

# AUSTERITY IN THE AFTERMATH OF THE GREAT RECESSION.\*

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## Abstract

This paper examines the effects of austerity on economic performance in advanced economies since the Great Recession (2010-2014). We define austerity shocks as reductions in government purchases that are larger than predicted declines implied by reduced-form forecasting regressions. In the cross section, austerity shocks are statistically associated with lower real per capita GDP, lower GDP growth, lower inflation and higher net exports. We estimate a cross-section multiplier (the impact of government purchases on output) that is substantially greater than 1 but find little evidence of spillovers (an impact of government purchases on foreign output). A multi-country DSGE model calibrated to the economies in Europe and the United States generates a multiplier consistent with its empirical counterpart. Counterfactuals suggest that the elimination of austerity would have cut output losses in the euro area in half. Austerity shocks were sufficiently contractionary that debt to GDP ratios in some European countries increased as a consequence of the endogenous reduction in GDP and tax revenue.

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# 1 Introduction

The economies in Europe contracted sharply and almost synchronously during the global financial crisis. In the aftermath of the crisis, however, economic performance has varied. An open question is whether differences in rates of recovery are due to differences in the severity of external shocks, the policy reactions to the shocks or the economic conditions at the time of the crisis. The financial press and many economists have attributed at least some of the slow rate of recovery to austerity policies that cut government expenditures and increased tax rates at precisely the time when faltering economies required stimulus. This paper shows that contractions in government purchases can in fact account for much of the divergence in national economic performance since the Great Recession.

Figure 1 plots real per capita GDP for 29 countries including the U.S., countries in the European Union, Switzerland, and Norway. The data is normalized so that per capita GDP is 100 in 2009:2 for every country. The figure also plots per capita GDP for the European aggregate. Overall, the aggregate European experience is similar to that of the United States. This similarity, however, masks a tremendous amount of variation across Europe. At one end of the spectrum is Greece for which the "recovery" never began. Greek per capita income at the end of 2014 is more than 25 percent below its 2008 level. While Greece's GDP performance is exceptionally negative, a contraction in GDP over this period is not unique. About a third of the countries in this sample have end-2014 levels of real per capita GDP below their 2008 levels. At the other end of the spectrum is Lithuania. Like Greece, Lithuania experienced a strong contraction during the Great Recession. However, it then returned to a rapid rate of growth quickly thereafter.

Our goal is to document cross-country differences in economic performance since 2010 and to study the extent to which the differences can be explained by macroeconomic policy. We do not attempt to explain the Great Recession and its transmission - rather, we focus on the divergence in the paths of economic recovery after the crisis. We first construct measures of austerity shocks that occurred during the 2010 to 2014 period. We find that austerity in government purchases - a reduction in government purchases that is larger than that implied by reduced-form forecasting regressions - is statistically associated with below forecast GDP in the cross-section. The negative relationship between austerity in government purchases and GDP is robust to the method used to forecast both GDP and government purchases in the 2010 to 2014 period, and holds for countries with fixed exchange rates and flexible exchange

rates.

In addition to the negative relationship with GDP, austerity in government purchases is negatively associated with consumption, investment, GDP growth and inflation. In terms of international variables, a shortfall in government purchases is associated with an increase in net exports and a depreciation of the trade-weighted nominal exchange rate. In general, these relationships are robust to the country's exchange rate regime though, not surprisingly, the impact on exchange rates is smaller and the impact on net exports larger for countries within the euro area and those with exchange rates fixed to the euro. We find a cross-sectional multiplier on government purchases that is greater than one. However, in contrast to other studies (see e.g. Auerbach and Gorodnichenko, 2012) we find little evidence of spillover effects (the impact of austerity shocks on foreign output).

We develop a multi-country DSGE model to make direct comparisons between the observed empirical relationships and the predictions from the model. The model features trade in intermediate goods, sticky prices, hand-to-mouth consumption, and financial frictions that drive a wedge between the marginal product of capital and the frictionless user cost of capital. The model is calibrated to reflect relative country size, observed trade flows and financial linkages, and the country's exchange rate regime. The model incorporates shocks to government purchases, shocks to the cost of credit and monetary policy shocks. We focus on these three shocks because there is broad agreement that these factors played an important role in shaping the reaction to the Great Recession. We then compare the model's predictions for macroeconomic aggregates with actual data in the 2010-2014 period.

The benchmark model generates predictions that are consistent with the data. In both the cross-sectional data and in the model, a one percent reduction in government purchases is associated with a two percent reduction in GDP. As in the data, the model also generates a positive relationship between austerity and net exports and a strong negative relationship between austerity and inflation. Among the features that are essential to generating large spending multipliers are hand-to-mouth consumption, consumption-labor complementarity in the utility function (Greenwood, Hercowitz and Huffman 1988) and significant trade linkages.

We use the model to conduct a number of counterfactual experiments. The model suggests that had countries not experienced austerity shocks, aggregate output in the euro area would have been only 1 percent below trend by the end of 2014 rather than nearly 9 percent below trend in the data and in the benchmark model. The output losses to the GIIPS economies would have been cut from nearly 14 percent below trend by the end of 2014 to only 1 percent

below trend. The elimination of austerity shocks has a smaller effect on GDP in the core economies (EU10).

Finally, the model also allows us to consider the dynamics of the debt-to-GDP ratio under different conditions. The main rationale for austerity is to reduce debt and bring debt-to-GDP ratios back to historical norms. However, according to our model, reductions in government spending had a sufficiently severe contractionary effect on economic activity that debt-to-GDP ratios in some countries actually increased as a consequence of austerity.

## 2 Empirical Findings

We begin by characterizing the economic performance of European countries and the United States following the crisis. Our primary data sources are Eurostat and the OECD. The dataset includes all countries in the European Union with the exception of Croatia and Malta (excluded due to data limitations) and with the addition of Norway and Switzerland (outside of the European Union but members of the European Free Trade Association, EFTA). Our sample covers the period 1960 to 2014; it is an unbalanced panel due to limitations in data availability for some countries.

Table 1 lists the countries in our data set together with each country's relative size, the share of imports in final demand and the country's exchange rate regime as of 2010. Country size varies from less than one percent of the European aggregate (e.g. Cyprus and Luxembourg) to over 100 percent (the U.S.).<sup>1</sup> The import share varies from a low of 13 percent in the U.S. to very high shares in Ireland and Luxembourg (44 percent and 57 percent, respectively). The average import share in Europe is 32 percent. The model in Section 3 will capture the extent of bilateral trade linkages between country pairs, as well as the overall openness to trade. Most countries in the sample have a fixed exchange rate because they are part of the euro area, or they have pegged their exchange rate to the euro. Nine have floating exchange rates.

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<sup>1</sup>Country size is measured as the country's final demand (in nominal US dollars) relative to the sum of all European countries' final demand, where final demand is GDP less net exports. The import share is the share of imports in final demand both averaged over 2005-2010. We construct this share from the OECD Trade in Value Added database.

## 2.1 Measuring Austerity

There are two conceptual issues in studying the impact of fiscal austerity on economic outcomes. One is that a policy can only be said to be austere relative to some benchmark. The second issue is the endogeneity of fiscal policy to the state of the economy – did a cut in government expenditures adversely affect output, or did government expenditures contract along with the decline in output? A commonly adopted approach is to identify periods of austerity as episodes when, for example, the primary balance (the general government balance net of interest payments) decreases by a certain amount. Such data is available from the IMF and the OECD, often reported as a share of “cyclically-adjusted GDP” as a way of correcting for the current stage of the business cycle. This approach partially addresses the issue of defining austerity by picking an arbitrary cut off, but does not address endogeneity. An alternative is the narrative approach pioneered by Romer and Romer (2004). This method relies on a subjective assessment of the historical policy record to identify policy shifts that are motivated by long-run fiscal consolidation rather than the need for short-run temporary fiscal stimulus. The narrative approach addresses the endogeneity problem, though it requires a great deal of judgment in interpreting policy statements by government officials. The identified policy shifts may also reflect the intent of policymakers and not capture the policies that are ultimately enacted.<sup>2</sup>

A third approach, and the one we adopt here, is to examine forecast errors in government purchases and their relationship with associated forecast errors in economic outcomes.<sup>3</sup> We borrow heavily from Blanchard and Leigh (2013) who take a similar approach. However, rather than relying on forecasts generated by the IMF or national governments, we produce our own forecast measures. This gives us the flexibility to consider different methods of detrending and additional explanatory variables.

In principle, any reduced-form forecast is admissible for constructing the forecast errors. We experimented with a variety of econometric specifications.<sup>4</sup> The constructed forecast

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<sup>2</sup>Alesina, Favarro and Giavazzi (2015a, 2016) use the Romer-Romer approach to identify the effect of multi-year fiscal plans on economic activity. Using historical data, they find strong effects of tax changes on economic activity. Our analysis differs in that we focus on the 2010-2014 period which was dominated by reductions in government expenditures.

<sup>3</sup>We also examined austerity in total government outlays, total revenue and the primary balance. This analysis suggested that, unlike government purchases, changes in tax revenue and the primary balance have limited explanatory power for economic performance. The results using these alternative measures of austerity are included in the appendix.

<sup>4</sup>House and Proebsting (2016) includes a detailed survey of the set of forecast methods used and a discussion of the sensitivity of the results to the forecast specification. Here we focus on our preferred forecast

errors can be interpreted as departures from “normal” fiscal policy reactions to economic fluctuations. If government purchases do not typically increase during economic contractions and this policy reaction continues in the 2010-2014 period, our procedure will categorize that spending path as “not austere.” On the other hand, if spending typically increases during recessions but does not do so in the aftermath of the crisis, our procedure will categorize that spending path as “austere.”

We adopt the following forecast specification for real government purchases

$$\begin{aligned} \ln G_{i,t} = & \ln G_{i,t-1} + g + \gamma \left( \ln \widehat{Y}_{EU,t-1} - \ln Y_{i,t-1} \right) \\ & + \theta^G \left( \ln Y_{i,t} - \ln \widehat{Y}_{i,t} \right) + \varepsilon_{i,t}^G. \end{aligned} \quad (2.1)$$

Here  $\ln G_{i,t}$  is the log of real government purchases in country  $i$  at time  $t$ ,  $\ln Y_{i,t}$  is the log of real Gross Domestic Product for country  $i$  at time  $t$ . The “hat” indicates the predicted value of the variable. This forecast specification accounts for both cross-sectional average growth in GDP (the parameter  $g$ ) and convergence dynamics (through the parameter  $\gamma$ ) as well as an estimated cyclical relationship (through the parameter  $\theta^G$ ). This forecast method appeals to basic growth theory as it assumes that all countries are ultimately converging to a common growth rate  $g$ . Thus, it predicts that growth rates in Central and Eastern European countries are expected to decline as their per capita GDP approaches Western European levels.

To implement this equation we first estimate average GDP growth for the EU12<sup>5</sup> for the period 1993-2005 (annual) with an OLS estimate of

$$\ln Y_{EU,t} = \beta_{EU} + g \cdot t + e_{EU,t}. \quad (2.2)$$

The estimated value for  $g$  is 0.019 (i.e., 1.9 percent annual growth) with a standard error of 0.0012. To construct the convergence parameter  $\gamma$  we then run the regression

$$\ln Y_{i,t} - \ln Y_{i,t-1} - \hat{g} = \gamma \left( \ln \widehat{Y}_{EU,t-1} - \ln \widehat{Y}_{i,t-1} \right) + \varepsilon_{i,t}^\gamma.$$

using a sample which includes all countries in Central and Eastern Europe<sup>6</sup> for the same time specifications for each variable in the analysis.

<sup>5</sup>Belgium, Denmark, Germany, Ireland, Spain, France, Italy, Luxembourg, Austria, Netherlands, Portugal and Finland.

<sup>6</sup>Bulgaria, Czech Republic, Estonia, Greece, Cyprus, Latvia, Lithuania, Hungary, Poland, Romania, Slovenia and the Slovak Republic.

period. Note, the variable  $\ln \hat{Y}_{EU,t-1}$  is the fitted value from (2.2). Our estimated value for  $\gamma$  is 0.023 with a standard error of 0.002. We then estimate the parameter  $\theta^G$  by least squares from (2.1) using all available data up to 2005. The fitted value for  $\ln \hat{Y}_{i,t-1}$  comes from our forecast of GDP which we discuss in detail below. The estimate of the cyclical parameter is  $\hat{\theta}^G = 0.38$  with a standard error of 0.06.

The parameters in the forecast equations are estimated using data *prior* to the crisis. Specifically, we use only data up to 2005:4 to estimate the parameters of the forecasting equations. Our period of interest is *after* the crisis, 2010-2014. The forecast errors for 2010 through 2014 are the difference between predicted values and the actual values. The predicted values are based on the forecasting parameters as well as information on government purchases up to 2009. So, for the year 2010, we use the actual realizations of  $\ln G_{i,2009}$  and  $\ln Y_{i,2009}$  in (2.1). Starting from  $t = 2011$ , we replace  $\ln G_{i,t-1}$  with its predicted value. Thus, for 2010-2014, our forecasts use data on government purchases up to 2009, but use observed data on GDP. The reason for including actual GDP in the forecast is that we want to limit the endogeneity of government purchases to the current state of the economy.

The out-of-sample residuals can be interpreted as unusually high or low realizations of that variable relative to its predicted values. Though they are not identified structural shocks from an econometric point of view, we can still ask whether there is a correlation between the forecast errors of government policy and various measures of economic performance.<sup>7</sup>

## 2.2 Measures of Economic Performance

We construct measures of economic performance in a similar manner to the forecasting procedure for government purchases. We use the following forecast specification for real GDP, consumption, and investment

$$\ln Y_{i,t} = \ln Y_{i,t-1} + g + \gamma \left( \ln \hat{Y}_{EU,t-1} - \ln Y_{i,t-1} \right) + \varepsilon_{i,t}^Y. \quad (2.3)$$

Equation (2.3) is written for real per capita GDP ( $Y$ ). As with the forecasts for government purchases, this forecast specification accounts for both average GDP growth (the parameter  $g$ ) and convergence dynamics (the parameter  $\gamma$ ). The parameters  $g$  and  $\gamma$  are estimated over the time period 1993 - 2005 just as they were in Section 2.1 and  $\ln \hat{Y}_{EU,t-1}$  is the fitted value

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<sup>7</sup>The statistical properties of the forecast errors for government purchases as well as forecast errors for several other measures of austerity are reported and discussed in the appendix.

from (2.2).<sup>8</sup> In addition to providing the forecasts for GDP, consumption and investment, the equation above also provides the variables  $\ln \widehat{Y}_{i,t-1}$  used in (2.1). As before, up to  $t = 2010\text{Q1}$ , we use actual GDP data for  $\ln Y_{i,t-1}$  in (2.3), and replace it by its forecast  $\ln \widehat{Y}_{i,t-1}$  thereafter. To construct forecasts for GDP growth, we take the difference in the log-level forecasts. That is,  $\Delta \ln \widehat{Y}_{i,t} = \ln \widehat{Y}_{i,t} - \ln \widehat{Y}_{i,t-1}$ .

For the remaining performance indicators (inflation, net exports and the nominal exchange rate), we impose a random-walk specification. To reduce the sensitivity to the last observation, for each country we take an average of the variable to be forecast for the two years 2008 and 2009 as the “last observation.” That is, our forecast for inflation is

$$\hat{\pi}_{i,t} = \frac{1}{8} \sum_{s \in 2008, 2009} \pi_{i,s} \quad (2.4)$$

for dates  $t$  after 2009.

We use “core inflation” (all items less energy and food) as reported by Eurostat. The exchange rate is the nominal effective exchange rate (the trade-weighted sum of bilateral nominal exchange rates). The net export measure is real exports in date  $t$  less real imports in date  $t$  divided by 2005Q1 nominal GDP.<sup>9</sup>

Figure 2 shows time series plots for government purchases and real GDP for Germany, France, Greece and the United States. The figures show the actual series (the solid line) and the prediction based on our forecasting regressions (the dashed line). The shaded portion of each figure shows the period of our analysis, 2010-2014. In Germany, the difference between the forecast for government purchases and actual government purchases is slight, indicating virtually no austerity, at least relative to the historical pattern of German fiscal policy. In contrast, government purchases in France and Greece are well below forecast. The forecasting equation for the United States picks up the expansion in US fiscal policy in 2008 and 2009, but suggests a significant contraction thereafter. In terms of economic performance (the graphs on the right), France and Greece experience output below forecast. German output was above forecast in 2011 and 2012, with the gap closing in 2013 and 2014. In the United States, the gap between forecasted and actual GDP is very slight.

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<sup>8</sup>There is a slight difference in the construction of  $g$  and  $\gamma$  for the performance measures because we use quarterly data for these estimates while we used annual data for the fiscal measures. This difference in the estimates is negligible. We also re-estimate  $g$  and  $\gamma$  for consumption and investment because their share in GDP is likely affected by growth dynamics.

<sup>9</sup>We multiply real exports and real imports by their respective deflators for 2005Q1, so that our measure of net exports equals nominal net exports over nominal GDP in 2005Q1.



## 2.3 Austerity and Economic Performance

We now turn our attention to the relationship between austerity and economic performance. Table 2 reports estimates from cross-sectional OLS regressions of the form

$$\tilde{X}_{i,2010-2014} = \alpha_0 + \alpha \tilde{G}_{i,2010-2014} + \Gamma \cdot \text{controls}_i + \varepsilon_i. \quad (2.5)$$

Here  $\tilde{X}_{i,2010-2014}$  denotes the average forecast error for any of the measures of economic performance,  $\frac{1}{5} \sum_{t=2010}^{2014} (\ln X_{i,t} - \ln \hat{X}_{i,t})$ . For consumption and investment, we express this average forecast error in terms of GDP by pre-multiplying it by the average share of consumption and investment in GDP over the 2000 - 2010 period,  $X_i/Y_i$ . Similarly,  $\tilde{G}_{i,2010-2014}$  is the average forecast error for government purchases, again in percent of GDP. Expressing forecast errors as a percent of GDP allows us to report the coefficient  $\alpha$  as a multiplier.<sup>10</sup> We include the forecast deviation of tax revenue in 2010-2014, Debt-to-GDP ratio prior to the financial crisis (end of 2007), and the change in TFP from 2009-2014 as additional controls.

Throughout the paper we often refer to the coefficients  $\alpha$  as “multipliers” but we should caution the reader as to the precise interpretation of these estimates. The estimated coefficients are based on the cross-sectional variation in measures of austerity rather than time-series variation. Moreover, because we do not condition on other variables, the reported multiplier includes the effects of shocks to economic variables other than austerity.

Table 2 reports estimates of the effects of shortfalls in government purchases on real GDP for five different econometric specifications. We consider three additional control variables: the average forecast error for total revenue, the debt to GDP ratio, and total factor productivity.<sup>11</sup> We report the negative of the coefficient to convey the effect of “austerity”, i.e., a government purchases *shortfall*, on GDP. The coefficient on government purchases absent any other variables that could explain the cross sectional variation in GDP, is  $-2.55$  with a standard error of 0.36. Taken at face value, this suggests that a shortfall in government purchases of one percent of GDP is associated with a decline in real GDP of 2.55 percent relative to forecast.

Columns (2), (3) and (4) show the effects of including additional covariates on the regres-

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<sup>10</sup>This approach follows Hall (2009) and Barro and Redlick (2009). Ramey and Zubairy (2014) discusses the advantages of directly estimating the multiplier rather than backing it out from an estimated elasticity.

<sup>11</sup>Total Revenue is the average forecast error of total government tax revenue over 2010 - 2014. The construction of the forecast for total tax revenue is the same as the forecast for government purchases. The government debt-to-GDP ratio for country  $i$  is measured by its value at the end of 2009. The TFP variable is the change in log TFP between 2009 and 2014.

sion results. Total revenue comes in significantly and slightly decreases the coefficient on the shortfall in government purchases. We add a measure of public debt prior to the recession to capture the potential drag of government debt on GDP. The results suggest that a country with ten percent greater debt to GDP in 2007 experienced a 0.7 percent lower level of GDP in 2010-2014 relative to forecast.<sup>12</sup> Higher levels of TFP relative to forecast are associated with stronger economic performance. Inclusion of the controls for tax revenue, government debt and TFP reduces the estimated coefficient on austerity from  $-2.55$  to  $-2.02$ . We will take specification (5) and the multiplier of  $-2.02$  as the benchmark for assessing the performance of the model in Section 3.

Table 3 reports results of regressions of other measures of economic performance on shortfalls in government purchases. In each regression, we include all of the control variables though the table reports only the coefficients on government purchases shortfalls. The table also shows the results for subsamples of fixed and floating exchange rates. In particular, we interact the average forecast deviation of government purchases with a dummy for fixed exchange rate countries and report estimates of the corresponding coefficients  $\alpha^{fix}$  and  $\alpha^{fl}$ .<sup>13</sup>

The results in the table indicate that shortfalls in government purchases are associated with declines in consumption, investment and GDP growth. These estimates are roughly the same across countries with fixed and floating exchange rates. The decrease in investment is noteworthy because many textbook models would predict a crowding-out effect where decreases in government purchases would lead to an increase in investment. Government spending shortfalls are also associated with lower inflation. Interestingly, this effect is independent of the exchange rate regime although the effect is stronger for fixed exchange rate countries. One possible interpretation of this finding is as evidence for a cross-sectional Phillips Curve relationship similar to the findings in Beraja et al. (2014), Beraja et al. (2016) and Nakamura and Steinsson (2014). There is also a strong positive association between net exports and government purchases shortfalls, which, for floating exchange rate countries, is associated with a depreciation of the nominal effective exchange rate.

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<sup>12</sup>The rise in household debt in 2002 to 2007 has been shown to predict variations in the depth of the recession across European countries (see e.g. Martin and Philippon (2014)). Inclusion of household debt does not come in significantly as an explanator for the post-crisis recovery.

<sup>13</sup>The regression allows for separate intercepts for each exchange rate regime though the coefficients on the control variables are restricted to be the same for all countries.

**Fiscal spillovers** We now analyze whether a shortfall in government purchases affects output in neighboring countries. We follow the approach taken in Auerbach and Gorodnichenko (2012). Specifically, we estimate the following regression

$$\tilde{X}_{i,2010-2014} = \alpha_0 - \alpha \times Gshock_i - \alpha^* \times Gshock_i^* + \varepsilon_i, \quad (2.6)$$

where  $Gshock_i$  is a measure of country  $i$ 's domestic government spending and  $Gshock_i^*$  is a measure of government spending spillovers to country  $i$ . Specifically,  $Gshock_i$  is defined as

$$Gshock_i = dom_i \frac{G_i}{Y_i} \tilde{G}_{i,2010-2014}$$

and  $Gshock_i^*$  is country  $i$ 's spillover shock:

$$Gshock_i^* = \sum_{j \neq i}^N imp_j^i \frac{G_j}{Y_i} \tilde{G}_{j,2010-2014}.$$

Country  $i$ 's domestic austerity shock  $Gshock_i$  is the average forecast residual of government purchases  $G_i$ , expressed in percent of domestic GDP. In contrast to our baseline regression (2.5), we multiply this austerity shock by  $dom_i$ , which is country  $i$ 's share of final demand that is accounted for by domestic production:

$$dom_i = 1 - \frac{Imp_i}{C_i + I_i + G_i},$$

where  $Imp_i$  are country  $i$ 's imports, and  $C_i$ ,  $I_i$  and  $G_i$  are its consumption, investment and government purchases. This corrects for countries' trade openness and captures the idea that domestic fiscal shocks 'leak out' to other economies if a large share of final demand is satisfied by imports.

Similarly, country  $i$ 's spillover shock  $Gshock_i^*$  is the sum of all other countries' austerity shocks, expressed in terms of  $i$ 's GDP and multiplied by a scaling factor,  $imp_j^i$ . This scaling factor is calculated as the share of country  $j$ 's final demand that is satisfied by imports from country  $i$ :

$$imp_j^i = \frac{Imp_j^i}{C_j + I_j + G_j},$$

where  $Imp_j^i$  denotes  $j$ 's imports from  $i$ . The scaling factor captures country  $i$ 's exposure to changes in country  $j$ 's final demand. By introducing this scaling factor, we implicitly

assume that a country's GDP response to a €1 reduction in government purchases in another country scales with its exports to that country. The scaling factor corrects for the observed heterogeneity in trade linkages across countries in our sample.<sup>14</sup> This specification distributes the effects of fiscal austerity in country  $i$  across its trading partners and to the domestic economy because  $dom_i + \sum_{j \neq i}^N imp_j^i = 1$ . Data on the domestic share,  $dom_i$ , and the import shares,  $imp_j^i$ , is taken from the OECD Trade in Value Added database, as explained in section 3.7.

Figure 4 illustrates the spillover effect of government purchase shortfalls on GDP in the cross-section. For the moment, we focus on the left panel, which displays the actual data. The vertical axis of the scatter plot displays the part of the average forecast residual for GDP (the dependent variable in regression (2.6) that cannot be explained by domestic government purchases shocks,  $Gshock$ , in log points times 100. The horizontal axis displays the spillover shock,  $Gshock^*$ , in the same units as the GDP forecast residual. For example, the value 0.5 on the horizontal axis is a *reduction* in foreign government purchases, scaled by the export share, corresponding to 0.005 log points of GDP.

Spillover shocks are relatively modest compared to domestic shocks. Despite strong reductions in government purchases across many countries, no country in our sample received a spillover shock exceeding one percent of its GDP. Indeed, spillover shocks are about a magnitude smaller than domestic shocks for most countries. One reason is that export shares,  $\sum_{j \neq i}^N imp_j^i$ , are somewhat smaller than the domestic shares,  $dom_i$ . Countries are therefore less exposed to foreign government purchases shocks than to domestic government purchases shocks. Another reason is that exports are naturally diversified, so that positive and negative spillover effects from different export markets cancel each other out. Overall, spillover shocks were negative over the sample period, meaning that all countries faced decreased government purchases in their export markets. Particularly hit were small countries exposed to large, austere countries such as Italy, Spain, France and the United Kingdom. This group comprises Luxembourg, Ireland and Cyprus. On the other end of the spectrum are countries with small export exposure, such as the United States, Italy and Greece, or countries like Latvia, which mainly export to Northern European markets and Germany. Formal regressions of equation (2.6) confirm that austerity in export markets has little or no impact on economic activity at

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<sup>14</sup>One difference between our analysis and the analysis in Auerbach and Gorodnichenko (2012) is that our scaling factor is imports as a share of total economic activity while their's is imports as a share of total government purchases.

home (see Table A4 in the Appendix). Our results are in contrast to Auerbach and Gorodnichenko (2012) who find strong and statistically significant positive spillover effects for the period before the great recession.<sup>15</sup>

### 3 Model

Next we develop a multi-country business cycle model of the 29 countries in our data set. The model will be used to make comparisons with the empirical patterns in Section 2. We will then be able to use the model to perform counterfactual policy analysis. The model includes every is calibrated to match both the economic size and bilateral trade flows of the 29 countries. The model incorporates many features from modern monetary business cycle models (e.g. Smets and Wouters (2007), Christiano et al. (2005)), international business cycles models (e.g. Backus et al. (1992), Backus et al. (1994), Chari et al. (2000), Heathcote and Perri (2002)), and financial accelerator models (e.g. Bernanke et al. (1999), Brave et al. (2012), Christiano et al. (2014)). The main ingredients of the model are (i) price rigidity (ii) international trade in intermediate goods, (iii) hand-to-mouth consumers, (iv) a net worth channel for business investment and (v) government purchases shocks, monetary policy shocks and spread shocks.

#### 3.1 Households

The world economy is populated by  $n = 1 \dots N$  countries. The number of households in any country  $n$  is  $\mathbb{N}_n$ . The model is written in per capita terms. To convert any variable to a national total, we scale by the population. Thus if  $X_{n,t}$  is per capita investment in country  $n$  at time  $t$ , total investment is  $\mathbb{N}_n X_{n,t}$ . In each period  $t$  the economy experiences one event  $s_t$  from a potentially infinite set of states. We denote by  $s^t$  the history of events up to and including date  $t$ . The probability at date 0 of any particular history  $s^t$  is given by  $\pi(s^t)$ .

Every country has a representative household, a single type of intermediate goods producing firm and a single type of final goods producing firm. As in Heathcote and Perri (2002), intermediate goods are tradable across countries, but final goods are nontradable. The households own all of the domestic firms.

We follow Nakamura and Steinsson (2014) who adopt the specification of Greenwood et

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<sup>15</sup>Our results cannot be directly compared because we use a different data sample and different forecasting methods, and we also use a different scaling factor  $imp_j^i$  on the austerity shocks. Using the same scaling factor as in Auerbach and Gorodnichenko (2012), our coefficients remain statistically insignificant.

al. (1988) in assuming that consumption and labor are complements for the household.<sup>16</sup> At date 0, the expected discounted sum of future period utilities for a household in country  $n$  is given by

$$\sum_{t=0}^{\infty} \sum_{s^t} \pi(s^t) \beta^t U(c_n(s^t), L_n(s^t))$$

We set the flow utility function  $U(\cdot)$  as

$$U(c_n, L_n) = \frac{1}{1 - \frac{1}{\sigma}} \left( c_n - \kappa_n \frac{L_n^{1 + \frac{1}{\eta}}}{1 + \frac{1}{\eta}} \right)^{1 - \frac{1}{\sigma}}$$

where  $\beta < 1$  is the subjective time discount factor,  $\sigma$  is the intertemporal elasticity of substitution for consumption,  $\eta$  is the Frisch labor supply elasticity and  $\kappa_n$  is a country specific weight on the disutility of labor. Households choose state-contingent consumption sequences  $c_n(s^t)$ , labor sequences  $L_n(s^t)$ , next period's capital stock  $K_n(s^t)$  and current investment  $X_n(s^t)$  to maximize the expected discounted sum of future period utilities subject to a sequence of budget constraints. Consumption is subject to a time-invariant value-added tax  $\tau_n^c$ .

A key feature of the model is a hand-to-mouth restriction on a fraction  $\chi$  of the consumers in the economy. These consumers receive income in proportion to their consumption share of total income and spend the entire amount on current consumption. That is, hand-to-mouth consumption each period is given by  $c_n^{htm}(s^t) \equiv \frac{\bar{C}_n}{\bar{Y}_n} Y_n(s^t)$  where the bars indicate steady state values.<sup>17</sup> *Aggregate* consumption is then given by

$$C_n(s^t) = (1 - \chi) c_n(s^t) + \chi c_n^{htm}(s^t).$$

This specification allows us to introduce hand-to-mouth behavior while leaving the other first-order conditions unchanged. Households in each country own the capital stock in their country. They supply labor to the intermediate goods producing firms and capital to the entrepreneurs. In return, they earn nominal wages net of labor taxes  $(1 - \tau_n^L) W_n(s^t) L_n(s^t)$  and nominal payments for capital  $\mu_n(s^t) K_n(s^{t-1})$ . Here  $W_n(s^t)$  is the state-contingent nominal wage,  $\tau_n^L$  is a constant labor tax rate and  $\mu_n(s^t)$  is the state-contingent nominal price of capital.<sup>18</sup> The

<sup>16</sup>Several studies provide empirical support for complementarities between consumption and labor. See, among others, Aguiar and Hurst (2005) and Aguiar et al. (2013).

<sup>17</sup>Technically, our specification for the hand-to-mouth consumers assumes that they spend a fixed share of domestic absorption  $Y_n(s^t)$  rather than a fixed share of nominal national income  $p_n(s^t) Q_n(s^t)$ . Quantitatively there is only a small difference between these specifications.

<sup>18</sup>Our specification of the payments associated with capital deserves some additional discussion. Rather

household also receives lump-sum transfers  $\mathbb{T}_n(s^t)$ . This transfer includes nominal profits from final goods firms and intermediate goods firms,  $\Pi_n^f(s^t) + \Pi^e(s^t)$ , nominal lump-sum taxes or transfers  $T_n(s^t)$ , profits or losses from the financial sector  $\Pi_n^{fin}(s^t)$  and the nominal amount consumed by hand-to-mouth consumers,  $P_n(s^t) c_n^{htm}(s^t)$  where  $P_n(s^t)$  is the date  $t$  nominal price of the final good.<sup>19</sup> Thus,

$$\mathbb{T}_n(s^t) \equiv \Pi_n^f(s^t) + \Pi_n^e(s^t) + \Pi_n^{fin}(s^t) - T_n(s^t) - P_n(s^t) c_n^{htm}(s^t)$$

In addition to direct factor incomes and transfer payments, the household may receive payments from both state-contingent and non-contingent bonds. Let  $b_n(s^t, s_{t+1})$  be the quantity of state-contingent bonds purchased by the household in country  $n$  after history  $s^t$ . These bonds pay off in units of a reserve currency which we take to be U.S. dollars. Let  $a(s^t, s_{t+1})$  be the nominal price of one unit of the state-contingent bond which pays off in state  $s^{t+1}$ . Each country has non-contingent nominal bonds that can be traded. Let  $S_n^j(s^t)$  be the number of bonds denominated in country  $j$ 's currency and held by the representative agent in country  $n$ . The gross nominal interest rate for country  $n$ 's bonds is  $1 + i_n(s^t)$ . The nominal exchange rate to convert country  $n$ 's currency into the reserve currency is  $E_n(s^t)$ .

The nominal budget constraints for the representative household in country  $n$  are

$$\begin{aligned} & P_n(s^t) [(1 + \tau_n^c) c_n(s^t) + X_n(s^t)] + (1 - \delta) \mu_n(s^t) K_n(s^{t-1}) + \sum_{j=1}^N \frac{E_j(s^t) S_n^j(s^t)}{E_n(s^t)} \\ & + \mathbb{I}_{\text{comp}} \left[ \sum_{s^{t+1}} \frac{a(s^t, s_{t+1}) b_n(s^t, s_{t+1})}{E_n(s^t)} - \frac{b_n(s^{t-1}, s_t)}{E_n(s^t)} \right] \\ & = \mu_n(s^t) K_n(s^t) + (1 - \tau_n^L) W_n(s^t) L_n(s^t) + \sum_{j=1}^N \frac{E_j(s^t) (1 + i_j(s^{t-1})) S_n^j(s^{t-1})}{E_n(s^t)} + \mathbb{T}_n(s^t) \end{aligned}$$

and the capital accumulation constraints are

$$K_n(s^t) = K_n(s^{t-1}) (1 - \delta) + \left[ 1 - f \left( \frac{X_n(s^t)}{X_n(s^{t-1})} \right) \right] X_n(s^t)$$

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than assuming that the households rent capital directly to firms, we assume that the households sell capital to entrepreneurs and then subsequently repurchase the undepreciated capital the following period. This assumption is convenient when we introduce financial market imperfections later.

<sup>19</sup>In addition to lending to other countries, households extend domestic loans to financial intermediaries who in turn lend to domestic entrepreneurs at a risky interest rate  $(1 + i_{n,t}) F(\lambda_{n,t}) e^{\epsilon_{n,t}^F}$ . Profits or losses on these loans are returned to the household as a lump sum transfer. We discuss the loans to the entrepreneurs in greater detail below.

with  $f(1) = f'(1) = 0$  and  $f''(1) \geq 0$ . As in Christiano et al. (2005), the function  $f(\cdot)$  features higher-order adjustment cost on investment if  $f''(1) > 0$ . The indicator variable  $\mathbb{I}_{\text{comp}}$  takes the value 1 if markets are complete and 0 otherwise.<sup>20</sup>

The first order conditions for an optimum are as follows. The optimizing household's Euler equation for purchases of state contingent bonds  $b_n(s^t, s_{t+1})$  requires

$$a(s^t, s_{t+1}) \frac{U_1(c_n(s^t), L_n(s^t))}{E_n(s^t) P_n(s^t)} = \beta \pi(s^{t+1}|s^t) \frac{U_1(c_n(s^{t+1}), L_n(s^{t+1}))}{E_n(s^{t+1}) P_n(s^{t+1})}$$

where  $U_j(\cdot)$  denotes the derivative of the function  $U(\cdot)$  with respect to its  $j^{\text{th}}$  argument. There are also Euler equations associated with the uncontingent nominal bonds  $S_n^j(s^t)$ . These require

$$\frac{U_1(c_n(s^t), L_n(s^t))}{P_n(s^t)} \frac{E_j(s^t)}{E_n(s^t)} = \beta (1 + i_j(s^t)) \sum_{s^{t+1}} \pi(s^{t+1}|s^t) \left[ \frac{E_j(s^{t+1})}{E_n(s^{t+1})} \frac{U_1(c_n(s^{t+1}), L_n(s^{t+1}))}{P_n(s^{t+1})} \right]$$

for all  $j = 1 \dots N$ . The labor supply condition is

$$-\frac{U_2(c_n(s^{t+1}), L_n(s^{t+1}))}{U_1(c_n(s^{t+1}), L_n(s^{t+1}))} = \left( \frac{1 - \tau_n^L}{1 + \tau_n^c} \right) \frac{W_n(s^t)}{P_n(s^t)},$$

Finally, the optimal choice for investment and capital requires

$$1 = \frac{\mu_n(s^t)}{P_n(s^t)} \left\{ 1 - f\left(\frac{X_n(s^t)}{X_n(s^{t-1})}\right) - \frac{X_n(s^t)}{X_n(s^{t-1})} f'\left(\frac{X_n(s^t)}{X_n(s^{t-1})}\right) \right\} + \beta \frac{U_1(c_n(s^{t+1}), L_n(s^{t+1}))}{U_1(c_n(s^t), L_n(s^t))} \frac{\mu_n(s^{t+1})}{P_n(s^{t+1})} \left(\frac{X_n(s^{t+1})}{X_n(s^t)}\right)^2 f'\left(\frac{X_n(s^{t+1})}{X_n(s^t)}\right).$$

### 3.2 Firms

There are three groups of productive firms in the model. First there are firms that produce the "final good." The final good is used for consumption, investment and government purchases within a country and cannot be traded across countries. The final good producers take intermediate goods as inputs. Second, intermediate goods firms produce country-specific goods which are used in production by the final goods firms. Unlike the final good, the intermediate goods are freely traded across countries. The intermediate goods firms themselves

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<sup>20</sup>Because models with incomplete markets often have non-stationary equilibria, we impose a small cost of holding claims on other countries. This cost implies that the equilibria is always stationary. For our purposes, we set the cost sufficiently low that its effect on the equilibrium is negligible.



take sub-intermediate goods or varieties as inputs (the domestic producers of the tradable intermediate in country  $n$  use only sub-intermediates produced in country  $n$  as inputs). The sub-intermediate goods are produced using capital and labor as inputs. Like the final good, neither capital nor labor can be moved across countries. Below we describe the production chain of these three groups of firms. We begin by describing the production of the intermediate goods which are traded across countries.

### 3.2.1 Tradable Intermediate Goods

Each country produces a single (country-specific) type of tradable intermediate good. We employ a two-stage production process to allow us to use a Calvo price setting mechanism. In the first stage, monopolistically competitive domestic firms produce differentiated “sub-intermediate” goods which are used as inputs into the assembly of the tradable intermediate good for country  $n$ . In the second stage, competitive intermediate goods firms produce the tradable intermediate good from a CES combination of the sub-intermediates. These firms then sell the intermediate good on international markets at the nominal price  $p_{n,t}$ . We describe the two-stage process of production of the intermediate goods in reverse, starting with the second stage.

**Second-Stage Producers** The second stage producers assemble the tradable intermediate good from the sub-intermediate varieties. The second stage firms are competitive in both the global market for intermediate goods and the market for subintermediate goods in their own country. The second-stage intermediate goods producers solve the following maximization problem

$$\max_{q_n(\xi, s^t)} \left\{ p_n(s^t) Q_n(s^t) - \int_0^1 \varphi_n(\xi, s^t) q_n(\xi, s^t) d\xi \right\}$$

subject to the CES production function

$$Q_n(s^t) = \left[ \int_0^1 q_n(\xi, s^t)^{\frac{\psi_q - 1}{\psi_q}} d\xi \right]^{\frac{\psi_q}{\psi_q - 1}}$$

where the parameter  $\psi_q > 1$ . Here  $Q_n(s^t)$  is the real quantity of country  $n$ 's tradable intermediate good produced at time  $t$ . The variable  $\xi$  indexes the continuum of differentiated types of sub-intermediate producers (thus  $\xi$  is one of the sub-intermediate types). The parameter  $\psi_q > 1$  governs the degree of substitutability across the sub-intermediate goods.

The date  $t$  nominal price of each sub-intermediate good is  $\varphi_n(\xi, s^t)$  and the quantity of each sub-intermediate is  $q_n(\xi, s^t)$ . It is straight-forward to show that the demand for each sub-intermediate has an iso-elastic form

$$q_n(\xi, s^t) = Q_n(s^t) \left( \frac{\varphi_n(\xi, s^t)}{p_n(s^t)} \right)^{-\psi_q}. \quad (3.1)$$

The competitive price of the intermediate  $p_n(s^t)$  is then a combination of the prices of the sub-intermediates. In particular,

$$p_n(s^t) = \left[ \int_0^1 \varphi_n(\xi, s^t)^{1-\psi_q} d\xi \right]^{\frac{1}{1-\psi_q}}. \quad (3.2)$$

**First-Stage Producers** The sub-intermediate goods  $q_n(\xi, s^t)$  which are used to assemble the tradable intermediate good  $Q_n(s^t)$  are produced in the first stage. The first-stage producers hire workers at the nominal wage  $W_n(s^t)$  and rent capital at the nominal rental price  $R_n(s^t)$ . Unlike the firms in the second stage, the first-stage, sub-intermediate goods firms are monopolistically competitive. They seek to maximize profits taking the demand curve for their product (3.1) as given. These firms each have access to a Cobb-Douglas production function

$$q_n(\xi, s^t) = Z_n(s^t) [k_n(\xi, s^t)]^\alpha [l_n(\xi, s^t)]^{1-\alpha}.$$

Because the first-stage producers are monopolistically competitive, they typically charge a markup for their products. The desired price naturally depends on the demand curve (3.1). Each type of sub-intermediate good producer  $\xi$  freely chooses capital and labor each period but there is a chance that their nominal price  $\varphi_n(\xi, s^t)$  is fixed to some exogenous level. In this case, the first-stage producers choose an input mix to minimize costs taking the date- $t$  price  $\varphi_n(\xi, s^t)$  as given. Cost minimization implies that

$$W_n(s^t) = MC_n(s^t) (1 - \alpha) Z_n(s^t) [k_n(\xi, s^t)]^\alpha [l_n(\xi, s^t)]^{-\alpha}$$

$$R_n(s^t) = MC_n(s^t) \alpha Z_n(s^t) [k_n(\xi, s^t)]^{\alpha-1} [l_n(\xi, s^t)]^{1-\alpha}$$

where  $MC_n(s^t)$  is the marginal cost of production. The capital-to-labor ratios are identical across the sub-intermediate firms, in particular

$$\frac{k_n(\xi, s^t)}{l_n(\xi, s^t)} = \frac{\alpha}{1 - \alpha} \frac{W_n(s^t)}{R_n(s^t)} = \frac{u_n(s^t) K_n(s^{t-1})}{L_n(s^t)}$$

This implies that (within any country  $n$ ) the nominal marginal cost of production is common for all the sub-intermediate goods firms. Nominal marginal costs can be equivalently expressed in terms of the underlying nominal input prices  $W_n(s^t)$  and  $R_n(s^t)$

$$MC_n(s^t) = \frac{W_n(s^t)^{1-\alpha} R_n(s^t)^\alpha}{Z_n(s^t)} \left( \frac{1}{1-\alpha} \right)^{1-\alpha} \left( \frac{1}{\alpha} \right)^\alpha.$$

**Pricing** The nominal prices of the sub-intermediate goods are adjusted only infrequently according to the standard Calvo mechanism. We let  $\varphi_n(\xi, s^t)$  denote the nominal price of sub-intermediate producer  $\xi$  that prevails at time  $t$  in country  $n$ . In particular, for any firm, there is a probability  $\theta$  that the firm cannot change its price that period. When a firm can reset its price it chooses an optimal reset price. Because the production functions have constant returns to scale, and because the input markets are competitive, all firms that can reset their price at time  $t$  optimally choose the same reset price  $\varphi_n^*(s^t)$ . The reset price is chosen to maximize the discounted value of profits. Firms act in the interest of the representative household in their country so they apply the household's stochastic discount factor to all future income streams. The maximization problem of a firm that can reset its price at date  $t$  is

$$\max_{\varphi_n^*(s^t)} \sum_{j=0}^{\infty} (\theta\beta)^j \sum_{s^{t+j}} \pi(s^{t+j}|s^t) \frac{U_1(c_n(s^{t+j}), L_n(s^{t+j}))}{(1 + \tau_n^c) P_n(s^{t+j})} (\varphi_n^*(s^t) - MC_n(s^{t+j})) Q_n(s^{t+j}) \left( \frac{\varphi_n^*(s^t)}{p_n(s^{t+j})} \right)^{-\psi_q}$$

The solution to this optimization problem requires

$$\varphi_n^*(s^t) = \frac{\psi_q}{\psi_q - 1} \frac{\sum_{j=0}^{\infty} (\theta\beta)^j \sum_{s^{t+j}} \pi(s^{t+j}|s^t) \frac{U_1(c_n(s^{t+j}), L_n(s^{t+j}))}{P_n(s^{t+j})} p_n(s^{t+j})^{\psi_q} MC_n(s^{t+j}) Q_n(s^{t+j})}{\sum_{j=0}^{\infty} (\theta\beta)^j \sum_{s^{t+j}} \pi(s^{t+j}|s^t) \frac{U_1(c_n(s^{t+j}), L_n(s^{t+j}))}{P_n(s^{t+j})} p_n(s^{t+j})^{\psi_q} Q_n(s^{t+j})}.$$

Because the sub-intermediate goods firms adjust their prices infrequently, the nominal price of the tradable intermediate goods are sticky. In particular, using (3.2), the nominal price of the tradable intermediate good evolves according to

$$p_n(s^t) = \left[ \theta p_n(s^{t-1})^{1-\psi_q} + (1 - \theta) \varphi_n^*(s^t)^{1-\psi_q} \right]^{\frac{1}{1-\psi_q}}. \quad (3.3)$$

Our specification of price setting entails firms setting prices in their own currency. As a result, when exchange rates move, the implied import price moves automatically (there is complete pass-through). This is somewhat at odds with the data which suggests that many exporting firms fix prices in the currency of the country to which they are exporting. See Betts and Devereux (1996), Betts and Devereux (2000) and Devereux and Engel (2003) for a discussion of the differences between local currency pricing and domestic currency pricing. See Gopinath and Itskhoki (2011) and Burstein and Gopinath (2014) for empirical evidence on the relationship between pass-through, price rigidity and exchange rate movements.

### 3.2.2 Nontradable Final Goods

The final goods are assembled from a (country-specific) CES combination of tradable intermediates produced by the various countries in the model. The final goods firms are competitive in both the global input markets (for the intermediate inputs) and the final goods market. The final goods producers solve the following maximization problem

$$\max_{y_n^j(s^t)} \left\{ P_n(s^t) Y_n(s^t) - \sum_{j=1}^N \frac{E_j(s^t)}{E_n(s^t)} p_j(s^t) y_n^j(s^t) \right\}$$

subject to the CES production function

$$Y_n(s^t) = \left( \sum_{j=1}^N \omega_{n,j}^{\frac{1}{\psi_y}} y_n^j(s^t)^{\frac{\psi_y-1}{\psi_y}} \right)^{\frac{\psi_y}{\psi_y-1}} \quad (3.4)$$

Here,  $y_n^j(s^t)$  is the amount of country- $j$  intermediate good used in production by country  $n$  at time  $t$ . The parameter  $\psi_y$  governs the degree of substitutability across the tradable intermediate goods and we assume that  $\omega_{n,j} \geq 0$  and  $\sum_{j=1}^N \omega_{n,j} = 1$  for each country  $n$ . Notice that the shares  $\omega_{n,j}$  are country-specific so each country produces a different mix of the various country-specific intermediate goods. Later, when we calibrate the model, we choose the  $\omega_{n,j}$  parameters to match data on bilateral import shares.

Demand for country-specific intermediate goods is isoelastic

$$y_n^j(s^t) = Y_n(s^t) \omega_{n,j} \left[ \frac{E_j(s^t) p_j(s^t)}{E_n(s^t) P_n(s^t)} \right]^{-\psi_y}$$

The implied nominal price of the final good is

$$P_n(s^t) = \left( \sum_{j=1}^N \omega_{n,j} \left[ \frac{E_j(s^t)}{E_n(s^t)} p_j(s^t) \right]^{1-\psi_y} \right)^{\frac{1}{1-\psi_y}}$$

Unlike the intermediate goods, the final good cannot be traded and must be used for either investment, consumption or government purchases in the period in which it is produced. Because the final goods firms have constant returns to scale production functions and behave competitively profits are zero in equilibrium.

### 3.3 The Supply of Capital and Financial Market Imperfections

The model incorporates a financial accelerator mechanism similar to Carlstrom and Fuerst (1997), Bernanke et al. (1999) and Christiano et al. (2014). Entrepreneurs buy capital goods from households using a mix of internal and external funds (borrowing). The entrepreneurs rent out the purchased capital to the first-stage sub-intermediate goods producers in their own country and then sell it back to the household the following period. The interest rate that entrepreneurs face for borrowed funds is a function of their financial leverage ratio. As a consequence, fluctuations in net worth cause changes in the effective rate of return on capital and thus directly affect real economic activity.<sup>21</sup>

Formally, at the end of period  $t$ , entrepreneurs purchase capital  $K_n(s^t)$  from the households at the nominal price  $\mu_n(s^t)$  per unit. Entrepreneurs finance the capital purchases with their own internal funds (net worth) and intermediated borrowing. Let end-of-period nominal net worth be  $NW_n(s^t)$ . Then to purchase capital, the entrepreneur will have to borrow  $B_n(s^t) = \mu_n(s^t) K_n(s^t) - NW_n(s^t)$  units of their own currency (entrepreneurs borrow money from the households in their country). Both  $B_n(s^t)$  and  $NW_n(s^t)$  are denominated in country  $n$ 's currency. The nominal interest rate on business loans equals the nominal interest rate on safe bonds times an external finance premium  $F(\lambda_n(s^t))$ , with  $F(1) = 1$ ,  $F' > 0$  and  $F'' < 0$ . Here  $\lambda_n(s^t) = \frac{\mu_n(s^t) K_n(s^t)}{NW_n(s^t)}$  is the leverage ratio.<sup>22</sup> The interest rate for securing next period's capital is then  $(1 + i_n(s^t)) F(\lambda_n(s^t)) e^{\epsilon_n^F(s^t)}$ , where  $\epsilon_n^F(s^t)$  is a shock to the interest rate spread. The function  $F(\cdot)$  implies that entrepreneurs who are more highly levered pay a higher interest

<sup>21</sup>See Brave et al. (2012) for the same approach. Christiano et al. (2014) microfound the dependence of the interest rate on the leverage ratio by introducing agency problems associated with financial intermediation.

<sup>22</sup>Technically we assume that for any  $\lambda < 1$ ,  $F(\lambda) = 1$  so there is no interest rate premium or discount for an entrepreneur who chooses to have positive net saving. Since the return on capital exceeds the safe rate in equilibrium, all entrepreneurs are net borrowers.

rate.

At the beginning of period  $t + 1$ , entrepreneurs earn a utilization-adjusted rental price of capital net of capital taxes  $(1 - \tau_n^K)u_n(s^{t+1})R_n(s^{t+1})$  and then sell the undepreciated capital back to the households at the capital price  $\mu_n(s^{t+1})$ . Depreciation costs are tax deductible. Varying the utilization of capital requires  $K_n(s^t)a(u_n(s^{t+1}))$  units of the final good. Each period, a fraction  $(1 - \gamma_n)$  of the entrepreneurs' net worth is transferred to the households.<sup>23</sup>

Each period, entrepreneurs choose  $K_n(s^{t+1})$  and utilization  $u_n(s^{t+1})$  to maximize expected net worth  $NW_n(s^{t+1})$ . Net worth evolves over time according to

$$\begin{aligned} \frac{NW_n(s^{t+1})}{\gamma_n} &= K_n(s^t) [(1 - \tau_n^K)u_n(s^{t+1})R_n(s^{t+1}) + \mu_n(s^{t+1})(1 - \delta(1 - \tau_n^K)) - P(s^{t+1})a(u_n(s^{t+1}))] \\ &\quad - (1 + i_n(s^t))F(\lambda_n(s^t))e^{\epsilon_n^F(s^t)}B_n(s^t). \end{aligned}$$

We assume that the entrepreneurs can set utilization freely depending on the date  $t$  realization of the state. The utilization choice requires the first order condition

$$(1 - \tau_n^K)R_n(s^t) = P_n(s^t)a'(u_n(s^t)).$$

Following Christiano et al. (2005) we assume that the utilization cost function is  $a(u) = \frac{\bar{h}}{P} [\exp\{h(u - 1)\} - 1] \frac{1}{h}$  where the curvature parameter  $h$  governs how costly it is to increase or decrease utilization from its steady state value of  $u = 1$ . Note that in steady state  $a(u) = 0$ .

The first order condition for the choice of  $K_n(s^t)$  requires

$$\begin{aligned} &(1 + i_n(s^t))F(\lambda_n(s^t))e^{\epsilon_n^F(s^t)} \\ &= \frac{\sum_{s^{t+1}} \pi(s^{t+1}|s^t) [(1 - \tau_n^K)u_n(s^{t+1})R_n(s^{t+1}) + \mu_n(s^{t+1})(1 - \delta(1 - \tau_n^K)) - P(s^{t+1})a(u_n(s^{t+1}))]}{\mu_n(s^{t+1})}. \end{aligned}$$

As is standard in financial accelerator models, the external finance premium  $F(\lambda_n(s^t))$  drives a wedge between the nominal interest rate on bonds and the expected nominal return on capital.<sup>24</sup> Notice that if  $F(\lambda_n(s^t)) = 1$  then we obtain the standard efficient outcome in which the market price of capital is the discounted stream of rental prices.

<sup>23</sup>We set  $\gamma_n = \frac{\beta}{F_n}$  so that net worth is constant in a stationary equilibrium.

<sup>24</sup>Our specification technically requires that the banks do not directly observe individual leverage ratios but instead observe only country-wide leverage when they set interest rates.

### 3.4 Government Policy

The model includes both fiscal and monetary policy variables. We assume that government purchases is exogenous and any changes in it are financed by lump sum taxes on the representative households. Consumption, labor and capital tax rates are kept constant. Government purchases in country  $n$  is governed by an auto-regressive process

$$G_n(s^t) = (1 - \rho_G) \bar{G}_n + \rho_G G_n(s^{t-1}) + \varepsilon_n^G(s^t).$$

We choose the parameter  $\bar{G}_n$  to match observe ratio's of government spending to GDP for each country.

Monetary policy is conducted through a Taylor Rule which stipulates that in each country, a monetary authority conducts open market operations in its own currency to target the nominal interest rate. The Taylor Rule we use has the form

$$i_n(s^t) = \bar{i}_n + \phi_i i_n(s^{t-1}) + (1 - \phi) (\phi_{GDP} GDP_n(s^t) + \phi_\pi \pi_n(s^t)) + \varepsilon_n^i(s^t) \quad (3.5)$$

For simplicity we assume that the reaction parameters  $\phi_{GDP}$ ,  $\phi_\pi$  and  $\phi_i$  are common across countries. In all of our numerical exercises, we require that  $\frac{\phi_\pi}{1 - \phi_i} > 1$  for local determinacy of the equilibrium (see e.g., Woodford and Walsh (2005)).

Countries in a currency union have a fixed nominal exchange rate for every country in the union. Because *currency* is freely mobile across countries, nominal interest rates for countries in a currency union must also be equal. As a consequence, individual nations in a currency union cannot have independent monetary policies. Instead, we assume that monetary policy for the countries within the union are set by a single monetary authority (the ECB in our case) that has a Taylor Rule similar to (3.5) with the exception that it reacts to the weighted average of innovations in GDP and inflation for the countries in the union. For our purposes, the currency union consists only of the countries in the euro area and the weights are proportional to GDP relative to the total GDP in the euro area.

### 3.5 Aggregation and Market Clearing

For each country  $n$ , aggregate production of the tradable intermediate goods is (up to a first-order approximation<sup>25</sup>) given by

$$Q_n(s^t) = Z_n(s^t) (u_n(s^t) K_n(s^{t-1}))^\alpha L_n(s^t)^{1-\alpha}.$$

Final goods production is given by (3.4) and, since the final good is nontradable, the market clearing condition for the final good is

$$Y_n(s^t) = C_n(s^t) + X_n(s^t) + G_n(s^t) + a(u_n(s^t)) K_n(s^{t-1}).$$

The market clearing for the intermediate goods produced by country  $n$  is

$$Q_n(s^t) = \sum_{j=1}^N \frac{\mathbb{N}_j}{\mathbb{N}_n} y_j^n(s^t).$$

Finally, the bond market clearing conditions require

$$\sum_{n=1}^N \mathbb{N}_n S_n^j(s^t) = \sum_{n=1}^N \mathbb{N}_n b_n(s^t, s_{t+1}) = 0 \quad \forall j.$$

Since no final goods are traded, net exports are comprised entirely of intermediate goods. For each country  $n$ , define nominal net exports as

$$NX_n(s^t) = p_n(s^t) Q_n(s^t) - \sum_{j=1}^n \frac{E_j(s^t)}{E_n(s^t)} p_j(s^t) y_n^j(s^t) = p_n(s^t) Q_n(s^t) - P_n(s^t) Y_n(s^t)$$

where the second equality follows from the zero profit condition for the final goods producers. We can use this expression to write nominal GDP as

$$NGDP_n(s^t) = p_n(s^t) Q_n(s^t) = NX_n(s^t) + P_n(s^t) [C_n(s^t) + X_n(s^t) + G_n(s^t)]$$

Note, since the equilibrium price level in the steady state is  $p = 1$ , real GDP is  $RGDP_n(s^t) = Q_n(s^t)$  (this is the real GDP calculation associated with a fixed price deflator in which the

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<sup>25</sup>As is well known in the sticky price literature, actual output includes losses associated with equilibrium price dispersion. In a neighborhood of the steady state, these losses are zero to a first order approximation. Since our solution technique is only accurate to first order, these terms drop out.



base year prices are chosen as corresponding to the steady state).

### 3.6 Steady state

We solve the model in a neighborhood of a non-stochastic steady state with zero inflation. Because inflation is zero, the Euler equations associated with the uncontingent nominal bonds imply that the nominal interest rate is  $1 + \bar{r}_n = \frac{1}{\beta}$  for all  $n$ . We use the notation  $\bar{X}_n$  to denote the steady state value of the variable  $X$  for country  $n$ . In the steady state, the nominal price of capital and the nominal price of the final consumption good are equal. The entrepreneurs optimal choice for capital implies that

$$\frac{1}{\beta} \bar{F}_n = (1 - \tau_n^K) \frac{\bar{R}_n}{\bar{P}_n} + (1 - \delta (1 - \tau_n^K)),$$

where we have defined the steady state interest rate spreads  $\bar{F}_n \equiv F_n(\bar{\lambda}_n)$ . Below we calibrate these spreads to match their observable counterparts. Once we have calibrated  $\bar{F}_n$ , the equation above determines the real rental price of capital  $\bar{R}_n/\bar{P}_n$  in each country. The utilization cost function  $a(u)$  is chosen to ensure that  $\bar{u}_n = 1$  and  $a(\bar{u}_n) = 0$ . With zero inflation, the steady state price of intermediates is a constant markup over the nominal marginal cost,  $\bar{p}_n = \frac{\psi_q}{\psi_q - 1} \overline{MC}_n$ .

We choose parameters to ensure that, all real exchange rates  $\bar{e}_{j,n} \equiv \frac{\bar{E}_j}{E_n} \frac{\bar{p}_j}{\bar{p}_n}$  are 1 in the steady state. Provided that  $\bar{e}_{j,n} = 1$  for all  $j, n$  it is straightforward to show that the price of the final consumption good and the price of the tradeable intermediate good are equal,  $\bar{P}_n = \bar{p}_n$ . Combining the expression for the real rental price of capital with the markup of price over marginal cost allows us to solve for each country's capital to labor ratio and real wage. Specifically,

$$\frac{\bar{K}_n}{\bar{L}_n} = \left[ \frac{\psi_q - 1}{\psi_q} \left( \frac{\alpha Z_n (1 - \tau_n^K)}{\frac{1}{\beta} \bar{F}_n - (1 - \delta (1 - \tau_n^K))} \right) \right]^{\frac{1}{1-\alpha}}$$

and

$$\frac{\bar{W}_n}{\bar{P}_n} = (1 - \alpha) \frac{\psi_q - 1}{\psi_q} Z_n \left( \frac{\bar{K}_n}{\bar{L}_n} \right)^\alpha.$$

Using the household's labor supply condition we have

$$\bar{L}_n = \left[ \frac{1}{\kappa_n} (1 - \alpha) Z_n \frac{\psi_q - 1}{\psi_q} \left( \frac{\bar{K}_n}{\bar{L}_n} \right)^\alpha \left( \frac{1 - \tau_n^L}{1 + \tau_n^c} \right) \right]^\eta.$$

We choose the free parameters  $\kappa_n$  to force  $\bar{L}_n = 1$  in the steady state. This determines the steady state capital stock  $\bar{K}_n$ , steady state investment  $\bar{X}_n$  and the real amount of the tradeable intermediate produced  $\bar{Q}_n$  per capita.

With  $\bar{e}_{j,n} = 1$  the bilateral import ratios will satisfy  $\frac{\bar{y}_n^j}{\bar{Y}_n} = \omega_{n,j}$ . Below we set the parameters  $\omega_{n,j}$  for each country to match the import ratios in our data set. This calibration will ensure that the model will match observed import ratios in the steady state with unitary real exchange rates. In addition to matching the import ratios, we will also calibrate the model to match the observed shares of government purchases,  $\bar{G}_n$ , net exports,  $\bar{NX}_n$ , and the relative country sizes,  $\frac{N_n \bar{Y}_n}{N_m \bar{Y}_m}$ . The implied net export share can be expressed in terms of country sizes and the import preference parameters. Inserting the market clearing condition for  $\bar{Q}_n$  into the definition of net exports,  $\bar{NX}_n = \bar{Q}_n - \bar{Y}_n$ , we have

$$\frac{\bar{NX}_n}{\bar{Y}_n} = \left( \sum_{j=1}^N \frac{N_j \bar{Y}_j}{N_n \bar{Y}_n} \omega_{j,n} \right) - 1.$$

Starting from the definition of net exports,  $NX_n = Q_n - Y_n$ , and inserting the marginal product of capital equation for  $Q_n$ , that is  $Q_n = \frac{\psi_q}{\psi_q - 1} \frac{R_n}{\alpha} K_n$  with  $\delta K_n = X_n$  gives

$$\begin{aligned} \frac{\psi_q}{\psi_q - 1} \frac{R_n}{\alpha \delta} X_n &= Y_n + NX_n \\ \frac{X_n}{Y_n} &= \frac{\alpha \delta}{\frac{\psi_q}{\psi_q - 1} R_n} \left( 1 + \frac{NX_n}{Y_n} \right). \end{aligned}$$

Using the market clearing condition  $Y_n = C_n + X_n + G_n$  gives the consumption share as a residual:

$$\frac{C_n}{Y_n} = 1 - \frac{X_n}{Y_n} - \frac{G_n}{Y_n}.$$

### 3.7 Calibration

**Preferences** We set the subjective time discount factor  $\beta$  to imply a long run real annual interest rate of four percent. We set the intertemporal elasticity of substitution  $\sigma$  to 0.50 and the Frisch elasticity of labor supply  $\eta$  to 1. These values are comparable to findings in the microeconomic literature on preference parameters (e.g. Barsky et al., 1997) and fairly standard in the macroeconomic literature (e.g. Nakamura and Steinsson, 2014; Hall, 2009). We set the share of rule-of-thumb consumers to  $\chi = 0.5$ . This is the value proposed by the

original study by Campbell and Mankiw (1989) and also corresponds to findings of more recent studies that look at the share of liquidity-constrained consumers (e.g. Martin and Philippon, 2014).

**Trade and Country Size** The preference parameters  $\omega_{n,j}$  are calibrated to the share of imports  $y_n^j$  in the production of the final good,  $Y_n$ , in the data. Standard import data cannot be used for this purpose because it is measured in gross terms, whereas our model requires data in value added terms. We therefore use data from the OECD on trade in value added (TiVA).<sup>26</sup> The dataset is derived from input-output tables, which themselves are based on national account data. The definition of imports and exports in TiVA correspond to those used in national account data and therefore captures both trade in goods and services. The data series FD\_VA ('Value added content of final demand') has information on the value added content (in US dollars) of final demand by source country for all country pairs in our data sample. We directly use these values for  $y_n^j$  and the implied final demand value for  $Y_n$  to calculate  $\omega_{n,j}$ . TiVA also has data for a 'rest of the world' aggregate. We lump together that data and data for countries that are not in our sample to construct the preference parameters  $\omega_{RoW,j}$  for the rest of the world in our sample. TiVA is available for 1995, 2000, 2005, and 2008 through 2011. We take an average of 2005 and 2010 to calibrate  $\omega_{n,j}$ .

The trade elasticity  $\psi_y$  is set to 0.5. This is comparable to parameter values used in international business cycle models with trade. In their original paper, Heathcote and Perri (2002) estimated  $\psi_y = 0.90$ . Using firm-level data, Cravino (2014) and Proebsting (2015) find elasticities close to 1.5.<sup>27</sup>

Country sizes are expressed in final demand,  $N_n Y_n$ . We choose the relative country sizes to match relative final demand observed in the TiVA tables, using an average of 2005 and 2010.

**Technology** The capital share parameter  $\alpha$  is set to 0.38, as in Trabandt and Uhlig (2011) who match data for 14 European countries and the US. The quarterly depreciation rate is set to 2.8% to match the share of private investment in final demand,  $X_n/Y_n$ , whose average value was 19.7% across all countries in our sample for the years 2000 - 2010.

The form of the investment adjustment cost  $f(\cdot)$  implies a relationship between invest-

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<sup>26</sup>Data is expressed in millions of US dollars. The data was downloaded on June 14, 2016.

<sup>27</sup>The literature on international trade outside of business cycle analysis typically adopts higher elasticities. For instance Broda et al. (2006) find a long-run trade elasticity of 6.8.

ment growth and Tobin's  $Q$ . In particular, if  $v_{n,t}$  is the Lagrange multiplier in the capital accumulation constraint then Tobin's  $Q$  can be defined as  $Q_n(s^t) = v_n(s^t)/U_{1,n}(s^t)$ . It is straightforward to show that the change in investment growth over time obeys the equation

$$\left[ \tilde{X}_n(s^t) - \tilde{X}_n(s^{t-1}) \right] = \frac{1}{\vartheta} \tilde{Q}_n(s^t) + \beta \left[ \tilde{X}_n(s^{t+1}) - \tilde{X}_{n,t} \right]$$

where  $\tilde{X}$  denotes the percent deviation from  $X$  from its steady state value. Thus the parameter  $\vartheta$  is similar to a traditional inverse  $Q$ -elasticity. We adopt the value  $\vartheta = 2.48$  from Christiano et al. (2005) which implies that a one percent increase in  $Q$  causes investment to increase by roughly 0.4 percent.

For the utilization cost function  $a(u) = \frac{\bar{R}}{\bar{P}} [\exp\{h(u-1)\} - 1] \frac{1}{h}$ , the elasticity of utilization with respect to the real rental price of capital is governed by the parameter  $h = \frac{a''(1)}{a'(1)}$ . We follow Del Negro et al. (2013) by setting  $h = 0.286$ . This implies that a one percent increase in the real rental price  $R_n/P_n$  causes an increase in the capital utilization rate of 0.286 percent.

**Price Rigidity** We calibrate the Calvo price setting hazard to roughly match observed frequencies of price adjustment in the micro data. Nakamura and Steinsson (2008) report that prices change roughly once every 8 to 11 months; Klenow and Kryvtsov (2008) report that prices change roughly once every 4 to 7 months. Evidence on price adjustment in Europe suggests somewhat slower adjustment. Alvarez et al. (2006) find that the average duration of prices is 13 months (for a quarterly model this corresponds to  $\theta_p = 0.77$ ). Our baseline calibration takes  $\theta_p = 0.80$ . This is somewhat higher than the empirical findings for U.S. price adjustment. Our main reason for adopting this calibration is to match the data indicating slightly more sluggish price adjustment in European countries compared to the U.S.<sup>28</sup>

**Financial Market Imperfections** The steady state external finance premiums,  $F_n(\bar{\lambda}_n)$ , are calculated as the average spread between lending rates (to non-financial corporations) and central bank interest rates. For every country, we calculate an average of 2005. The data source for the spread data is the ECB for euro area countries, the Global Financial Database and national central banks for the remaining countries. See the appendix for more details on the data sources.

For the two remaining parameters we adopt the calibration from Brave et al. (2012). The

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<sup>28</sup>For purposes of comparison, Christiano et al. (2005) have  $\theta_p = 0.6$ , Del Negro et al. (2013) have  $\theta_p = 0.88$  and Brave et al. (2012) have  $\theta_p = 0.97$ .

elasticity of the external finance premium with respect to leverage  $F_\epsilon$  is 0.20 and the quarterly persistence of the shocks to the external finance premium is set to 0.99.

**Fiscal and Monetary Policy** We set the steady state ratio of government purchases to GDP to match the average ratio in data provided by the OECD and Eurostat for 2000 to 2010. Our benchmark calibration is summarized in Table 4. The persistence of the government purchase shock is set to 0.93 as in Del Negro et al. (2013). We choose our Taylor rule parameters to be  $\phi_\pi = 1.5$ ,  $\phi_{GDP} = 0.5$  and  $\rho_i = 0.75$ .

Measured austerity shocks are based on annual data. To convert them to a quarterly series to feed into the model we interpolate the annual forecast errors using the Chow-Lin method (Chow and Lin, 1971).

**Tax Rates** We use implicit tax rates to calibrate the values for  $\tau_n^C$ ,  $\tau_n^L$  and  $\tau_n^K$ . Our approach to classify taxes and calculate tax rates for consumption, labor and capital builds on early work by Mendoza et al. (1994), which was further refined in Eurostat et al. (2014). The principal idea is to classify tax revenue by economic function using data from the National Tax Lists and then approximate the base with data from the national sector accounts. Compared to statutory tax rates, the advantages of these rates are that they take into account the net effect of existing rules regarding exemptions and deductions, and also incorporate social security contributions in labor taxes. Annual tax rates can be measured with error because tax payments do not always coincide with the timing of taxable income. We therefore use the average over 2000 through 2009 to calculate steady-state tax rates. The appendix includes a list of all countries and steady-state implicit tax rates. A more detailed discussion of how these tax rates are calculated, see Proebsting et al. (2016).

## 4 Model and Data Comparison

We next simulate the calibrated model's reaction to shocks and compare the simulated data to the actual data. Our approach is to treat the austerity forecast deviations calculated in Section 2 as structural shocks. In addition to the austerity shocks, we also include shocks to monetary policy and shocks to financial markets. Including other shocks is important because it is likely that some of the observed differences in economic performance can be traced to shocks other than austerity.

## 4.1 Forcing Variables

Here we briefly describe how the shocks are constructed.<sup>29</sup>

**Monetary Policy Shocks** To measure monetary policy shocks we estimate a generalized Taylor rule of the form suggested by Clarida et al. (1997):<sup>30</sup>

$$i_{n,t} = \rho_i i_{t-1} + (1 - \rho_i) [\pi_{n,t} + r_n + \phi_\pi (\pi_{n,t} - \pi_n^*) + \phi_{GDP} (\ln GDP_{n,t} - \ln \overline{GDP}_{n,t})] + \varepsilon_{n,t}^i$$

where  $i_{n,t}$  is the nominal interest rate,  $r_n$  is the long-run interest rate,  $\pi_{n,t}$  is inflation,  $\pi_n^*$  is the inflation target,  $\ln GDP_{n,t} - \ln \overline{GDP}_{n,t}$  is the percent deviations of real GDP from its trend, and  $\varepsilon_{n,t}^i$  is a structural shock. Inflation is measured using the GDP deflator. The interest rate and the inflation rate are measured in annual percent. We impose a value for  $\rho = 0.79$  (see Clarida et al. (1997)) and estimate  $\phi_\pi$  and  $\phi_{GDP}$  for the U.S. over the period 1980.1 - 2005.4. This estimation implicitly assumes that the U.S. has been adhering to a fairly stable monetary rule since the early 1980's.

We then impose the estimated coefficients  $\phi_\pi$ ,  $\phi_{GDP}$  and the constrained coefficient  $\rho$  for each of the countries in Europe that have an independent monetary policy. We do not estimate separate Taylor rules for each central bank primarily because of data limitations. For the euro area, we assume that the ECB reacts to the weighted average of inflation and output over all countries in the euro. With these coefficients we then estimate country-specific intercepts (corresponding to the parameters  $r_n - \phi_\pi \pi_n^*$  in the Taylor rule). We can then recover the monetary policy shocks for each country  $n$  as  $\hat{\varepsilon}_{n,t}^i = i_{n,t} - \hat{i}_{n,t}$ .

**Financial Shocks** We take our measure of financial shocks from data on spreads between lending rates and central bank interest rates. For the U.S., data on lending rates comes from the Federal Reserve Survey of Terms of Business Lending. For European countries, we use a dataset provided by the ECB, which we supplement with data from national central banks and the Global Financial Database.

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<sup>29</sup>See the Appendix for more details.

<sup>30</sup>The original rule analyzed by Clarida et al. (1997) depends on expected inflation and the expected output gap instead of contemporaneous inflation and output gap.

## 4.2 Benchmark Model Performance

We feed the estimated structural shocks for the 2010-2014 period into the model and compare the simulated data with actual data. Throughout, we treat the simulated data (in terms of detrending, scaling and definitions of variables, etc.) in the same way as we treat the empirical data. The benchmark model includes all three structural shocks (austerity shocks, monetary policy shocks and financial shocks) and the baseline calibration given in Table 4.

Table 5 shows a comparison of the cross-sectional multipliers generated by the model and the data. The first three columns of the table reproduce the empirical coefficients from Table 3. The corresponding coefficients from the simulated data of the benchmark model are in the last three columns. Several points are worth emphasizing. First, the estimated coefficients from the model are consistent with the estimates from the data in terms of magnitude and sign. Empirically, the government purchases multiplier is 2.02; the corresponding multiplier in the model is 1.95. The response of inflation to government purchases is 0.41 in the data and 0.26 in the model (that is, a shortfall in spending is associated with deflation). The inflation response is somewhat greater for fixed exchange rate countries and weaker for floating exchange rate countries in both the data and the model.

The model does a better job of explaining consumption than investment. While the signs of the responses of consumption and investment are consistent across the model and the data, the magnitudes in the model fall short of the empirical estimates. The hand-to-mouth restriction on consumption is critical for generating the large drop in consumption in the model, while the financial shocks are not as successful in generating a sufficiently negative reduction in investment.

In both the model and the data, austerity shocks generate a positive response of net exports. The decrease in government purchases results in a drop in demand for the home good. The decline in demand causes firms to reduce their demand for labor, putting downward pressure on wages and employment. This drop in income causes hand-to-mouth consumers to reduce consumption one-for-one with the drop in GDP. Overall, and despite the positive wealth effect that stimulates consumption of unconstrained households, demand for intermediate goods falls more than supply. Note also that GHH preferences accentuate this effect. If a wealth effect on labor supply were present, households would reduce their labor supply and counterbalance the fall in demand.

Figures 3a - 3g compare scatterplots of the actual data (the left panels) with scatterplots of

the simulated data (the right panels). Note, the plot of the actual data conditions on the full set of control variables (i.e., specification 5 in Table 2). That is, we plot  $(\tilde{X}_i - \hat{\Gamma} \cdot \text{controls}_i, \tilde{G}_i)$ . In each panel, the austerity shocks (i.e., forecast errors) are on the horizontal axis. The units of both axes are log points times 100. The panels also show the OLS regression lines for the fixed exchange rate countries (the solid dots) and the floating exchange rate countries (the open dots).

The scatterplots reveal several differences between the actual data and the simulated data. First, and most importantly, the actual data has substantially more noise than the simulated data. This is not surprising since the model includes only a limited number of shocks. Second, the inflation data exhibits substantially more variation across countries within the euro area than the model permits. In the model, even though there are sharp differences in government purchases across countries, there is a strong tendency for countries in the currency union to have inflation rates that are nearly the same. On the other hand, the model displays substantial differences in inflation for countries that are *not* in the euro area, while in the data, inflation for these countries does not differ radically from inflation in the euro area. This may be due to the fact that even though the non-euro countries technically have floating exchange rates and independent monetary policy, the monetary authorities in these countries do not depart much from the policies enacted by the ECB. Third, in both the model and in the data, austerity shocks are associated with depreciation of nominal effective exchange rates in countries that float (Figure 3f). However, for fixed exchange rate countries, the model predicts a weak negative relationship while there is a weak positive relationship in the data.

To get a better sense of what is driving the results, Table 6 reports the cross-sectional multipliers for macro variables when the forcing variables – government purchases, monetary shocks, and financial shocks – are each fed into the model. The two left-most panels report the data and the results for the benchmark model; the three other panels report the results for each shock separately. The explanatory variable in all regressions are the government purchase shocks as they are observed in the data and fed into the benchmark model. That is, the government spending shocks always serve as the right-hand-side variable while the left-hand-side variable changes as we vary the shocks fed into the model.

This exercise makes clear that the negative relationship between austerity and economic performance in the model is driven primarily by austerity shocks. When *only* government purchases shocks are fed into the model, the coefficient on GDP is 1.8, compared to 1.95 in the benchmark model. Monetary policy shocks and spread shocks generate a fall in economic



activity, but the magnitudes are much smaller than for government purchases shocks. Because monetary policy was generally contractionary and credit conditions were tight during this time period, they reinforced the impact of austerity. But austerity itself accounts for most of the cross-sectional variation in the data.<sup>31</sup>

The one statistic that does depend heavily on shocks other than austerity is the cross sectional response of inflation in countries with floating exchange rates. For these countries, the coefficient on inflation is  $-0.19$  in the data (indicating an *decrease* in inflation following a contraction in government spending) but is  $0.32$  in the model with only government shocks. To understand the dynamics of inflation, first consider a decline in government spending in a closed-economy New Keynesian model. Under fairly standard assumptions about parameters, the fall in government spending reduces labor demand by more than the fall in labor supply, and therefore wages will fall. The decline in government spending is thus associated with falling costs and is deflationary. In our open economy setting, however, reductions in government purchases are associated with inflation for countries with floating exchange rates due to the depreciation of the nominal exchange rate (see the coefficient  $-0.92$ ). The depreciation raises the price of imports and stimulates demand for exports increasing the price level and inflation.

Adding monetary policy shocks helps bring the model's implications for inflation back into line with the data. During the 2010-2014 period, austere countries tended to have interest rates above the level suggested by the Taylor rule. These high interest rates reduce consumption and output, push down inflation and result in an appreciation of the nominal exchange rate. Thus, for our sample of economies with floating exchange rates, the combination of government spending shocks and contractionary monetary policy shocks results in falling prices and deflation.

### 4.3 Variations on the Benchmark Model

Table 7 reports the results of simulations under alternative parameterizations of the model, holding the shock processes the same as in the benchmark case. For each simulation, we report the cross-sectional multiplier for GDP and inflation as well as the rank correlation<sup>32</sup> and the standard deviation of GDP relative to the data.

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<sup>31</sup>The standard deviation of simulated GDP (averaged over 2010-2014) across countries is almost identical with and without monetary policy shocks.

<sup>32</sup>We rank countries by their average GDP deviation over 2010 through 2014 in both the data and the model, and then calculate Spearman's rho.

We consider the following alternative cases:

(i.) *No hand-to-mouth consumers.* This specification is the benchmark specification but with the share of rule-of-thumb consumers to  $\chi = 0$ .

(ii.) *Separable preferences.* Instead of GHH preferences used in the benchmark model, we switch the household's utility function to

$$\sum_{t=0}^{\infty} \sum_{s^t} \pi(s^t) (\beta^i)^t \left[ \frac{(C_{n,t}^i)^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} - \kappa_n \frac{(L_{n,t}^i)^{1+\frac{1}{\eta}}}{1+\frac{1}{\eta}} \right].$$

Unlike the GHH specification, this specification implies that variations in consumption have a wealth effect on labor supply.

(iii.) *Low Price Rigidities.* We reset the price rigidity Calvo parameter to  $\theta_p = 0.25$  (quarterly). This implies an average duration of prices of roughly 4 months.

(iv.) *Wage Rigidities.* We introduce sticky wages as in Erceg et al. (2000) (see the Appendix for additional details). We set the wage Calvo parameter to  $\theta_w = 0.80$  (quarterly). This implies an average duration of wages of roughly 15 months.

(v.) *Passive Monetary Policy.* The monetary authority for each country adopts a more accommodative stance. In particular, we set the Taylor rule coefficients for each country to  $\phi_{GDP} = \phi_{\pi} = 0.1$  compared to the benchmark settings of  $\phi_{GDP} = \phi_{\pi} = 0.5$ .

(vi.) *Zero-Lower-Bound (ZLB).* The ECB policy rate is fixed at zero while the other countries are away from the bound. We introduce the ZLB into the model by adding a (large) fictional country to the euro area that sets interest rates for the euro area but doesn't trade with any countries. This fictional country is sufficiently large to ensure that changes in inflation and economic activity within Europe do not have a perceptible feedback on the interest rate. The ZLB is assumed to persist indefinitely in this policy experiment.<sup>33</sup>

(vii.) *Strong Financial Accelerator.* We set the elasticity of the external finance premium with respect to the leverage ratio to  $F_{\varepsilon} = 0.8$ . Thus, holding the value of capital fixed, a one percent increase in net worth entails a reduction in the external finance premium of 80 basis points.

(viii.) *No Euro.* This specification allows the countries in the euro area to have floating exchange rates with independent monetary policy and thus to react to local shocks.

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<sup>33</sup>See House, Proebsting and Tesar (2016) for additional discussion of the ZLB solution.

(ix.) *No Trade*. This setting eliminates all trade across countries and thus, the countries interact only because of common monetary policies and correlated shocks.

(x.) *High Trade Elasticity*. The high trade elasticity sets the parameter  $\psi_y = 5$  relative to the benchmark setting of 0.5. Setting the trade elasticity higher makes foreign and domestic intermediate goods closer substitutes.

A comparison of the multipliers on GDP and inflation across the different cases gives a sense of which features of the model are critical for generating relationships between austerity, output and inflation that match the data. Increased wage rigidity, passive monetary policy and a stronger financial accelerator have little impact on the magnitude of the multipliers. Imposing incomplete markets (not reported) also has little impact on the benchmark results. The addition of the zero-lower-bound (ZLB) to the model actually *decreases* the cross-sectional multiplier on GDP relative to the benchmark. At first pass, this is somewhat surprising. A number of studies find that there is a larger response of output to government expenditure shocks at the ZLB because monetary policy cannot be used to offset the impact of the fiscal shock (see e.g. Blanchard et al., 2016; Kilponen et al., 2015). When we examine the impulse responses generated by our model, we obtain much larger responses to government expenditure shocks for countries at the ZLB (see Figure 5). However, a larger *time-series* multiplier does not necessarily translate into a larger *cross-sectional* multiplier. This is particularly true if the countries in question are all members of a currency union. As emphasized by Nakamura and Steinsson (2014), in a monetary union, the monetary policy reaction is governed by the average GDP and inflation paths for the union as a whole, not by the experiences of individual countries. In our model, if the nominal interest rate is away from the ZLB then the ECB will respond to aggregate output and inflation for the union as a whole. From the perspective of the simulated scatter plot in Figure 3a, the offsetting monetary policy would limit the fall in output for all of the solid dots but this policy would have no effect on the cross-sectional variation in economic performance. Similarly, if the interest rate is *at* the ZLB and the ECB *cannot* respond, then the solid dots fall more but again, the cross-sectional variation in output, and thus the estimated multiplier, is essentially unchanged.

A significant share of hand-to-mouth consumers and GHH preferences are key for generating a large multiplier on GDP. Trade also plays an important role. Greater substitutability between home and foreign goods weakens the impact of a home austerity shock on output, and increases the spillover to its trading partners. In the extreme case of autarky (the “no

trade” case in the last column), the multiplier on GDP increases from 1.95 to 3.85 (thanks to the higher multiplier among fixed exchange rate countries, and despite the lower multiplier among floating exchange rate countries), and the inflation multiplier increases by a factor of 10.

## 5 Counter-Factual Policy Simulations

We next use the model as a laboratory for considering counterfactuals and to conduct policy experiments. The model makes it possible to assess the costs and benefits of alternative policy options and illuminates the channels through which national policies are transmitted to other economies.

Figure 5 and Table 8 report results from a simulation of the model with and without austerity. We report results for our benchmark specification but we impose the ZLB on the euro area as described above. Because the counterfactual experiment emphasizes the time series dimension, the ZLB is important in generating the large reduction in output across Europe even though it not particularly important for analyzing the cross-section. The figure shows the actual time path of GDP in the data (the solid line), and two simulated time paths: one with the measured austerity shocks (the dashed line) and one with no austerity shocks (the dotted line). Table 8 reports the corresponding forecast errors in GDP, inflation and consumption for the euro area, countries with floating exchange rates, the GIIPS economies (Greece, Ireland, Italy, Portugal and Spain) and the EU10<sup>34</sup>. The first column shows the estimated forecast error for the last quarter of 2014. The second column shows the end-2014 prediction based on the benchmark model with the ZLB.

The model performs reasonably well in the time-series dimension of the data. GDP falls by almost 9 percent in the euro area in both the data and in the benchmark specification. Most of this decline stems from the GIIPS economies (14 percent in the model, 18 percent in the data). For floating exchange rate countries, the model overestimates the drop in GDP (2.3 percent in the model versus 0.45 percent in the data). The model has a harder time capturing the muted deflationary response in the data. The model predicts a fall of 2.15 percent in inflation in the euro area compared to a fall of only 0.89 percent in the data. This is in contrast to our cross-sectional results, where our model underpredicts inflation differences across countries.

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<sup>34</sup>This includes Belgium, Germany, Estonia, France, Luxembourg, Netherlands, Austria, Slovenia, Slovak Republic and Finland.

Thus, while the time-series evidence for the Phillips-Curve in the data is relatively weak, there is somewhat more evidence in favor of the Phillips-Curve in the cross-section.

The “No Austerity” experiment (column 3) is a scenario in which there are no negative shocks to government purchases. During the 2010 to 2014 period, with the exception of Switzerland, there was virtually no positive fiscal stimulus in Europe. Simulating the benchmark model eliminating all the negative fiscal shocks shows that, for the euro area overall, fiscal policy was a significant drag on output. This is particularly true for the GIIPS economies, which would have declined by only 0.87 by the end of 2014 – a fraction of what actually occurred. Even in the counterfactual without fiscal shocks, output in most European countries fell. This decline is primarily due to contractionary monetary policy shocks and financial shocks during this period.<sup>35</sup>

Figure 6 shows output trajectories for a “No Euro” experiment. In this counterfactual, the countries experienced austerity shocks over the period but were free to pursue independent monetary policy and allow their currencies to float (Note: unlike the previous counterfactual, we do not impose the ZLB for this experiment). While there are many ramifications of such an “exit strategy” from the euro that are not captured in our model, the experiment does provide some insight into the opportunity cost of a shared monetary policy. Under the full float scenario, GIIPS output would fall by 1.5 percentage points less relative to the benchmark while the EU10 would experience a larger output decline of 1 percentage point relative to the benchmark. Examination of the implied exchange rate changes in Figure 8 reveals the obvious: the nominal exchange rate depreciates in the GIIPS region, stimulating exports and output. In contrast, under the euro, the EU10 already enjoys the export advantage of a relatively weak currency (at least relative to the non-euro markets) due to the poor performance in the rest of the euro area. Interestingly, Figure 6 suggests that the path of GDP for the euro area as a whole would barely be affected by this drastic policy change even though there would be significant redistributive consequences *within* the euro area.

Finally, a “No Trade” experiment (not reported) reveals that, while direct spillover effects are small in the cross-section, trade does play a role in the transmission of shocks. Had countries been in autarky, the negative austerity shocks in GIIPS would have produced a substantial decline in GIIPS’ GDP while the EU10 would have seen a modest *increase* in output. Thus, the negative consequences of austerity policies in the GIIPS countries were, to

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<sup>35</sup>While we do not include an explicit sovereign risk premium in the model, the financial shocks will reflect sovereign default risks to some extent.

an extent, shared with other nations in the region.

## 5.1 Austerity and the Impact on Debt-to-GDP Ratios

A significant motivation for austerity policies was to slow the escalation of debt-to-GDP ratios that occurred across the euro area (reaching close to 80 percent in the EU10 and 95 percent in the GIIPS countries in 2010). While reductions in government expenditures should, all else equal, reduce deficits and debt levels over time, the impact on the debt-to-GDP *ratio* is not obvious. As our previous analysis shows, reductions in government expenditures may have a negative impact on economic activity, and this will in turn reduce tax revenues. Further, trade linkages and shared monetary policy in Europe mean that fiscal actions in one country will be readily transmitted to neighboring countries, affecting *their* fiscal positions.

Figure 7 compares the trajectories of debt-to-GDP ratios for the euro area, floating exchange rate countries, GIIPS and EU10 under different assumptions. The dark line shows the actual data. The dark dotted line is a “static” estimate that assumes that GDP and tax revenue is unaffected by changes in government purchases (i.e. reductions in government spending reduce debt but have no impact on the rest of the economy). According to this measure, the austerity measures undertaken by the GIIPS countries should have resulted in a decline in the debt-to-GDP ratios by more than 20 percentage points from 2008 to 2014. In reality, debt-to-GDP ratios rose by 20 percentage points. This static view misses three endogenous responses captured by our model: First, reductions in government purchases cause reductions in GDP. Second, reductions in GDP lead to reductions in tax revenue. Both of these effects lead to an increase in the debt-to-GDP ratio. Third, some of the fiscal austerity will spillover into other countries.<sup>36</sup> Taking these channels into account (the “benchmark” series), our model actually predicts an *increase* in the debt-to-GDP ratio in the GIIPS region, of a magnitude similar to that observed in the data. The fit of our model is surprisingly good given that our model assumes that tax *rates* did not change over time.

Our final experiment considers how debt-to-GDP ratios would have evolved if no austerity measures had been implemented. To answer this question, we simulate our model under the alternative scenario in which there were no negative shocks to government purchases.

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<sup>36</sup>Another channel through which austerity might affect the debt-to-GDP ratio is its effect on sovereign risk premia. Our model ignores this channel. Consequently, the data and simulated data in Figure 7 refer to changes in the cumulative sum of the primary balance, that is the evolution of debt excluding interest payments.

The model predicts a more modest increase in the debt-to-GDP ratio for GIIPS countries. Interestingly, the EU10 countries would have also seen their debt-to-GDP ratios rise, although under the benchmark, their debt-to-GDP ratios went down. The positive effect for the GIIPS countries stems from a strong increase in GDP in the absence of negative fiscal shocks. This effect is weaker for the EU10 countries because their baseline government purchases shocks were not as severe as those experienced by the GIIPS countries. The improved performance of the GIIPS countries leads to a contractionary monetary policy response for the euro area overall, depressing GDP across the region as a whole. This effect is sufficiently strong for the EU10 countries that their debt-to-GDP ratio increases. While we would not take the results of this model literally as a prescription for the European debt crisis, our model does suggest that efforts to reduce debt through austerity in the depths of an economic recession were counterproductive.

## 6 Conclusion

Since the end of the Great Recession in 2009, advanced economies have experienced radically different recoveries. Some enjoyed a return to normal economic growth following the financial crisis while others have suffered through prolonged periods of low employment and low growth. We have attempted to make sense of this diversity of experiences by examining cross-country variation in economic activity empirically and through the lens of a dynamic general equilibrium model. Despite substantial noise in the data, there are clear patterns that suggest that an important fraction of the differences in economic performance can be attributed to fiscal austerity. In particular, the evidence suggests that contractions in government purchases played a surprisingly large role in reducing output in many countries.

We use a multi-country DSGE model to see whether standard macroeconomic theory can explain the observed changes in economic activity. The model features government purchases shocks, monetary policy shocks, and shocks to financial markets and allows us to make direct comparisons between the observed empirical relationships in the data and the model's predictions. The model is calibrated to match the main features of the European countries in our dataset including country size, observed trade flows and exchange rate regimes. The model output broadly matches the empirical patterns observed in the data. In particular, the model successfully reproduces a large cross-sectional multiplier of government austerity shocks on output.

We use the model to conduct a number of counterfactual experiments. Our analysis suggests that austerity was a substantial drag on GDP especially for the GIIPS countries. Economic integration shaped the GDP response to austerity in opposite ways: On the one hand, trade integration redistributed its negative consequences across euro area countries. On the other hand, the single monetary policy accentuated the impact of different fiscal policies. Our analysis also suggests that had countries in the euro area abstained from negative fiscal shocks, output would have been substantially higher and may have even resulted in lower debt-to-GDP ratios across the region.



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Table 1: COUNTRY SIZE, IMPORT SHARES AND EXCHANGE RATE REGIMES

Country	Size	Import share	XRT regime	Country	Size	Import share	XRT regime
Belgium	2.6 %	31.3 %	Euro	Bulgaria	0.3 %	40.3 %	Peg
Germany	18.3 %	24.3 %	Euro	Denmark	1.7 %	26.9 %	Peg
Ireland	1.1 %	44.2 %	Euro	Estonia	0.1 %	42.2 %	Peg
Greece	1.9 %	25.5 %	Euro	Latvia	0.1 %	36.8 %	Peg
Spain	8.4 %	24.1 %	Euro	Lithuania	0.2 %	32.2 %	Peg
France	15.3 %	21.2 %	Euro	Czech Republic	1.0 %	37.1 %	Floating
Italy	12.5 %	22.0 %	Euro	Hungary	0.7 %	38.9 %	Floating
Cyprus	0.1 %	39.5 %	Euro	Poland	2.5 %	28.8 %	Floating
Luxembourg	0.2 %	56.9 %	Euro	Romania	0.9 %	28.2 %	Floating
Netherlands	4.1 %	21.0 %	Euro	Sweden	2.4 %	28.8 %	Floating
Austria	2.1 %	30.3 %	Euro	United Kingdom	15.4 %	23.9 %	Floating
Portugal	1.4 %	28.3 %	Euro	Norway	1.9 %	25.3 %	Floating
Slovenia	0.3 %	38.1 %	Euro	Switzerland	2.8 %	31.7 %	Floating
Slovak Republic	0.4 %	41.5 %	Euro	United States	91.5 %	13.3 %	Floating
Finland	1.3 %	27.5 %	Euro	RoW	162.9 %	8.4 %	Floating

*Notes:* Table displays the 29 countries plus the Rest of the World in our sample. Size is measured as the country's final demand relative to the sum of all European countries' final demand. Final demand is measured as GDP less net exports. Shares are averaged over 2005 and 2010. The import share is measured as the share of (value added) imports in final demand using the OECD TiVA database. The exchange rate regime is as of 2010. Countries with a peg have their currencies pegged to the Euro. Countries with a floating currency are either free or managed floaters or countries with a wide crawling peg. The classification follows Itzetzi et al. (2004), [http : //www.carmenreinhardt.com/data/browse-by-topic/topics/11/](http://www.carmenreinhardt.com/data/browse-by-topic/topics/11/).

Table 2: AUSTERITY AND GDP

	(1)	(2)	(3)	(4)	(5)
Gov't. Purchases	-2.55 (0.36)	-2.48 (0.34)	-2.39 (0.31)	-1.99 (0.32)	-2.02 (0.31)
Total Revenue		-1.13 (0.56)			-0.70 (0.49)
Gov't Debt to GDP			-0.07 (0.02)		-0.02 (0.03)
TFP				0.49 (0.12)	0.39 (0.14)
$R^2$	0.66	0.70	0.75	0.79	0.82

*Notes:* Table displays the regression coefficients  $\alpha$  and  $\beta$  of the multivariate regressions (2.5). Each column represents a separate regression. The dependent variable is the average deviation of real GDP per capita from its forecast over 2010 - 2014. For the independent variables: 'Gov't Purchases' is the average deviation of real government purchases per capita (deflated by the GDP deflator) from their forecast over 2010 - 2014, 'Total Revenue' is the average deviation of real government revenue per capita (deflated by the GDP deflator) from their forecast over 2010 - 2014, 'Gov't Debt' is the end-of-2007 nominal government debt level (normalized by the average of 2000-2007 nominal GDP), 'TFP' is the change in TFP between 2009 and 2014.

Table 3: AUSTERITY AND OTHER MEASURES OF ECONOMIC PERFORMANCE

	All Countries		By Currency Regime		
	$\alpha$	$R^2$	$\alpha^{Fix}$	$\alpha^{Fl}$	$R^2$
GDP	-2.02 (0.31)	0.82	-2.00 (0.39)	-1.92 (0.57)	0.82
Inflation	-0.41 (0.15)	0.35	-0.51 (0.20)	-0.19 (0.29)	0.37
Consumption	-1.35 (0.27)	0.68	-1.36 (0.34)	-1.19 (0.49)	0.69
Investment	-1.55 (0.23)	0.76	-1.63 (0.29)	-1.26 (0.42)	0.78
NX to GDP	1.43 (0.28)	0.55	1.50 (0.34)	1.05 (0.50)	0.61
Exchange Rate	-0.91 (0.50)	0.15	0.36 (0.46)	-3.37 (0.68)	0.57
GDP Growth	-0.59 (0.12)	0.72	-0.54 (0.16)	-0.61 (0.23)	0.74

*Notes:* Table displays the regression coefficients on government purchases ( $\alpha$  in regression (2.5) and for the multipliers  $\alpha^{Fix}$  and  $\alpha^{Fl}$  for the regression with separate coefficients for fixed and floating exchange rate countries, after controlling for government revenue, government debt and TFP as is done in specification (5) of Table 2. Each row represents a separate regression. The dependent variables are average forecast errors in real GDP per capita, the inflation rate based on the Harmonized Index for Consumer Prices excluding Food and Energy, real consumption per capita, real investment per capita, real net exports over nominal 2005Q1 GDP, the nominal effective exchange rate and real GDP per capita growth.



Table 4: CALIBRATION

Description	Parameter	Value	Source
<b>Preferences</b>			
Discount factor (quarterly)	$\beta$	0.99	Standard value
Coefficient of relative risk aversion	$\frac{1}{\sigma}$	2	Standard value
Frisch elasticity of labor supply	$\eta$	1	Barsky et al. (1997)
Share of rule-of-thumb consumers	$\chi$	0.5	Campbell and Mankiw (1989), Martin and Philippon (2014)
<b>Trade and Country Size</b>			
Trade preference weights	$\omega_n^j$	$x$	OECD Trade in Value Added Dataset
Trade demand elasticity	$\psi_y$	0.5	e.g. Heathcote and Perri (2002), Cravino (2014), Proebsting (2015)
Country size	$N_n Y_n$	$x$	OECD Input-Output Tables
<b>Technology</b>			
Capital share	$\alpha$	0.38	Trabandt and Uhlig (2011)
Depreciation (quarterly)	$\delta$	0.028	Average private investment share, $X/Y = 0.197$ , 2000 - 2010
Utilization cost	$a''$	0.286	Del Negro et al. (2013)
Investment adjustment cost	$f''$	2.48	Christiano et al. (2005)
Elasticity of substitution between varieties	$\psi_q$	10	Standard value
<b>Price Rigidity</b>			
Sticky price probability	$\theta_p$	0.80	Alvarez et al. (2006)
<b>Financial Market Imperfections</b>			
SS External finance premium	$F_n(\lambda_{ss})$	$x$	ECB, Global Financial Database and national sources
Elasticity external finance premium	$F_\epsilon$	0.20	Brave et al. (2012)
Persistence spread shock	$\rho_F$	0.99	Brave et al. (2012)
<b>Fiscal and Monetary Policy</b>			
Gov't purchases over final demand	$\frac{C_n}{Y_n}$	$x$	OECD and Eurostat
Persistence government spending shock	$\rho_G$	0.93	Del Negro et al. (2013)
Labor and Capital tax rates	$\tau^L, \tau^K$	$x$	Own calculations based on National Tax Lists
Consumption tax rates	$\tau^C$	$x$	Own calculation based on Eurostat data
Taylor rule persistence	$\phi_i$	0.75	
Taylor rule GDP coefficient	$\phi_{GDP}$	0.5	
Taylor rule inflation coefficient	$\phi_\pi$	0.5	

Notes: Values marked with  $x$  are country- or country-pair specific.

Table 5: COMPARISON OF MODEL AND DATA: BENCHMARK CALIBRATION

	Data			Benchmark		
	$\alpha$	$\alpha^{Fix}$	$\alpha^{Fl}$	$\alpha$	$\alpha^{Fix}$	$\alpha^{Fl}$
GDP	-2.02 (0.26)	-2.00 (0.31)	-1.92 (0.51)	-1.95	-2.01	-1.74
Inflation	-0.41 (0.13)	-0.51 (0.16)	-0.19 (0.25)	-0.26	-0.29	-0.13
Consumption	-1.35 (0.22)	-1.35 (0.27)	-1.19 (0.43)	-1.06	-1.15	-0.77
Investment	-1.56 (0.19)	-1.64 (0.23)	-1.26 (0.37)	-0.59	-0.65	-0.39
Net Exports over GDP	1.43 (0.24)	1.50 (0.27)	1.05 (0.44)	1.29	1.31	1.24
Exchange Rate	-0.91 (0.42)	0.36 (0.37)	-3.37 (0.60)	-0.17	-0.10	-0.53
GDP Growth	-0.59 (0.10)	-0.54 (0.12)	-0.61 (0.20)	-0.29	-0.33	-0.20

*Notes:* Table displays data and model results for the multiplier  $\alpha$  in regression (2.5) and for the multipliers  $\alpha^{Fix}$  and  $\alpha^{Fl}$  for the regression with separate coefficients for fixed and floating exchange rate countries. See also Table 3.

Table 6: COMPARISON OF MODEL AND DATA: INDIVIDUAL SHOCKS

	Data			Benchmark			Only Govt			Only Money			Only Spread		
	All	Fix	Float	All	Fix	Float	All	Fix	Float	All	Fix	Float	All	Fix	Float
GDP	-2.02 (0.26)	-2.00 (0.31)	-1.92 (0.51)	-1.95	-2.01	-1.74	-1.79	-1.91	-1.50	-0.10	0.03	-0.41	-0.06	-0.14	0.16
Inflation	-0.41 (0.13)	-0.51 (0.16)	-0.19 (0.25)	-0.26	-0.29	-0.13	-0.17	-0.35	0.32	-0.14	0.01	-0.48	0.05	0.05	0.03
Consumption	-1.35 (0.22)	-1.35 (0.27)	-1.19 (0.43)	-1.06	-1.15	-0.77	-0.93	-1.07	-0.52	-0.10	0.01	-0.34	-0.04	-0.09	0.10
Investment	-1.56 (0.19)	-1.64 (0.23)	-1.26 (0.37)	-0.59	-0.65	-0.39	-0.46	-0.51	-0.33	-0.07	0.00	-0.25	-0.06	-0.15	0.19
Net Exports over GDP	1.43 (0.24)	1.50 (0.27)	1.05 (0.44)	1.29	1.31	1.24	1.22	1.22	1.22	0.03	0.01	0.09	0.04	0.08	-0.07
Exchange Rate	-0.91 (0.42)	0.36 (0.37)	-3.37 (0.60)	-0.17	-0.10	-0.53	-0.31	-0.09	-0.92	0.15	-0.01	0.45	-0.01	0.00	-0.05
GDP Growth	-0.59 (0.10)	-0.54 (0.12)	-0.61 (0.20)	-0.29	-0.33	-0.20	-0.33	-0.38	-0.20	-0.00	0.01	-0.05	0.04	0.04	0.05

*Notes:* Table displays data and model results for the multiplier  $\alpha$  in regression (2.5) and for the multipliers  $\alpha^{Fix}$  and  $\alpha^{Fl}$  for the regression with separate coefficients for fixed and floating exchange rate countries. The benchmark calibration includes shocks to government spending (“Govt”), the Taylor rule (“Money”) and interest rate spreads (“Spread”). The following columns display results if only one of those shocks is fed into the model.

Table 7: ROBUSTNESS

	Data	Bench- mark	No RoTh	Separ pref	Low pri rigid	Wage rigidity	Pass mon policy	ZLB	Strong fin acc	No Euro	No Trade	Hi trade elast
All												
GDP	-2.02	-1.95	-1.32	-1.17	-1.35	-1.96	-1.94	-1.83	-2.08	-1.51	-3.85	-0.78
Inflation	-0.41	-0.26	-0.20	-0.27	-0.48	-0.18	-0.65	-0.27	-0.27	0.08	-2.16	-0.11
Fixed												
GDP	-2.00	-2.01	-1.32	-1.19	-1.36	-2.03	-1.78	-1.74	-2.09	-1.40	-4.89	-0.61
Inflation	-0.51	-0.29	-0.15	-0.25	-0.45	-0.23	-0.22	-0.23	-0.24	0.19	-2.02	-0.06
Floaters												
GDP	-1.92	-1.74	-1.24	-1.11	-1.32	-1.70	-2.27	-1.74	-2.00	-1.73	-0.86	-1.05
Inflation	-0.19	-0.13	-0.27	-0.28	-0.47	-0.00	-1.68	-0.14	-0.26	-0.14	-2.56	-0.27
Simulated GDP												
Rank Corr.	1.00	0.63	0.52	0.63	0.63	0.62	0.51	0.41	0.63	0.57	0.50	0.73
Rel. Std. Dev.	1.00	0.60	0.45	0.35	0.40	0.60	0.62	0.70	0.60	0.44	2.07	0.23

*Notes:* The table displays the estimated  $\alpha$  in regression (2.5) with regressors being fiscal shocks observed in the data. The rank correlation for GDP is the Spearman rank coefficient of the simulated GDP data averaged over 2010 - 2014 compared to the actual GDP data averaged over 2010 - 2014. Similarly, the relative standard deviation is the standard deviation of simulated GDP averaged over 2010 - 2014 relative to the standard deviation observed in the data for that time period.

Table 8: COUNTERFACTUAL ANALYSIS

	Data	Benchmark + ZLB	No Austerity + ZLB
Euro area			
GDP	-8.86	-8.72	-0.94
Inflation	-0.89	-2.15	-0.04
Consumption	-11.08	-7.67	-1.12
Floaters			
GDP	-0.45	-2.27	0.35
Inflation	-0.30	-2.68	0.50
Consumption	3.15	0.96	0.41
GIIPS			
GDP	-18.00	-14.41	-0.87
Inflation	-1.47	-1.60	0.55
Consumption	-20.12	-12.07	-0.98
EU10			
GDP	-3.66	-5.67	-0.97
Inflation	-0.55	-2.46	-0.37
Consumption	-5.98	-4.98	-1.19

*Notes:* Table displays average percent deviations from the steady state for simulated data at the end of 2014.

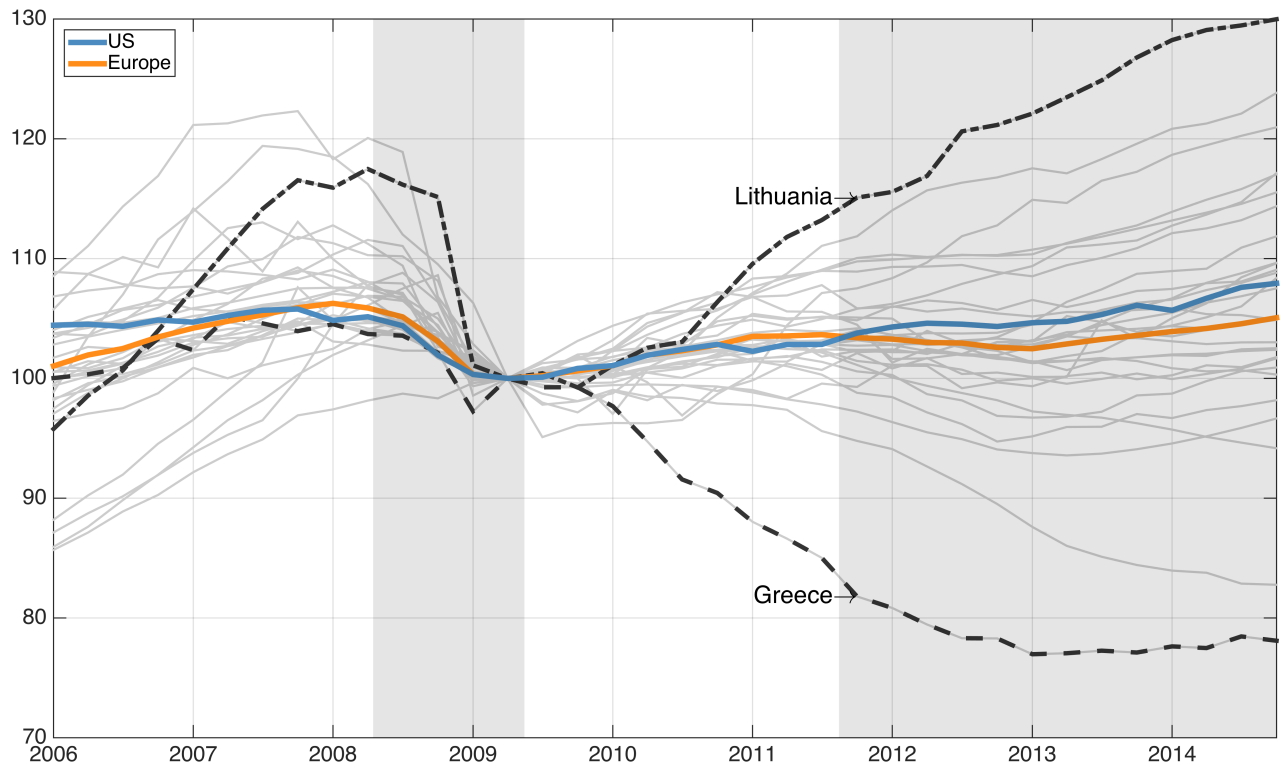


Figure 1: REAL PER CAPITA GDP BEFORE, DURING AND AFTER THE CRISIS

*Note:* The figure plots the time paths of real per capita GDP for the period 2006:1-2014:4 for the countries in our data set. The paths are indexed to 100 in 2009:2. The two shaded regions indicate recession dates according to the NBER and CEPR.

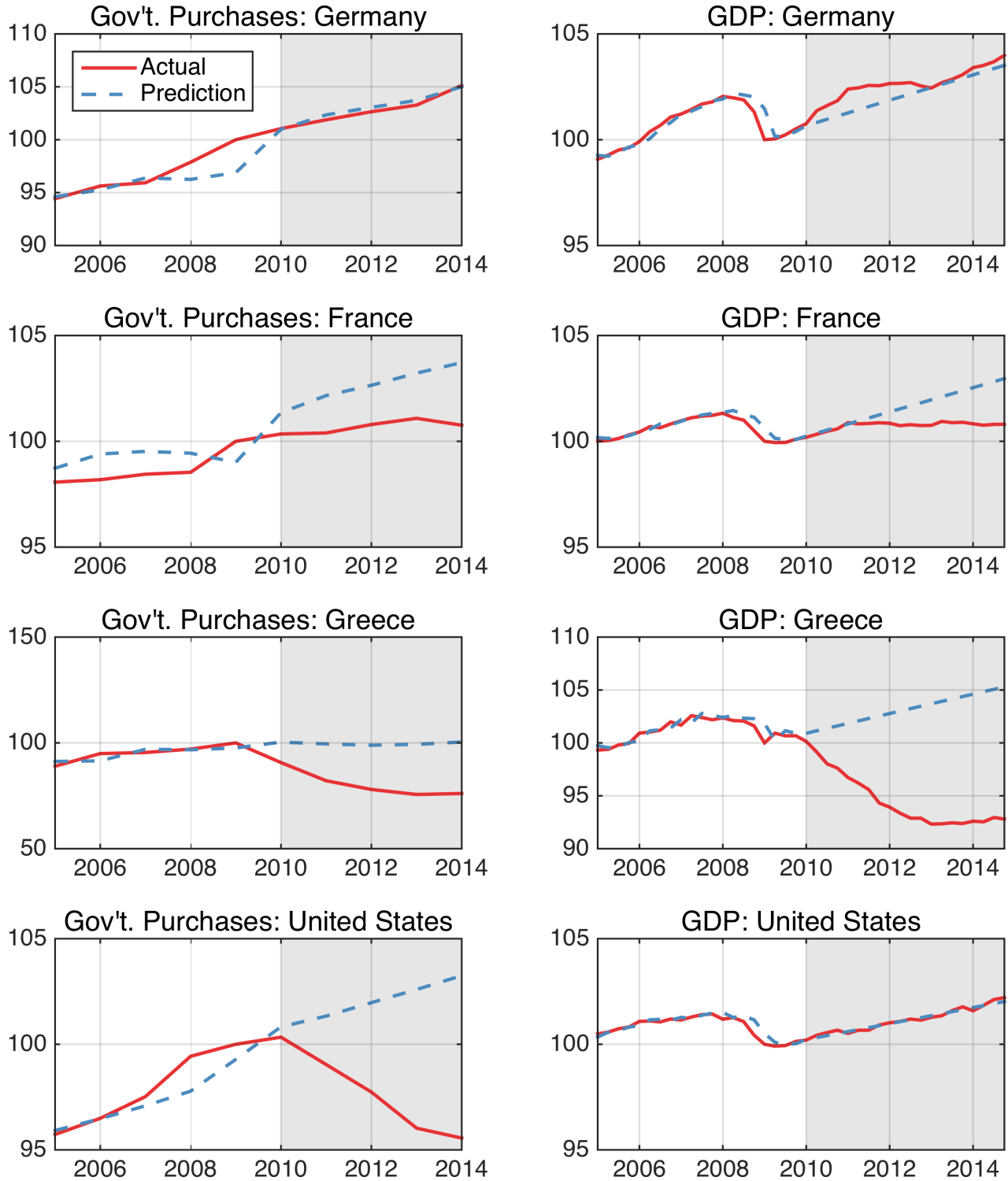


Figure 2: GOVERNMENT PURCHASES AND GDP

*Note:* Left column panels display real government purchases for various countries on a log scale (normalized to 2009=100), together with their predicted values. Right column panels display the corresponding series for real GDP per capita.

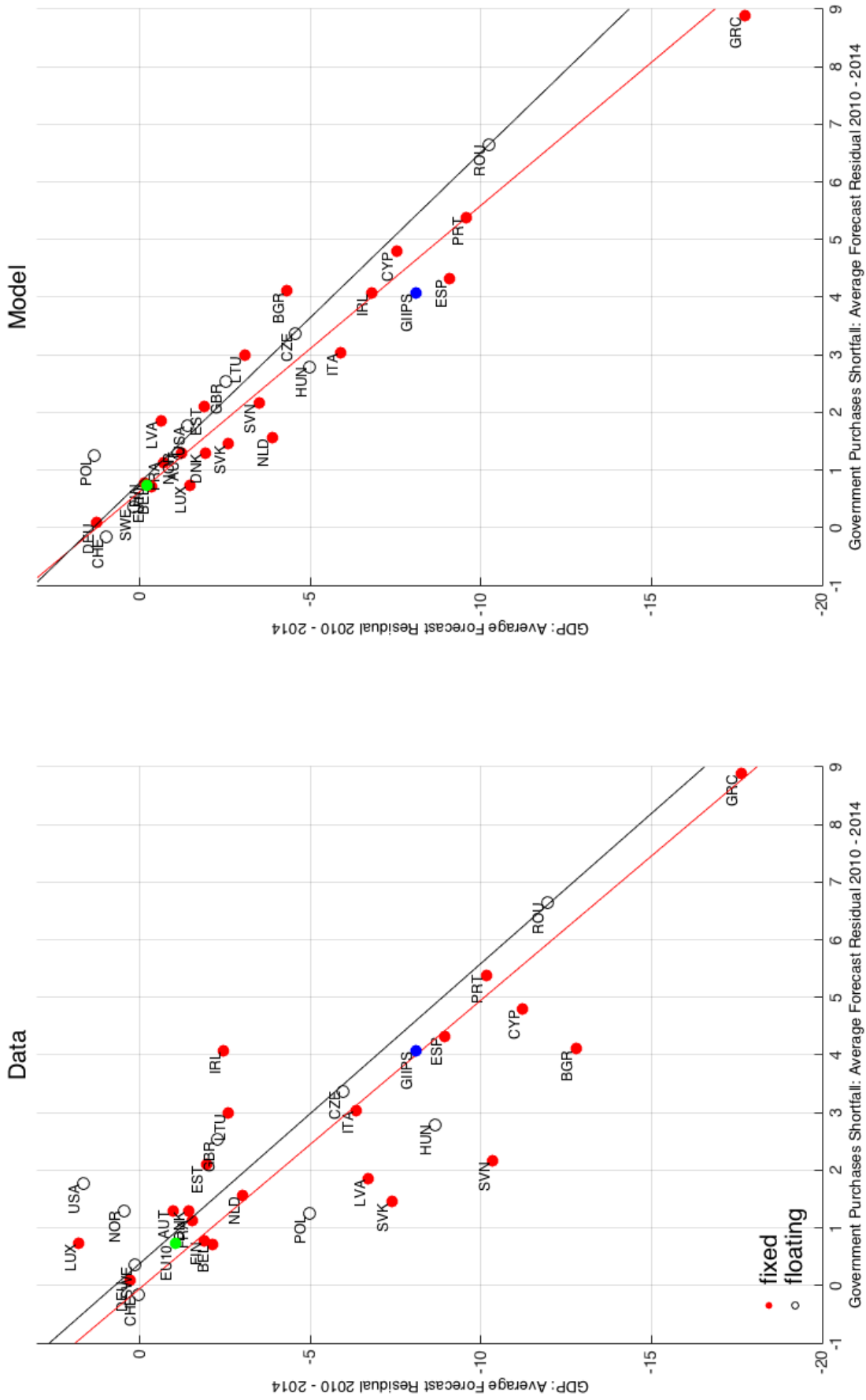


Figure 3a: GDP AND AUSTRITY: DATA VS. MODEL

Note: Figure displays a scatter plot of the average forecast residual of GDP over 2010 - 2014, in log points, versus the average forecast residual for the shortfall in government purchases, also in log points. Countries are classified by their exchange rate regime (red: euro / pegged to euro; black: floating currency). Regression lines are based on data points from each exchange rate regime. Left panel is based on actually observed data and displays the GDP residual after controlling for government revenue, government debt and TFP as is done in specification (5) of Table 2; right panel refers to data from the simulated model. See text for details on the forecast specification.



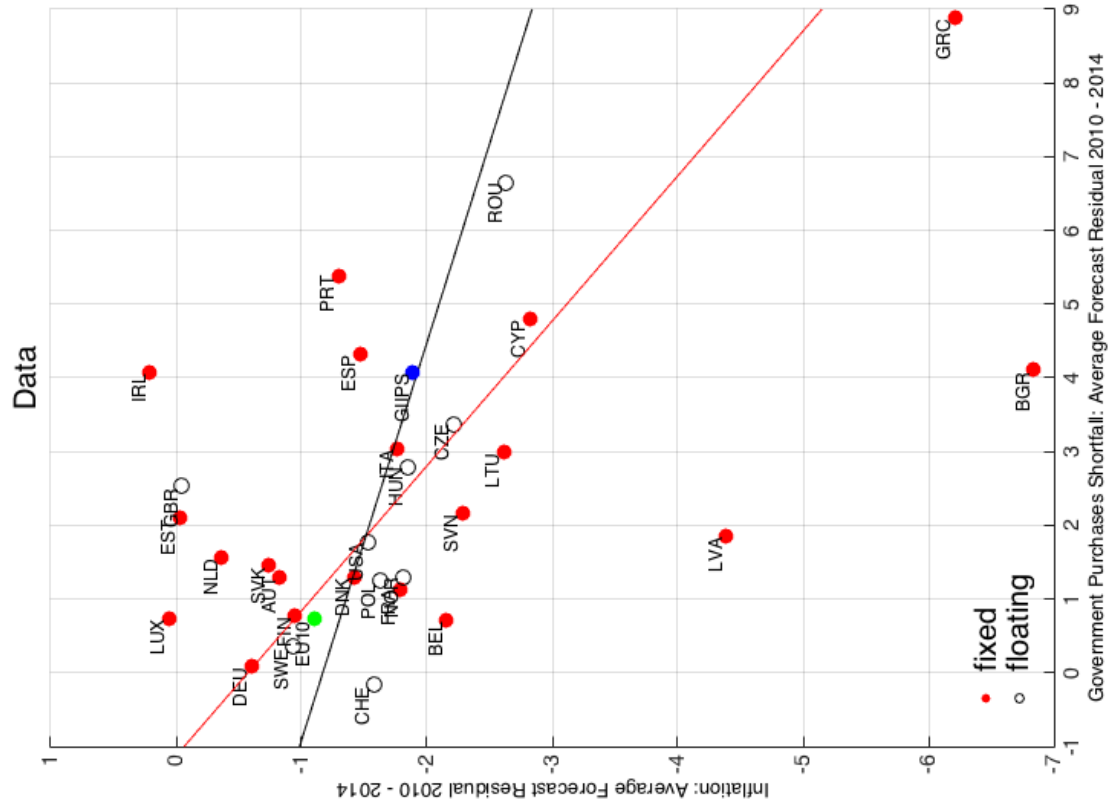
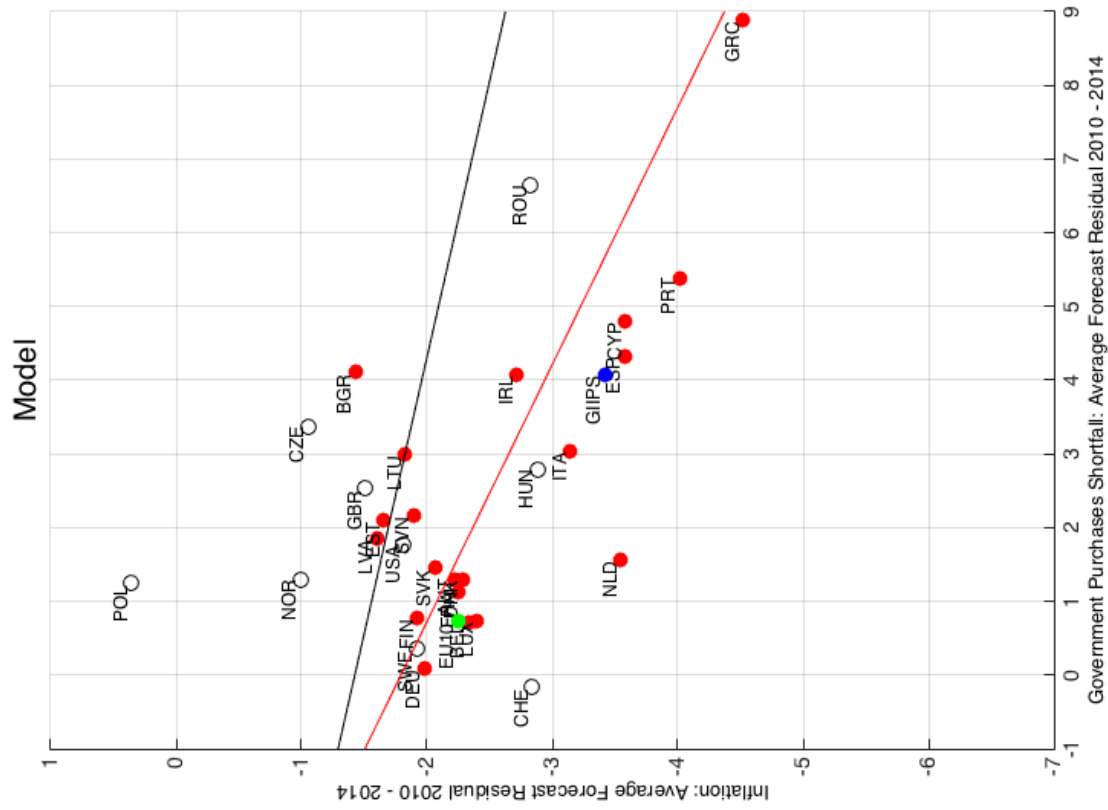


Figure 3b: INFLATION AND AUSTERITY: DATA VS. MODEL

Note: See Figure 3a.



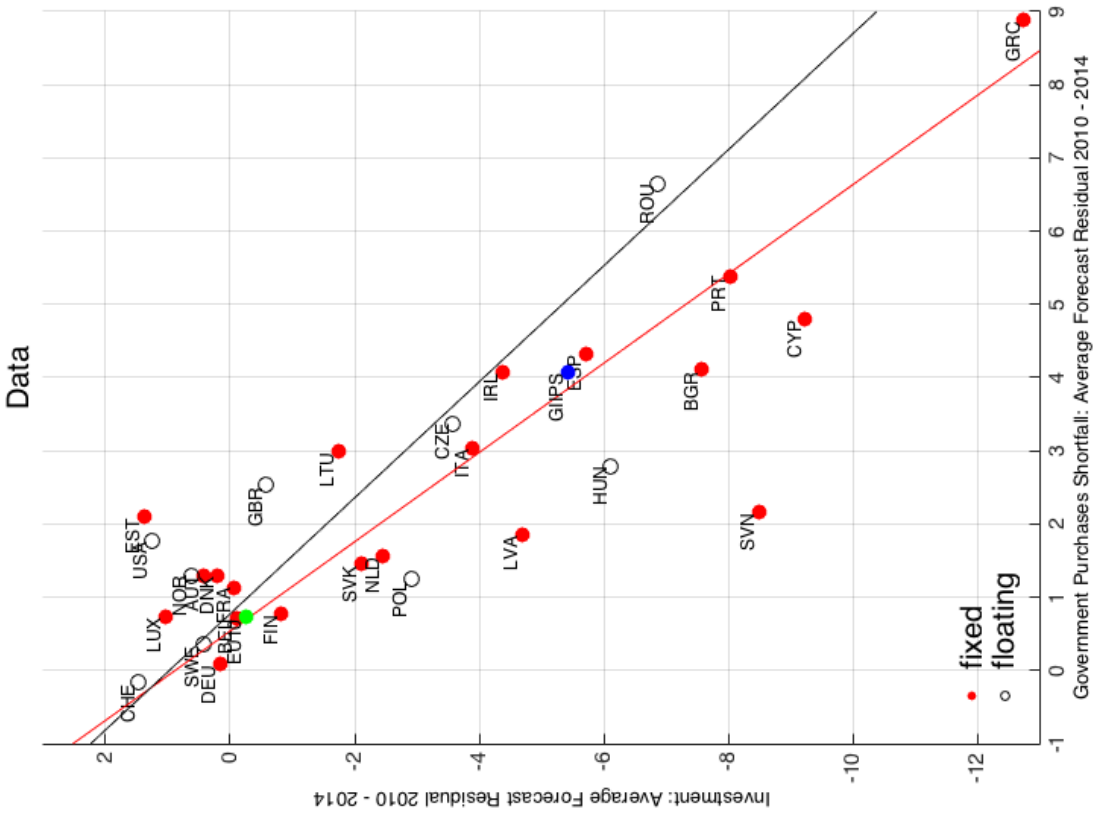
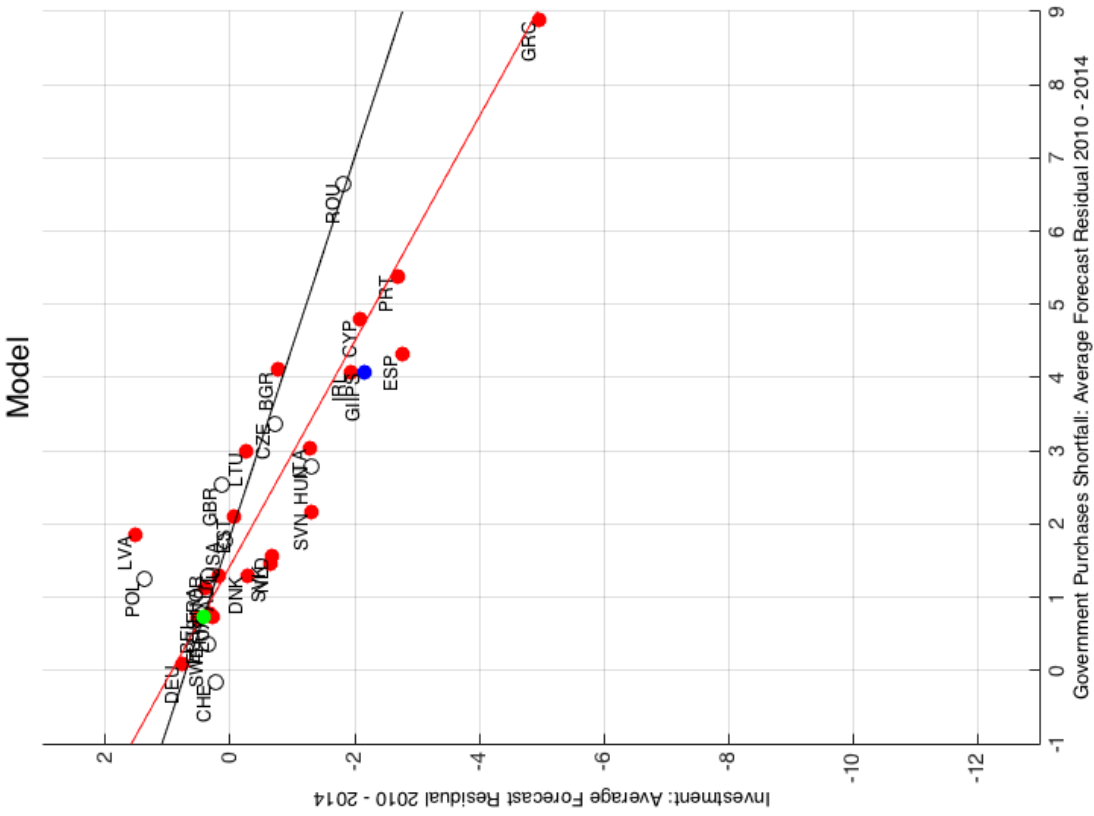


Figure 3d: INVESTMENT AND AUSTERITY: DATA VS. MODEL

Note: See Figure 3a.

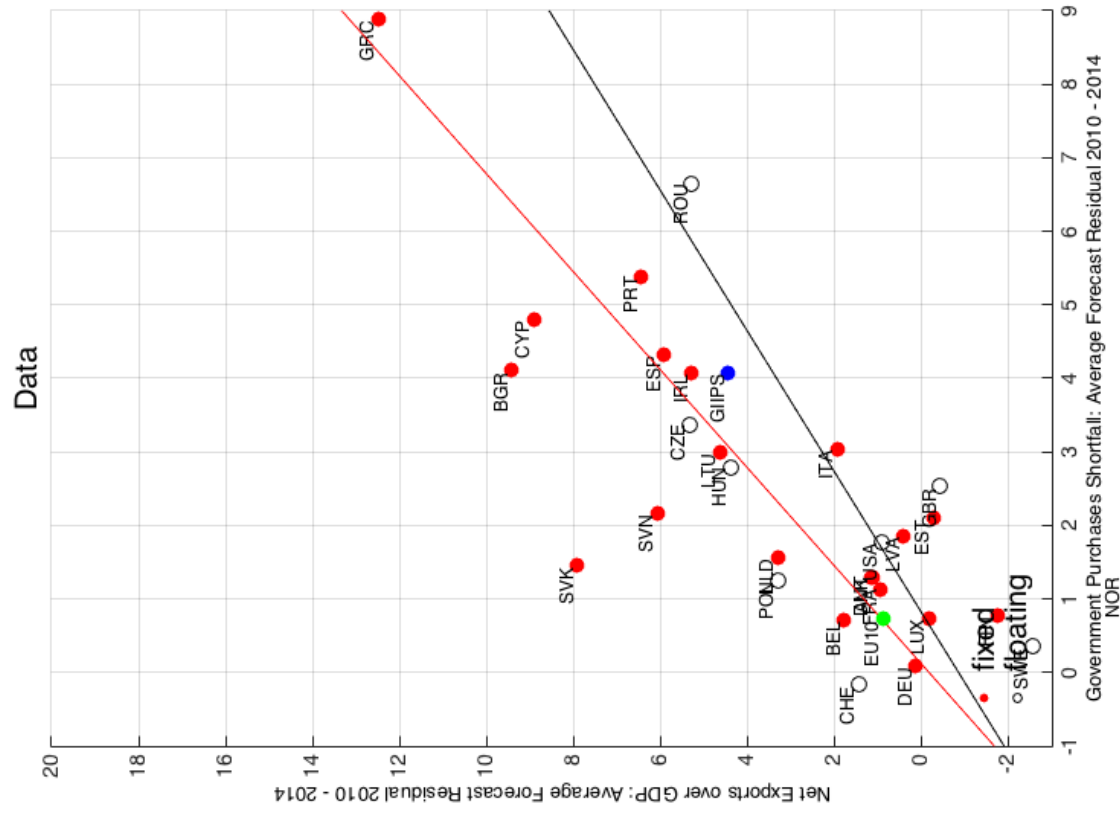
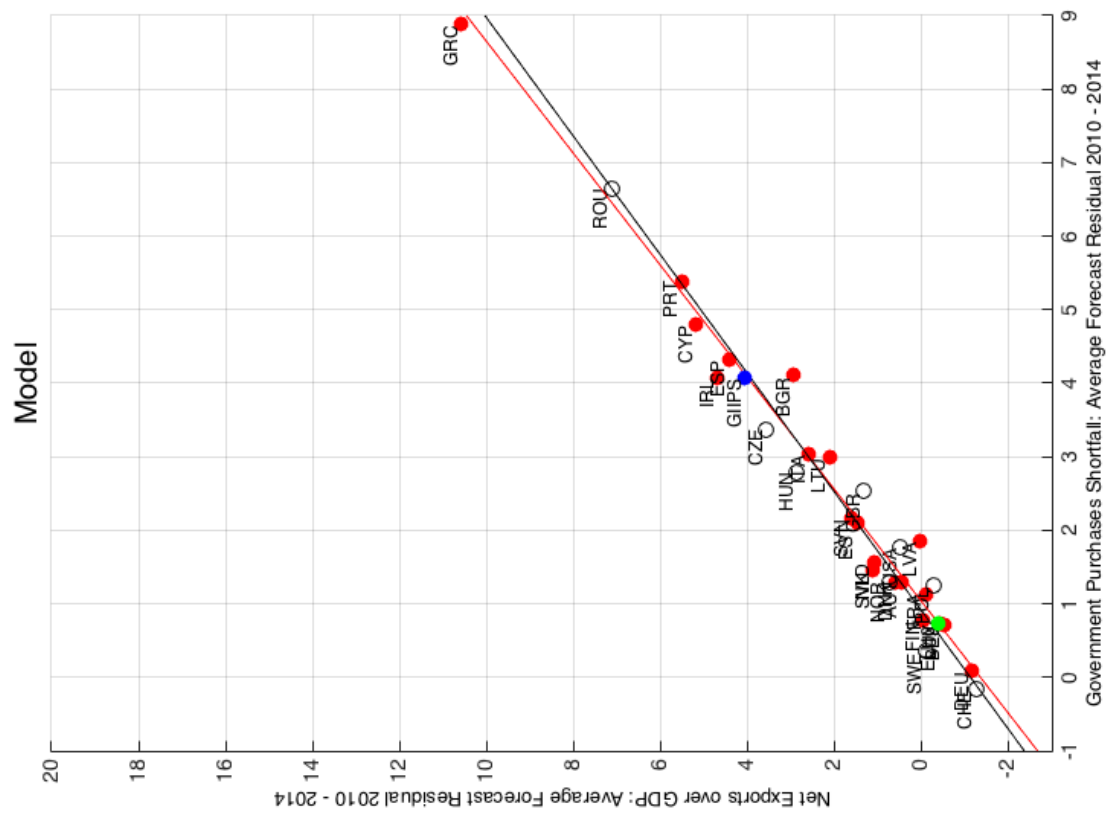


Figure 3e: NET EXPORTS AND AUSTERITY: DATA VS. MODEL

Note: See Figure 3a.

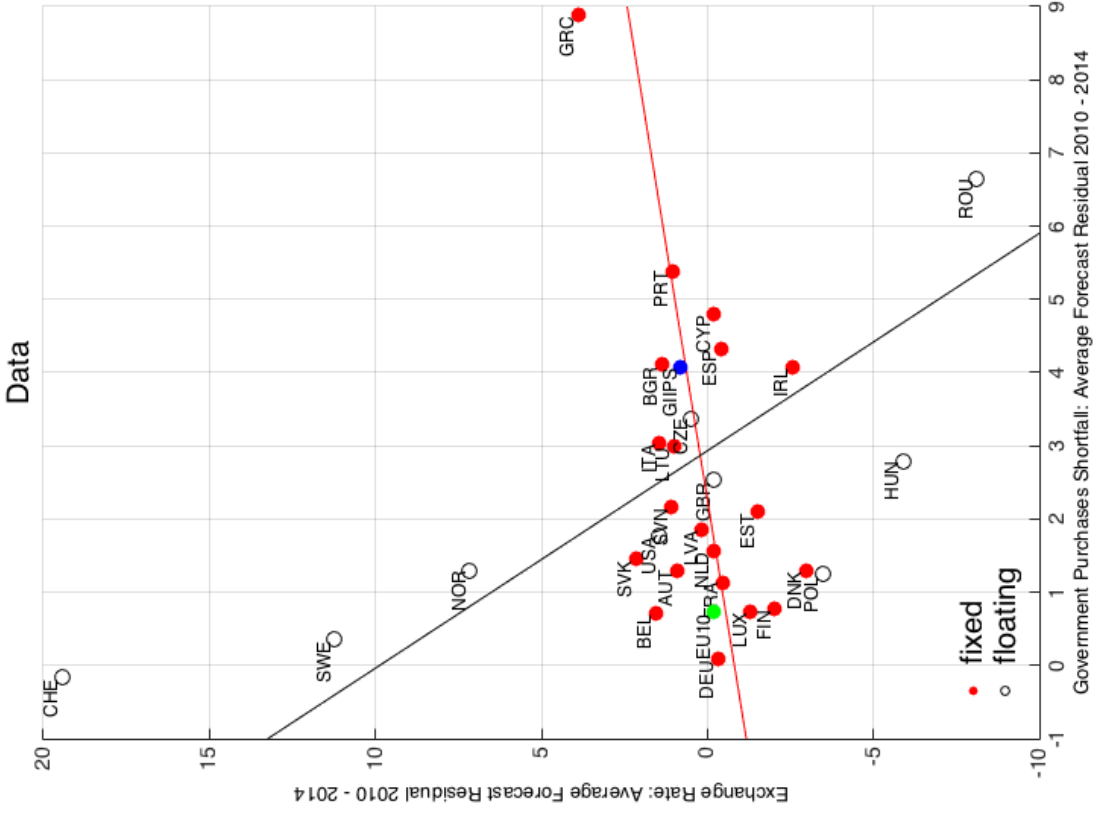
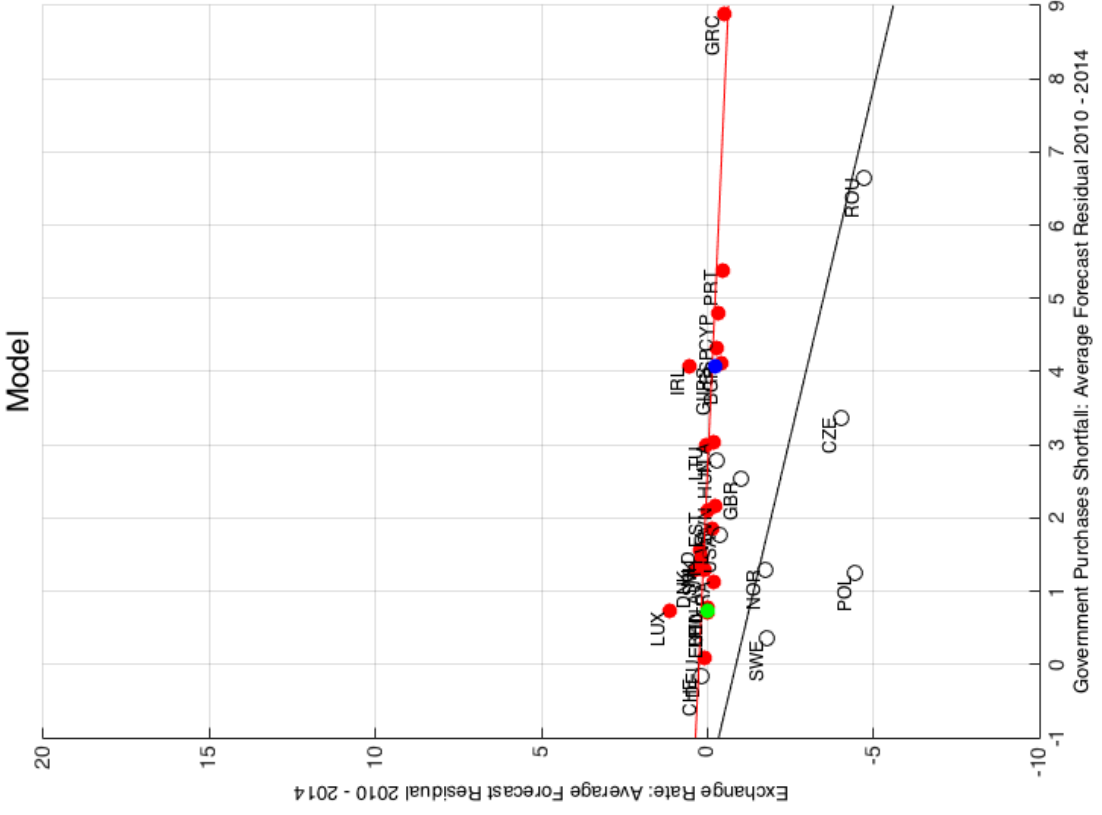


Figure 3f: NOMINAL EFFECTIVE EXCHANGE RATE AND AUSTERITY: DATA VS. MODEL

Note: See Figure 3a.

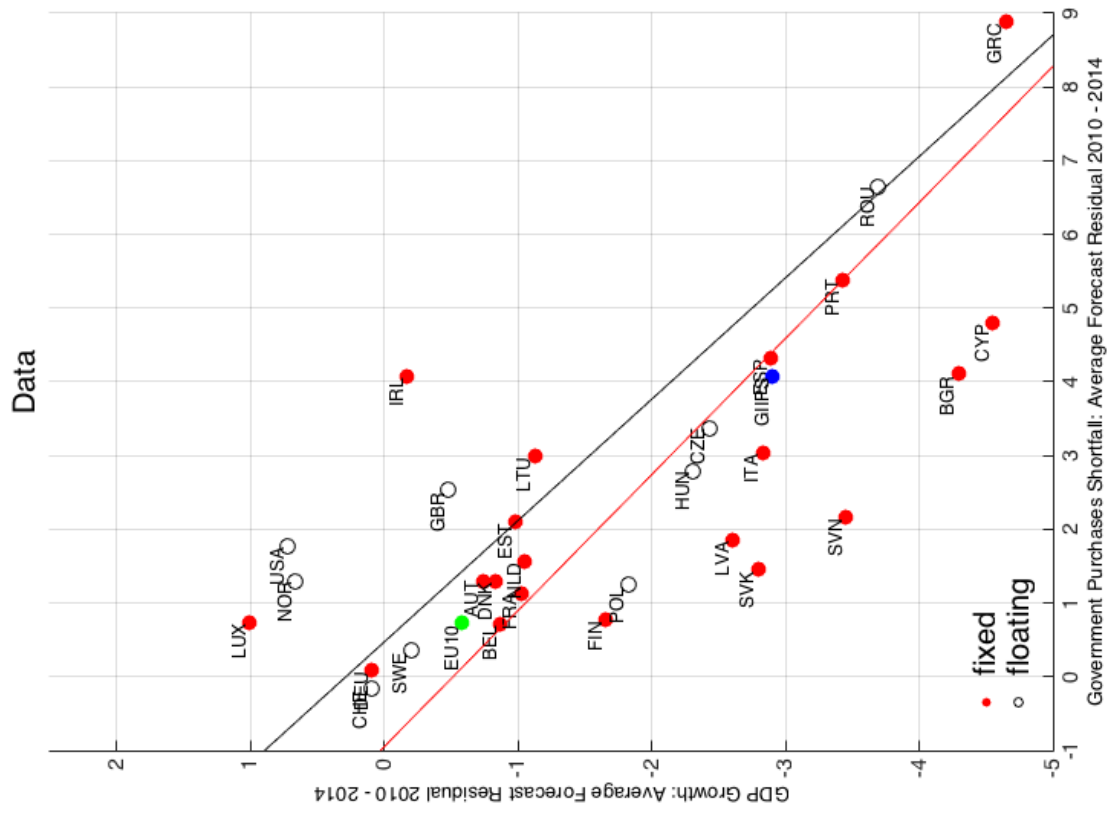
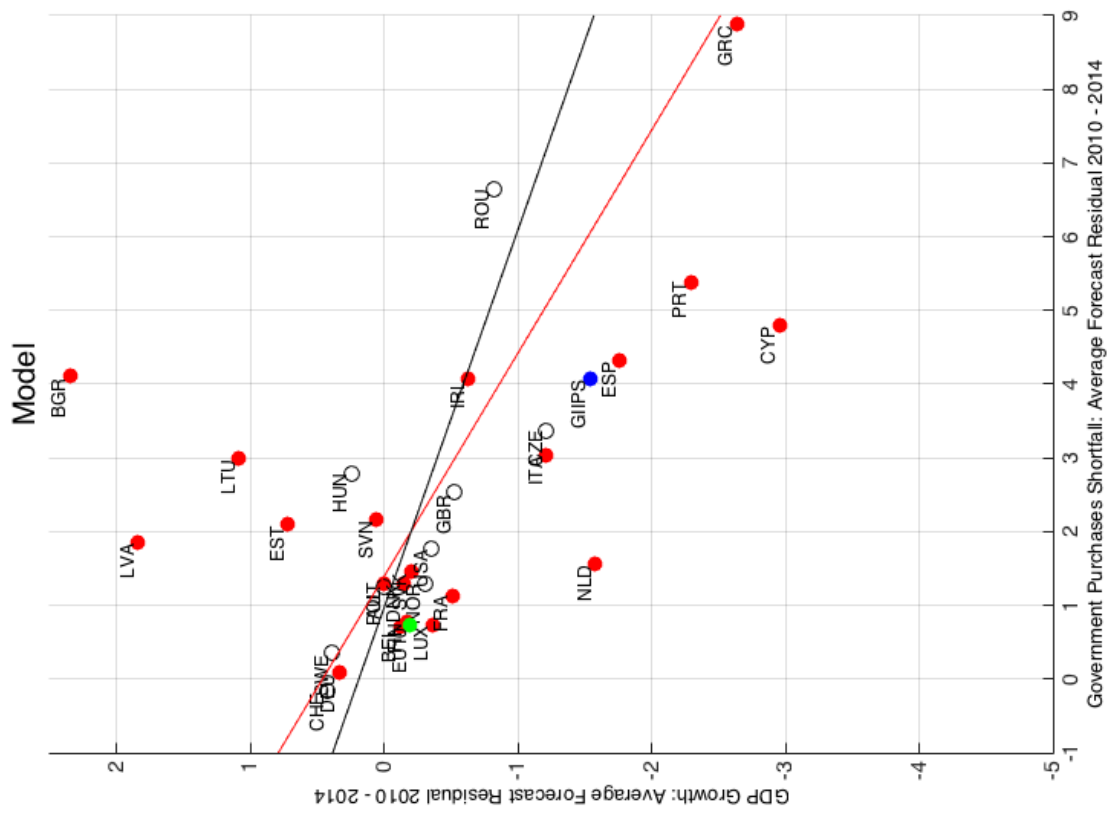


Figure 3g: GDP GROWTH AND AUSTERITY: DATA VS. MODEL

Note: See Figure 3a.

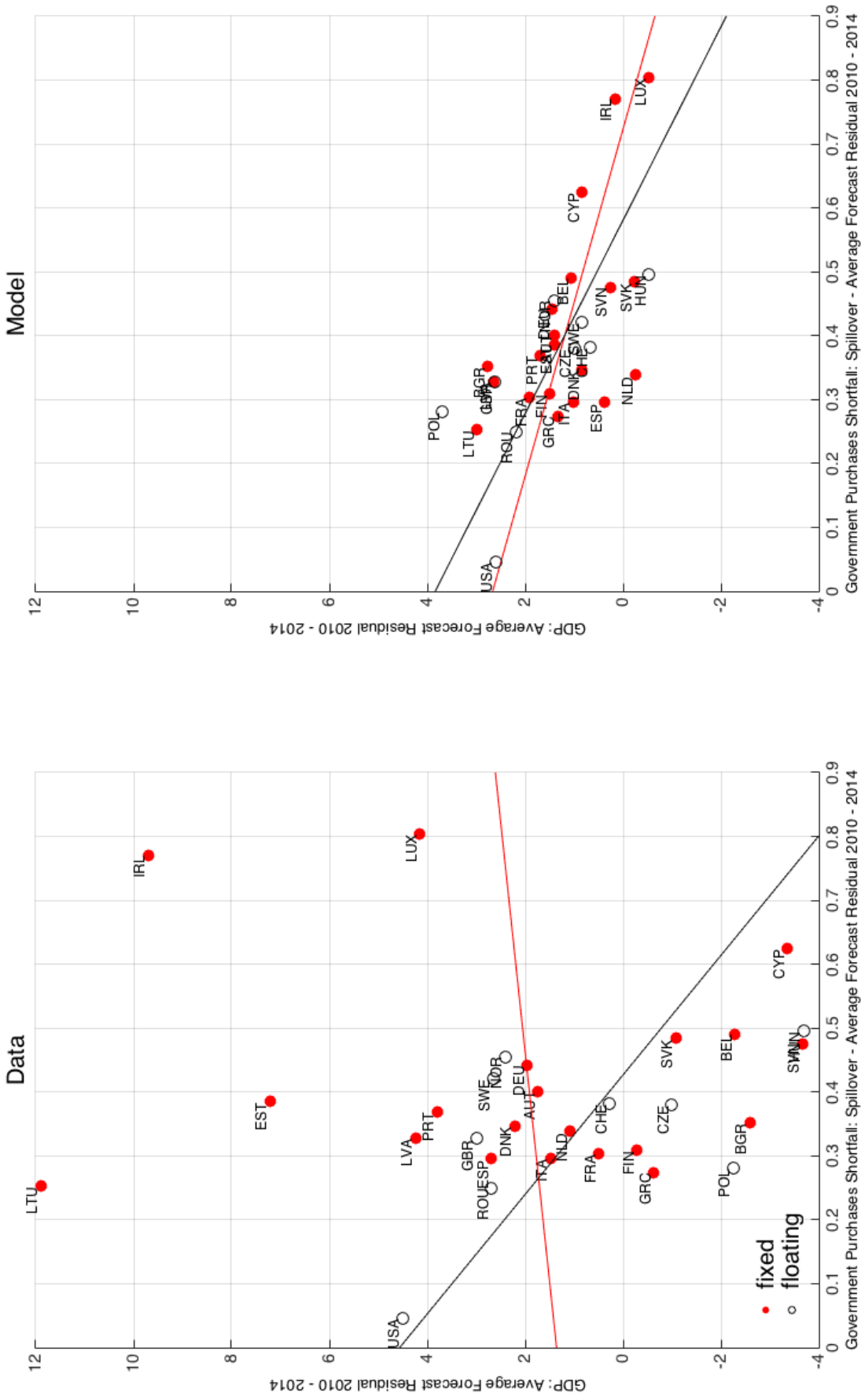


Figure 4: GDP AND AUSTERITY IN DATA: DOMESTIC AND SPILLOVER EFFECT

Note: Figure displays a scatter plot of the average forecast residual of GDP over 2010 - 2014, in log points, versus the average forecast residual for the shortfall in foreign government purchases, expressed in terms of a country's GDP and multiplied by a scaling factor,  $Gshock * s$ . The displayed GDP residual is calculated after controlling for the domestic government purchase shock,  $Gshock$ . Left panel is based on actually observed data; right panel refers to data from the simulated model. Countries are classified by their exchange rate regime (red: euro / pegged to euro; black: floating currency). See text for details on the forecast specification.

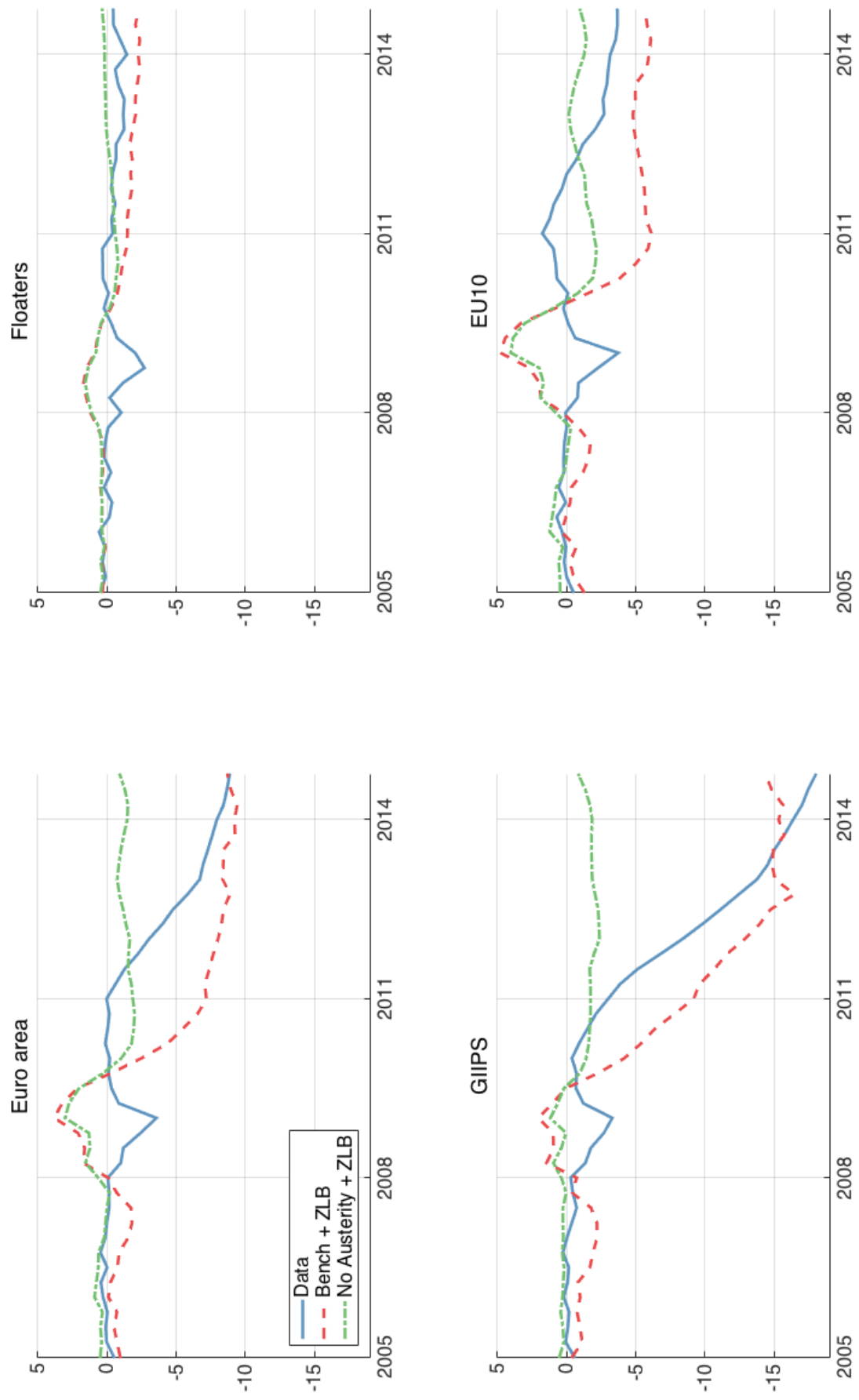


Figure 5: GDP: 'NO AUSTERITY', ZLB AND BENCHMARK

Note: Figures display simulated real GDP under the 'No Austerity' experiment, the ZLB experiment and the benchmark (in percent deviations from the stationary equilibrium). The graph denoted 'Data' are forecast deviations of real GDP.



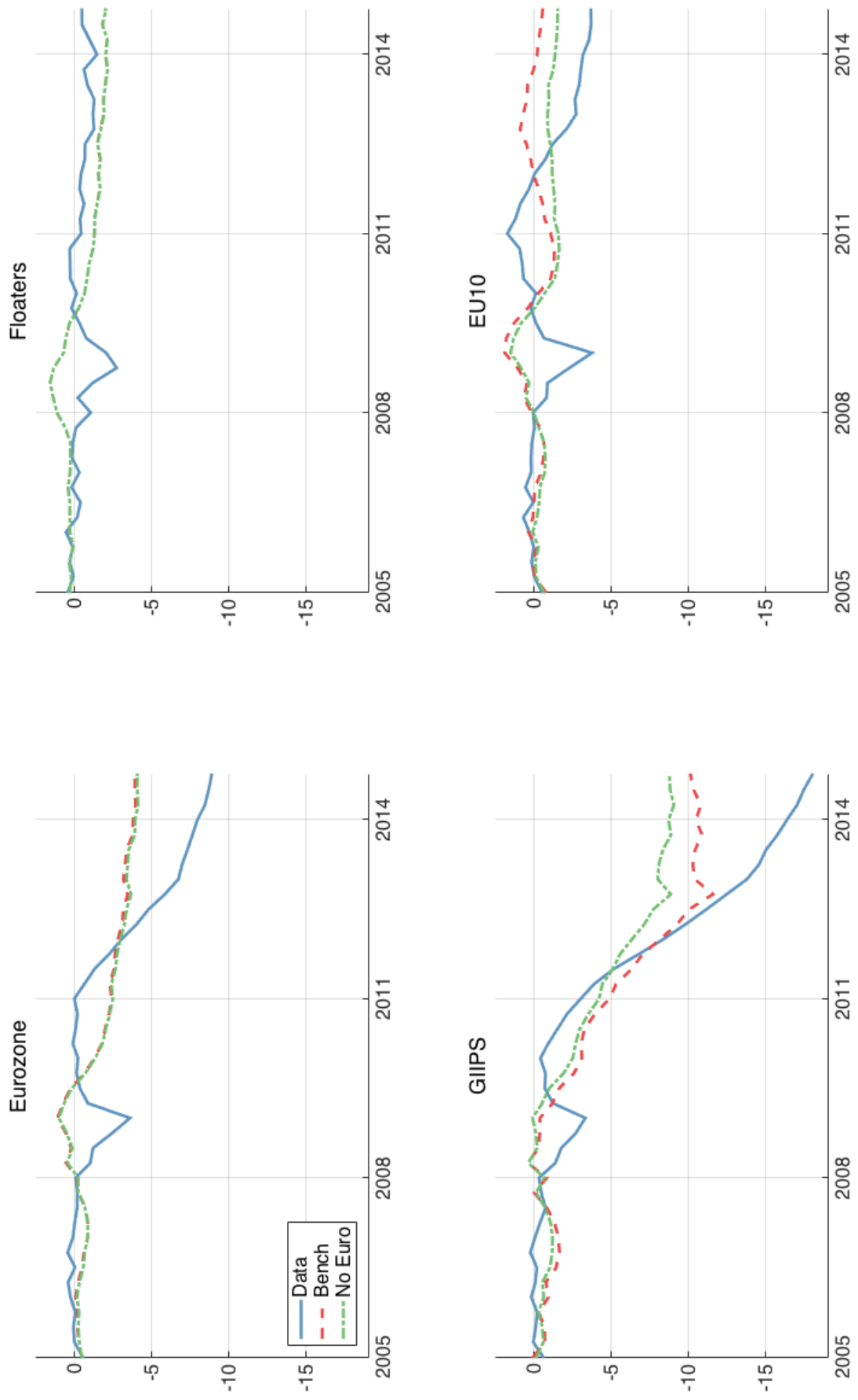


Figure 6: GDP: 'No Euro' and BENCHMARK

Note: Figures display simulated real GDP under the 'No Euro' experiment and the benchmark (in percent deviations from the stationary equilibrium).

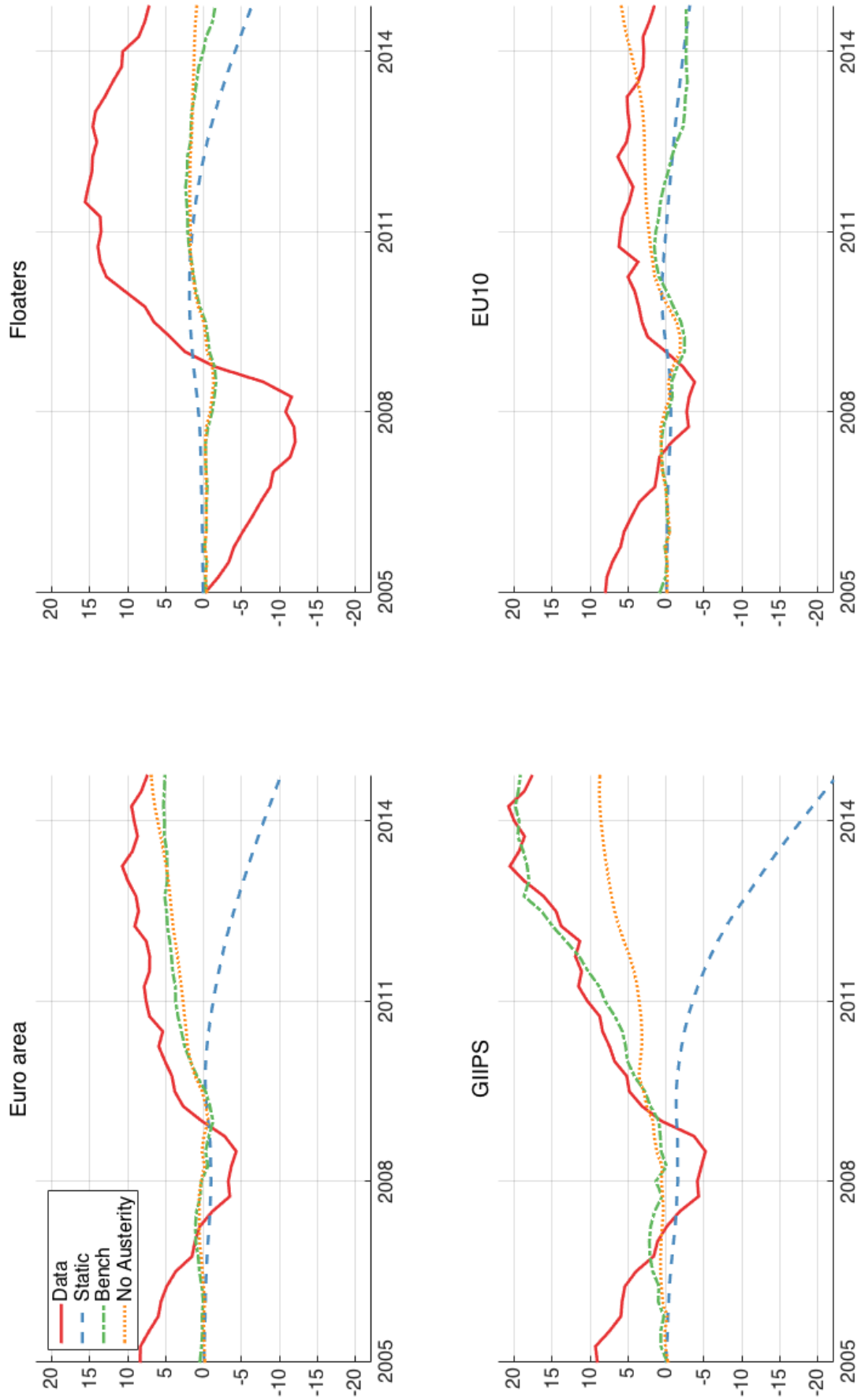
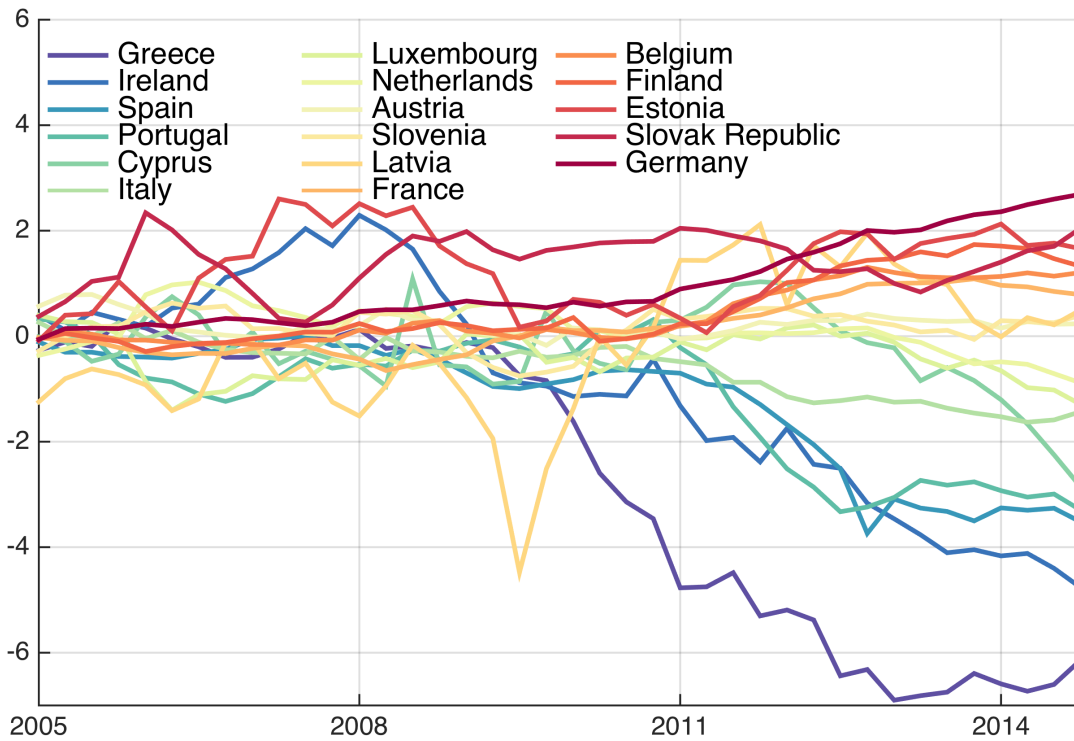
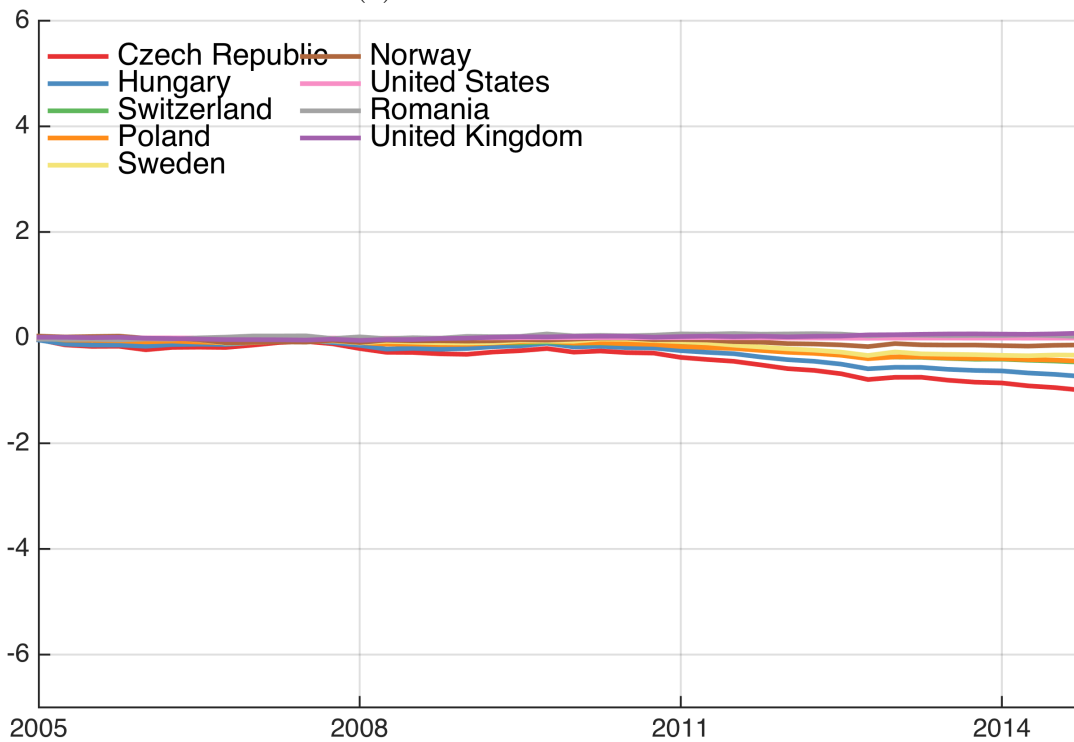


Figure 7: DEBT TO GDP: BENCHMARK AND 'NO AUSTERITY'

Note: Figures display simulated debt-to-GDP ratios under the benchmark specification and the 'No Austerity' experiment (in percent deviations from the stationary equilibrium). The graph denoted 'Data' are deviations of the debt-to-GDP ratio from its 2008-2009 average. The 'Static' graph depicts the evolution of the debt-to-GDP ratio if GDP and tax revenue remained constant, but only government purchases varied.



(a) EUROZONE COUNTRIES



(a) FLOATING COUNTRIES

Figure 8: NOMINAL EFFECTIVE EXCHANGE RATE: 'NO EURO' RELATIVE TO BENCHMARK

*Note:* Figures display effective nominal exchange rates under the 'No Euro' experiment relative to the benchmark (in percent). Positive values mean that the nominal effective exchange is stronger relative to the benchmark.