γ_c, this gives us the following steady-state restriction linking σ and φ

$$\varphi = \frac{\mu^{-1}(\sigma - 1)(1 - \psi)}{\gamma_c} - 1 \tag{A. 27}$$

In our benchmark calibration, we parameterize c_y rather than (as usual) the capital depreciation rate. The value of δ implied by this calibration can be backed out as follows:

$$\delta = \frac{1 - \gamma_c - \gamma_g}{\frac{K}{Y}} \tag{A. 28}$$

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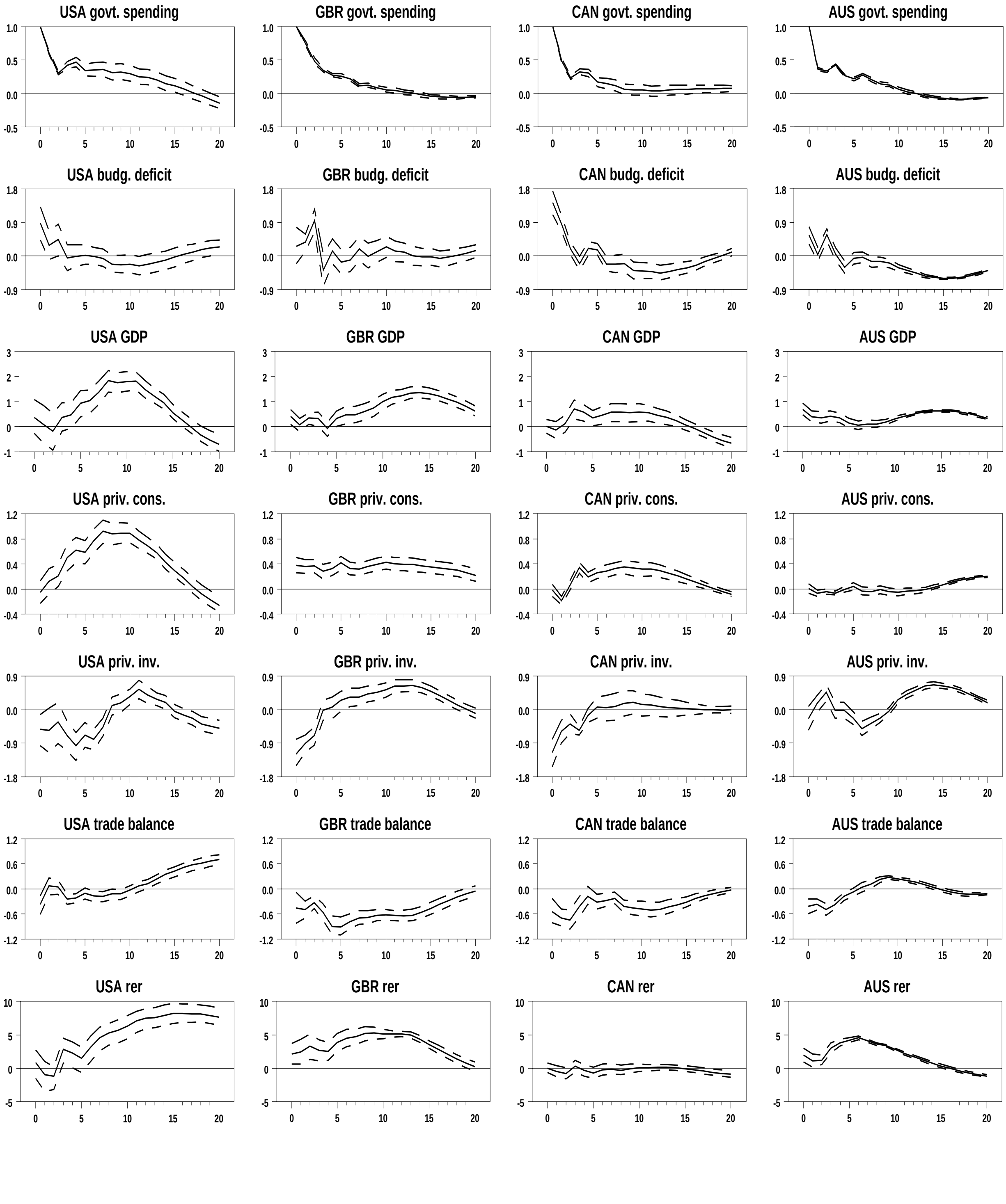

Figure 1: Baseline impulse responses

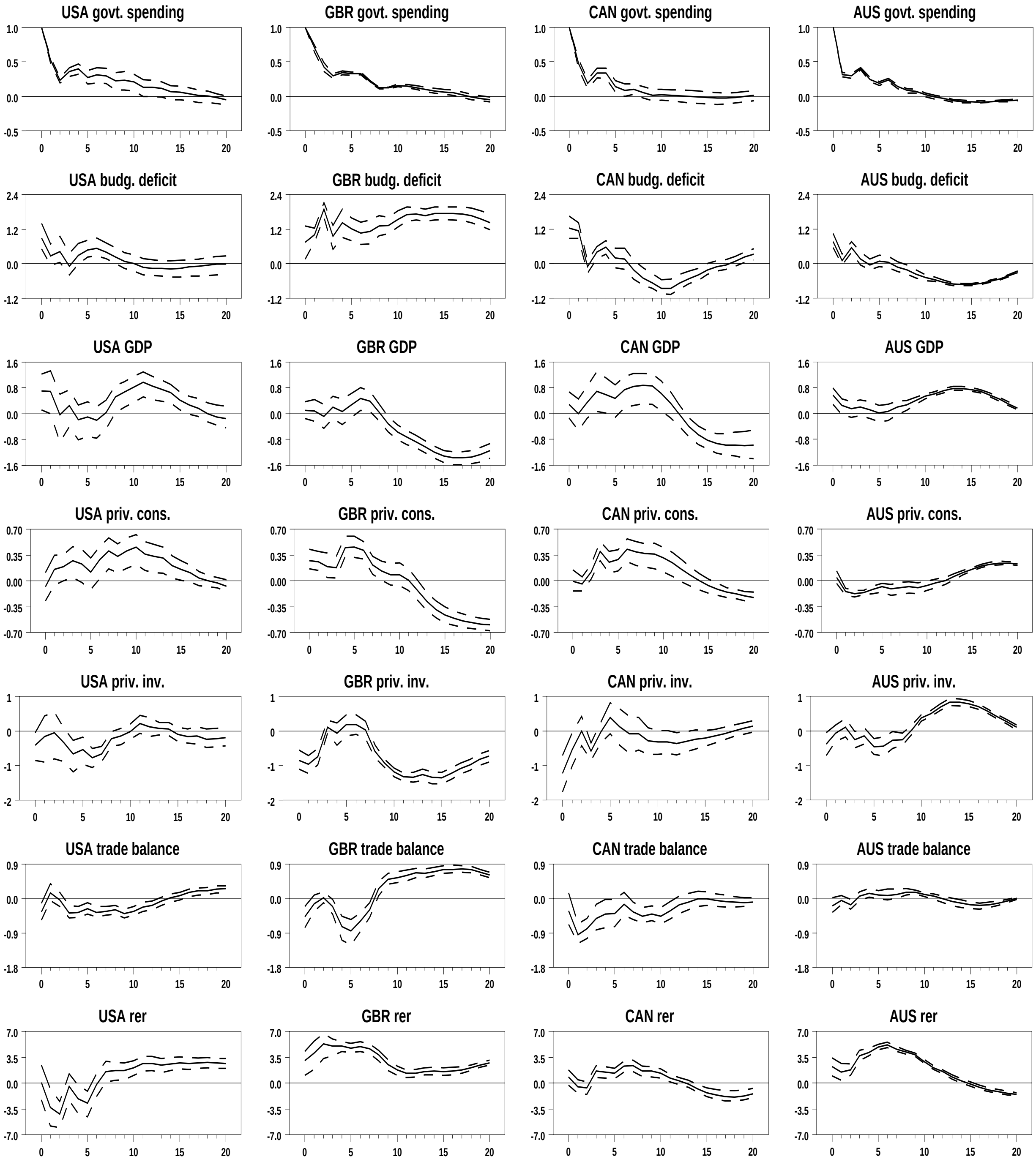

Figure 2: Sample starts 1980:1

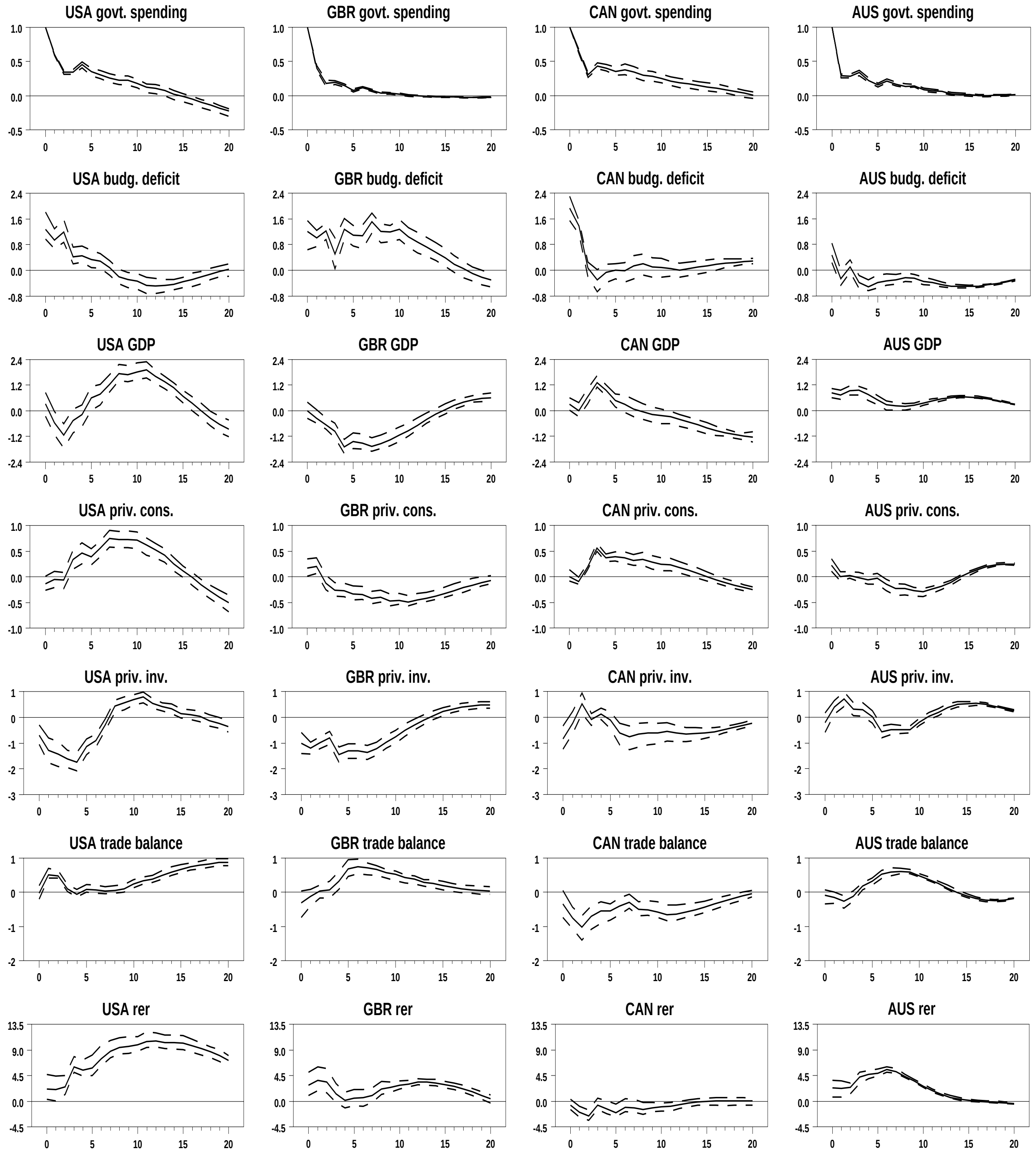

Figure 3: Government spending deflator

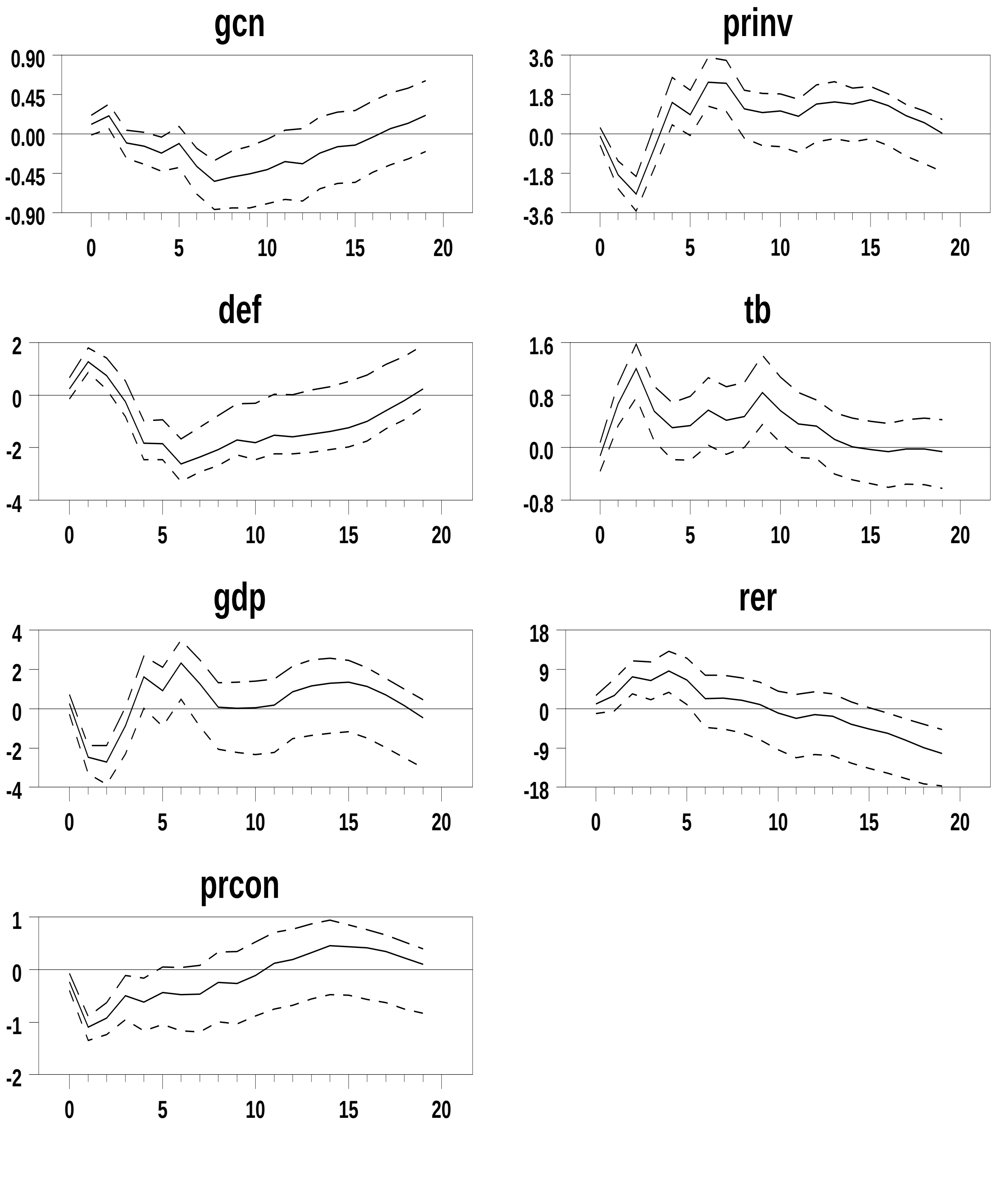

Figure 4: Shock to 1980:1 dummy variable

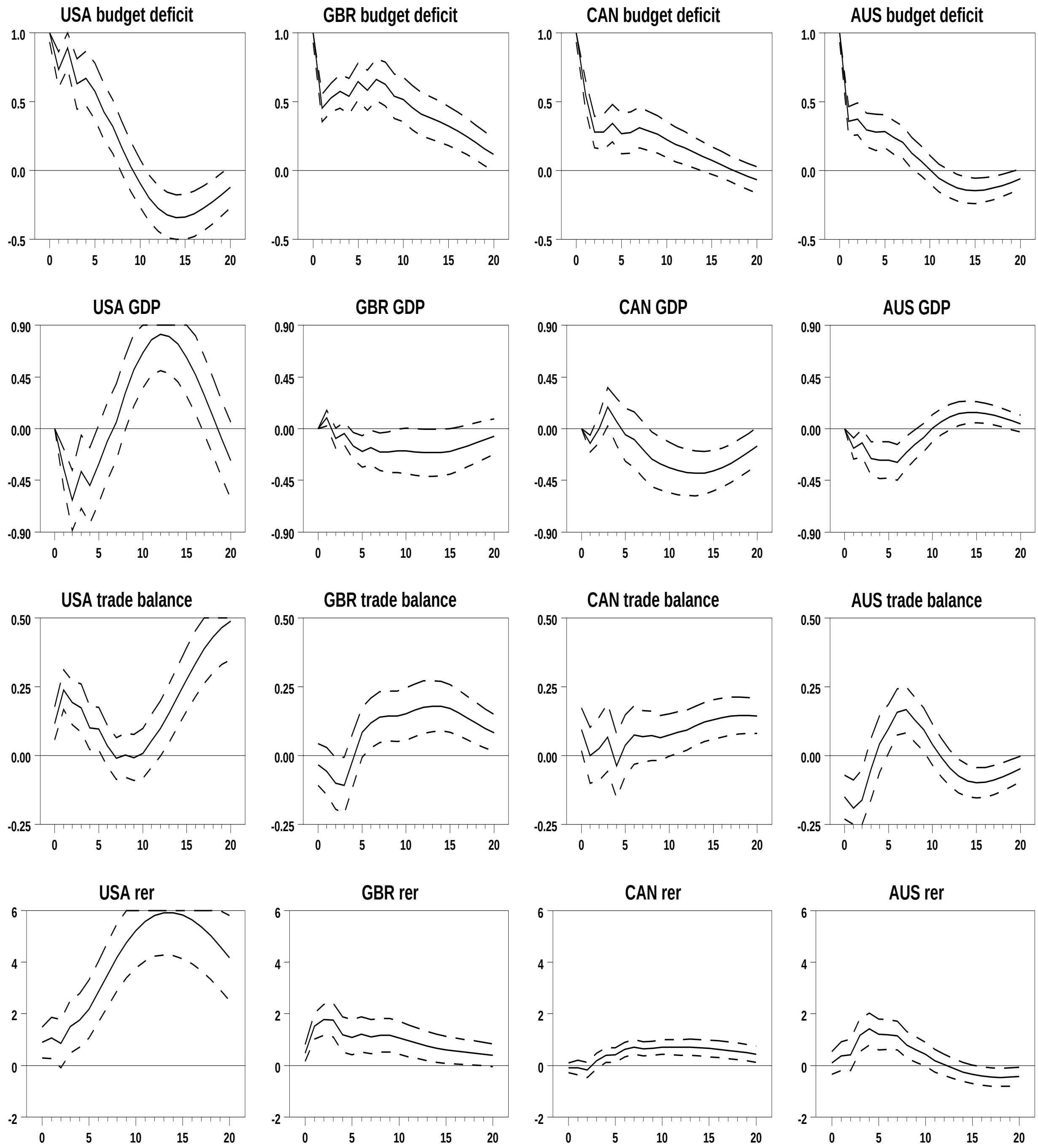

Figure 5: Kim and Roubini identification

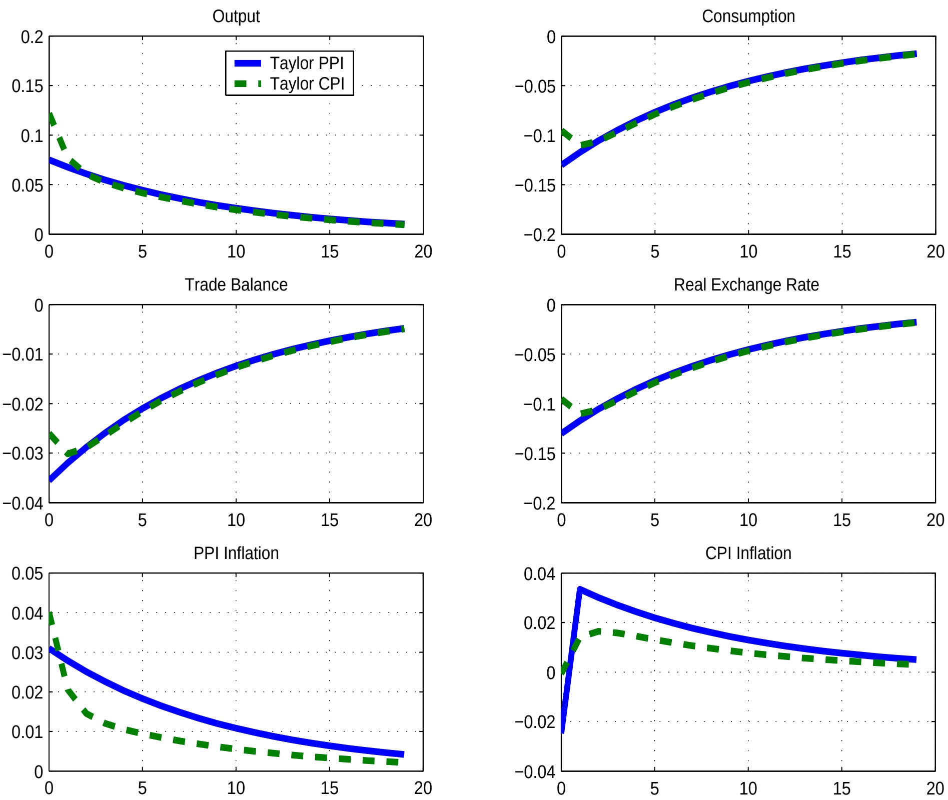

Figure 6: Responses to a Government Spending Shock: Baseline Model

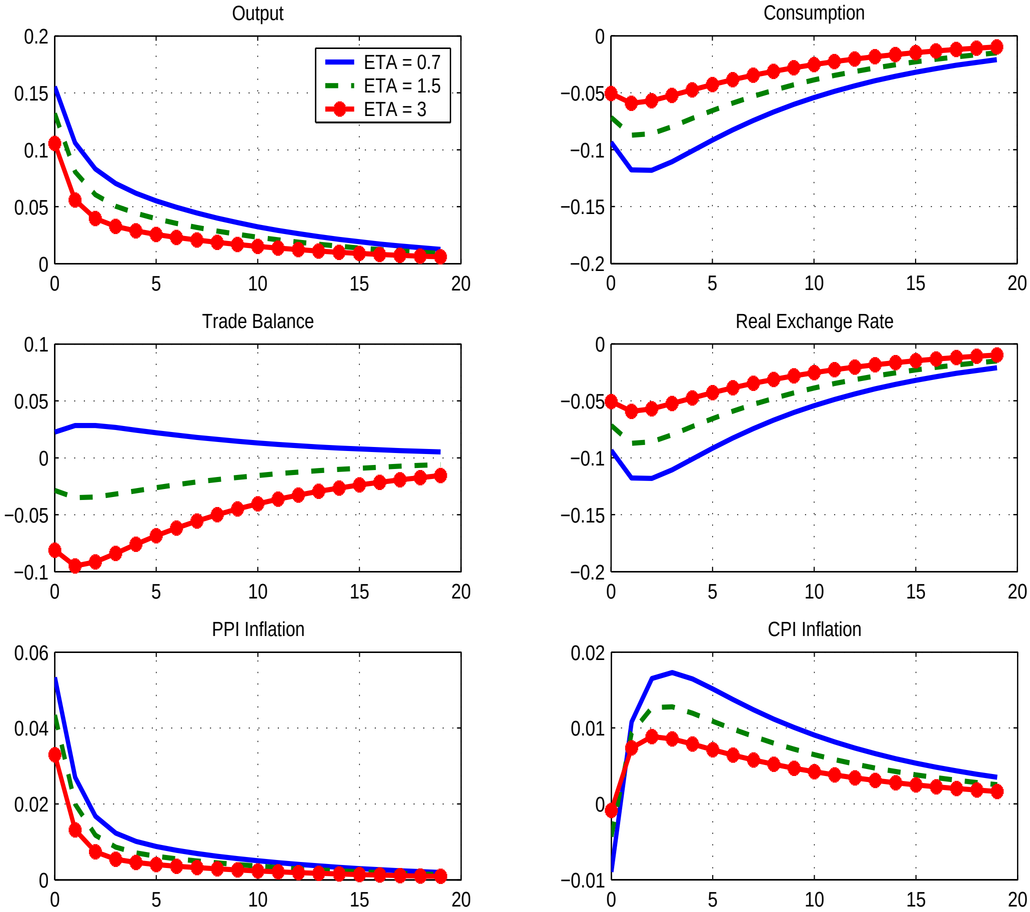

Figure 7: Responses to a Government Spending Shock in the Baseline Model: Effect of Varying the Elasticity of Substitution between Domestic and Foreign Goods η.

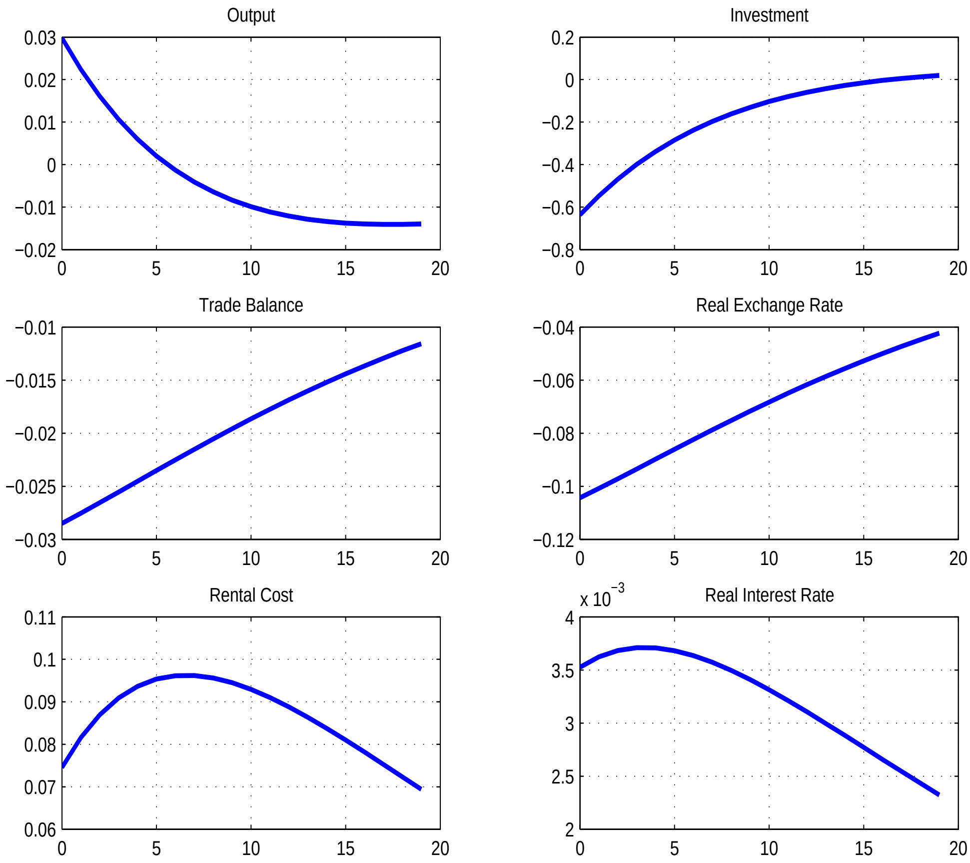

Figure 8: Responses to a Government Spending Shock: Model with Investment.

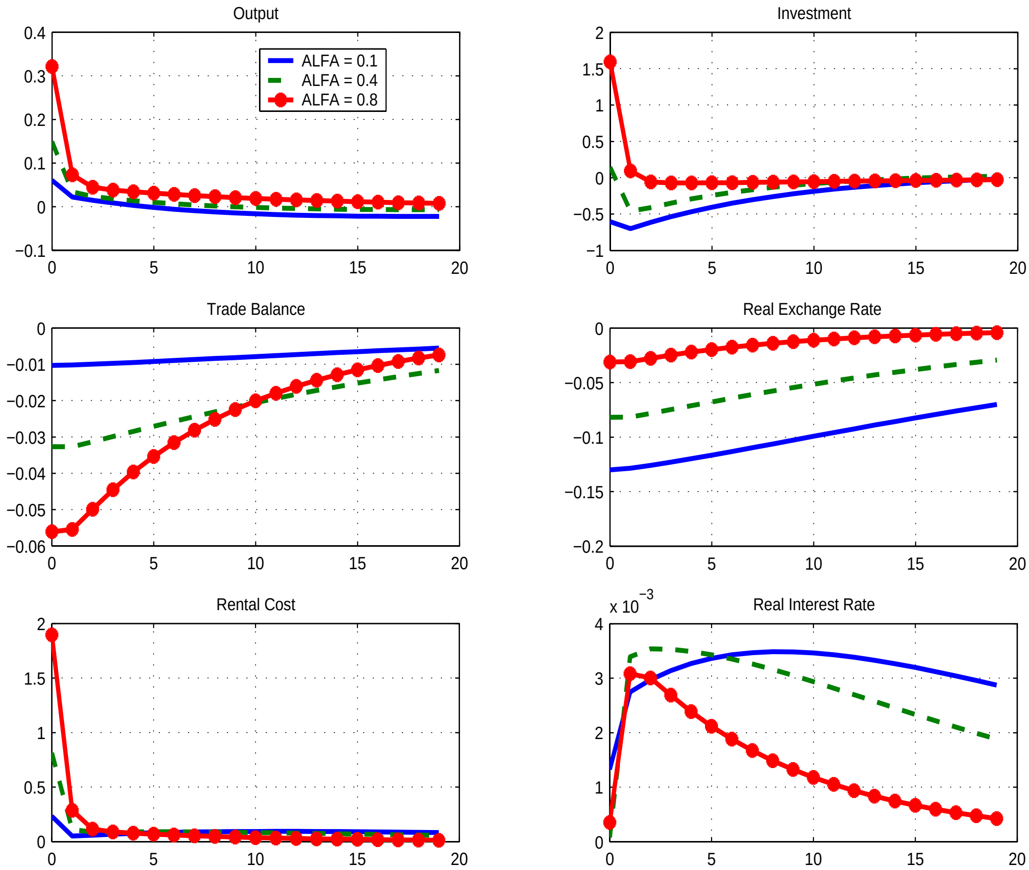

Figure 9: Responses to a Government Spending Shock in the Model with Investment: Effect of Varying the Degree of Openness α.

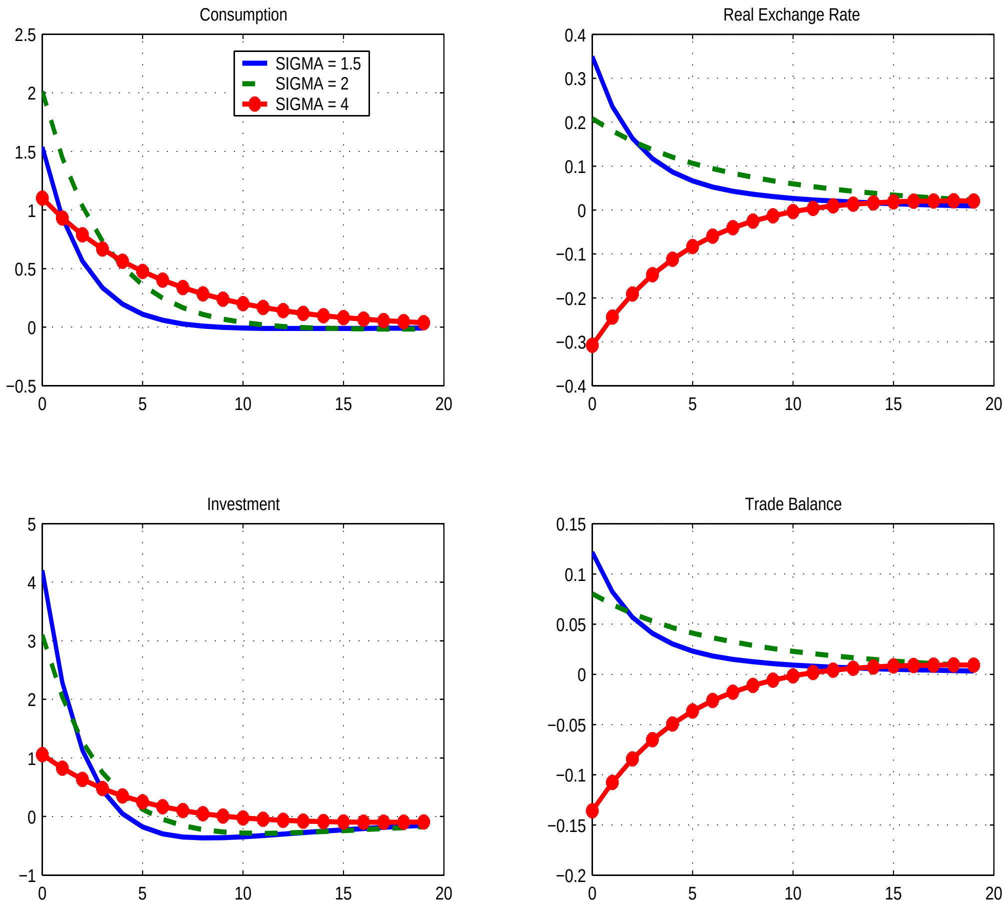

Figure 10: Responses to a Government Spending Shock in the Model with Investment and Non-Separable Utility: The Role of the Intertemporal Consumption Elasticity σ.

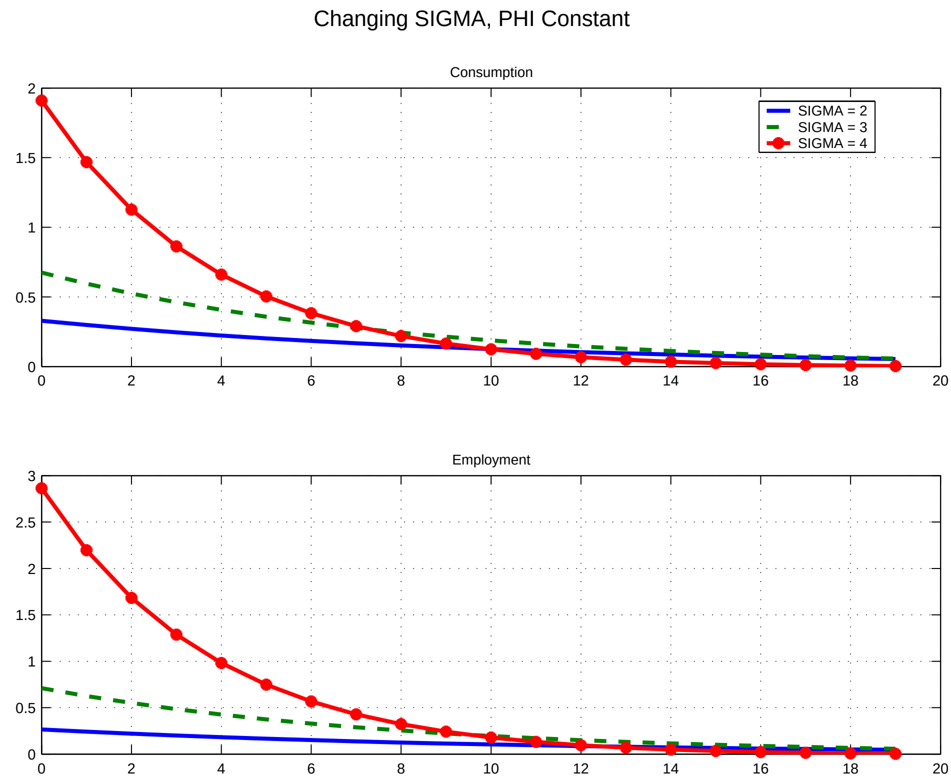

Figure 11: Responses to a Government Spending Shock in the Model with Non-Separable Utility: Effect of Alternative Values of σ, with φ Constant.

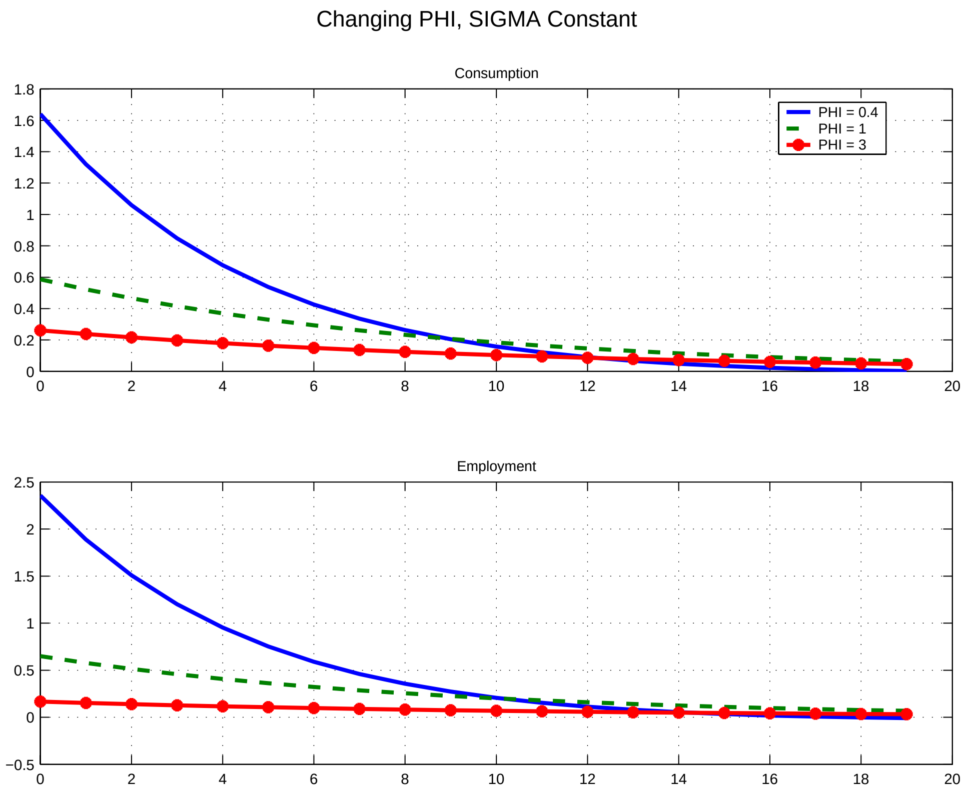

Figure 12: Responses to a Government Spending Shock in the Model with Non-Separable Utility: Effect of Alternative Values of φ, with σ Constant.

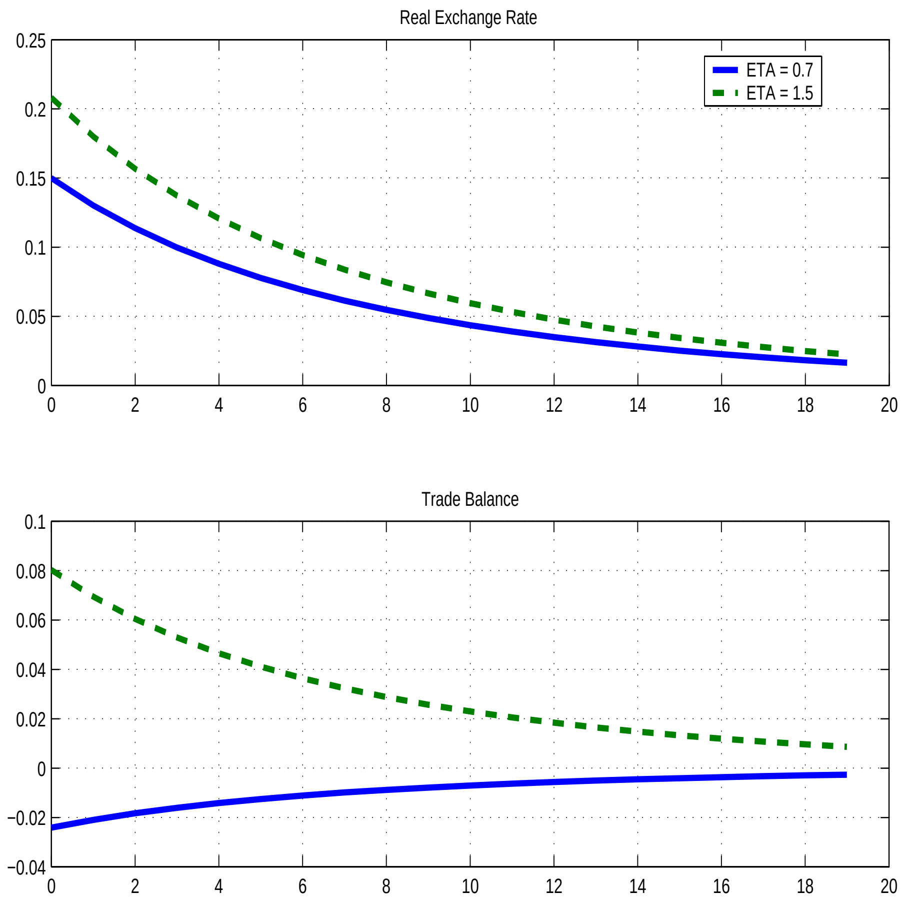

Figure 13: Responses to a Government Spending Shock in the Model with Non-Separable Utility: The Role of the Elasticity of Substitution between Domestic and Foreign Goods η.