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. We construct measures of "austerity shocks" - a reduction in government spending that is larger than that implied by reduced-form forecasting regressions - for the 2010-2014 period. 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 on government purchases on foreign output). We develop a multi-country DSGE model to make direct comparisons between the observed empirical relationships and the model predictions. The model is calibrated to reflect relative country size, trade and financial linkages, and the exchange rate regime. The model incorporates austerity shocks, shocks to the cost of credit and monetary policy shocks. The benchmark model generates predictions that are qualitatively in line with those seen in the data and explains about a third of the cross-sectional variation in the data. However, the model is unable to reproduce the magnitude of the estimated multiplier, even with large markups, constrained monetary policy, and high wage and price rigidities. Relative to the benchmark case, the model suggests that a counterfactual fiscal policy of no change in government spending rather than austerity would have reduced output losses in the euroarea by about 25 percent.

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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 the difference in outcomes is 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 constructs measures of austerity and asks whether austerity can in fact account for 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 2009:3 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 of 2014 levels of real per capita GDP below their 2008 levels. At the other end of the spectrum is Lithuania. Unlike Greece, Lithuania experienced only a very strong contraction during the Great Recession, but then returned to a rapid rate of growth quickly thereafter.

Our goal is to document the 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 consider both spending-based measures of austerity and revenue-based measures of austerity. We find that austerity in government outlays - a reduction in government spending that is larger than that implied by reduced-form forecasting regressions - is statistically associated with below forecast GDP in the cross-section. This is particularly true for government purchases, a subcategory of total government outlays. 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.

Revenues and the primary balance generally have a weak or statistically insignificant relationship with our measures of economic performance. Among the revenue variables we consider, changes in the VAT are also negatively associated with GDP in the cross section. We will consider changes in the VAT as an additional "shock" along with reductions in government purchases, but ultimately changes in he VAT are found to play an insignificant role in explaining cross-sectional differences in our sample.

Given the robustness of the relationship between austerity shocks to government purchases and GDP forecast errors, we focus our empirical analysis on the impact of austerity as measured by government purchases. We find that austerity in government purchases is positively associated with net exports and the trade-weighted real exchange rate (that is, a real appreciation), and negatively associated with GDP growth and inflation. In general, these relationships are robust to the country's exchange rate regime though, not surprisingly, the impact on international variables (net exports and the trade-weighted real exchange rate) is smaller for countries within the euroarea and those with exchange rates fixed to the euro. We find a cross-sectional multiplier on government purchases that is greater than 1. However, in contrast to other studies (see e.g. Auerbach and Gorodnichenko, 2012) we find no evidence of spillover effects (the impact of austerity shocks on foreign output).

The second stage of our analysis develops 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, sticky wages, 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 VAT, shocks to the cost of credit and monetary policy shocks. We focus on these four 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 predictions for GDP, inflation, net exports and the exchange rate with actual data in the 2010-2014 period.

The benchmark model generates predictions that are qualitatively consistent with the data. However, the effects stemming from austerity are generally weaker in the model than in the data. In the cross-section data, a one percent reduction in government spending is associated with a 2.8 percent reduction in GDP (a coefficient of -2.8). In the analogous regression based on model-generated data, the coefficient is -0.76. The model generates a positive relationship between austerity and net exports and the negative relationship between austerity and inflation and GDP growth, again qualitatively matching the data but with smaller coefficients.

We examine a wide variety of model specifications (changes to parameters relative to the benchmark and different shocks) to better understand the mechanisms through which shocks to government purchases, taxes, monetary policy and interest rate spreads contribute to the dispersion in economic outcomes. Government expenditure shocks have the largest impact on the cross-sectional variation, with a smaller impact stemming from monetary policy. Because countries that experience "austerity shocks" also tend to have negative monetary shocks (at least negative from the perspective of a country-specific Taylor rule), government spending shocks and monetary policy shocks work in concert to explain the dispersion in the data. VAT shocks and shocks to interest rate spreads (the financial accelerator) generate very little variation in the cross-sectional data. Openness to trade tends to weaken the impact of government expenditure shocks, while more price stickiness and markups that vary with demand increase the impact of government expenditure shocks. In general, however, the model is unable to generate a cross-sectional multiplier of the magnitude observed in the data even when Keynesian effects are strong.

Finally, we use the model to conduct a number of counterfactual experiments. We interpret the results of these experiments relative to the benchmark model. The model suggests that had countries not experienced negative austerity shocks (i.e. a counterfactual where negative shocks are set to zero), aggregate output in the euroarea would have fallen only 1.8 percent relative to trend rather than 2.8 percent. The output losses to the GIIPS economies would have been cut in half, while the impact on the core economies (EU10) would have been only slightly less negative. While direct spillover effects are small, trade does play a role in the distribution of the impact of shocks. Relative to the benchmark, the negative austerity shocks in the GIIPS region not only caused their output to fall, but pulled down output in the rest of Europe as well.

2 Empirical Findings

We begin by characterizing the economic performance of European nations and the United States following the crisis. Our primary data sources are Eurostat and the OECD. The dataset includes all nations 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 (both averaged over 2005 and 2010) and the country's exchange rate regime as of 2010. 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. Country size varies from less than one percent of the European aggregate (e.g. Cyprus and Luxembourg) to over 100 percent (the U.S.). The import share is the share of imports in final demand.[1] 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.

2.1 Background

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

[1] We construct this share from the OECD Trade in Value Added database, as we explain later.

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.

A third approach, and the one we adopt here, is to examine forecast errors in fiscal policy variables (government purchases, total outlays, total revenue and the primary balance) and their relationship with associated forecast errors in economic outcomes. 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. Also, in addition to focusing on the reaction of GDP, we include the reactions of net exports, inflation, consumption, investment, the exchange rate, the unemployment rate and the debt-to-GDP ratio in our analysis.

We examine seven measures of government austerity across countries: government purchases, total government outlays, total revenue, the primary balance, the statutory VAT rate, the income tax rate and the tax rate on corporate profits. Government purchases includes the sum of final government consumption expenditure and government gross fixed capital formation. Total government outlays is the sum of government purchases and outlays for social benefit programs and interest payments. Total government revenue is the sum of consumption, capital and labor income tax collections (including mandatory social contributions to government health care and retirement programs). The primary balance is total government revenue less total government outlays excluding net interest payments. The tax rates are all statutory rates. The VAT rate is the standard VAT for typical products. The income tax rate is the top tax rate on personal income and the corporate profit tax rate is the top tax rate on corporate income.

2.2 Measures of Austerity

In principle, any reduced-form forecast is admissable for constructing the forecast errors. We experimented with a variety of econometric forecast specifications. 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. Below, we discuss our preferred forecast specifications for each variable in the analysis. The constructed forecast errors can be interpreted as departures from "normal" fiscal policy reactions to economic fluctuations. If government spending does 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 pathas "austere." Austerity shocks generated in this way are not econometrically exogenous. We do not have a valid instrument for government expenditure and revenue and for that reason, the empirical patterns we report must be interpreted cautiously. We focus on the observed, quantitative changes in policy variables and ask whether there is evidence that such changes are associated with changes in economic variables and whether the quantitative changes are large enough to explain observed variations in economic performance.

Government Spending and Revenue We use the following forecast specification

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

Equation (2.1) is written for real government purchases. The same specification is applied to total real outlays and total real revenues. Here $\ln G_{i,t}$ is the log of real government spending 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 γ) as well as an estimated cyclical relationship (through the parameter θ^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.

Note that the parameters g and γ are the same regardless of the fiscal variable being forecasted while the parameter θ^G depends on the fiscal measure (so we have θ^G for the cyclical reaction of government spending, θ^{TR} for the cyclical reaction of total revenue, etc.). To implement this equation we first estimate the average GDP growth for the EU12[2] for the period 1993-2005 (annual) with an OLS estimate of

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

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 γ we then run the regression

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

using a sample which includes all countries in Central and Eastern Europe[3] for the same time period. Note, the variable $\ln \widehat{Y}_{EU,t-1}$ is the fitted value from (2.2). Our estimated value for γ is 0.023 with a standard error of 0.002. We then estimate the parameter θ^G by least squares from (2.1) using all available data up to 2005. For the moment, we will postpone discussion of the construction of the predicted variables $\ln \widehat{Y}_{i,t-1}$. The estimates for the cyclicality parameters (OLS standard errors in parenthesis) are $\hat{\theta}^G = 0.38$ (0.60), $\hat{\theta}^{TR} = 0.82$ (0.46) and $\hat{\theta}^{TO} = 0.19$ (0.66).

The parameters in the forecast equations are estimated using data *prior* to the crisis. We then construct out-of-sample residuals or forecast errors as the difference between predicted values and the actual values for the crisis period. For these forecasts, we replace $\ln G_{i,t-1}$ and $\ln Y_{i,t-1}$ by their predicted values in (2.1).

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. In our analysis below, we will focus on the forecasts for the post-recession period 2010-2014. We treat the crisis period itself (2007-2009) as an anomalous period in that the forecasting regression does not use data during the crisis and we do not attempt to account for patterns

[2]Belgium, Denmark, Germany, Ireland, Spain, France, Italy, Luxembourg, Austria, Netherlands, Portugal and Finland.

[3]Bulgaria, Czech Republic, Estonia, Greece, Cyprus, Latvia, Lithuania, Hungary, Poland, Romania, Slovenia and the Slovak Republic.

in the data during the crisis.

While the fiscal shocks suffer from standard endogeneity problems, our forecast specification does reduce one direct source of endogeneity by including contemporaneous GDP. Namely, we eliminate the direct connection between current economic activity and either spending or taxation.

The Primary Balance and Tax Rates For the primary balance, we run a fixed-effects regression of the form

$$\frac{PB_{i,t}}{GDP_{i,t}} = f_i + \theta^{PB}\left(\ln GDP_{i,t} - \ln \widehat{GDP}_{i,t}\right) + \varepsilon^{PB}_{i,t} \tag{2.3}$$

where θ^{PB} is a common cyclical adjustment. The estimation period is 1960-2005. The estimate for θ^{PB} is 0.32 with an OLS standard error of 0.04.

For the tax rates τ^C, τ^N and τ^K we impose pure random-walk specifications. To reduce the sensitivity to the last observation, for each country we take an average of the variable $\tau^j_{i,t}$ for the two years 2004 and 2005 as the last "observation." That is, our forecast for the tax rates is simply

$$\hat{\tau}^j_{i,t} = \frac{1}{2}\sum_{s\in 2004,2005} \tau^j_{i,s} \quad \text{for } j = C, N, K \tag{2.4}$$

for dates t after 2005.

Summary Table 2a reports the statistical properties of the log difference between the actual time series and the forecast for the seven measures of fiscal austerity discussed above. The first two rows of the table report the mean forecast error for 2010-2014 and the standard deviation of the forecast errors. The figures reported are "percentage errors" (i.e., they are forecast errors $\times 100$). The lower panel of the table reports the correlation coefficients across the errors. Based on our forecast specification, average government purchases was roughly 5.6 percent below forecast in 2010-2014 with a standard deviation of nearly 11 percent. Total outlays displays similar patterns and is highly correlated with the forecast errors in government purchases. Tax revenues were below forecast and had a somewhat smaller standard error compared to purchases and outlays. On average the primary balance was above forecast in the 2010-2014 period.

Figures 2a and 2b show actual and forecasted values of log government purchases and total revenues for two countries: France and Germany, respectively. During the 2010-14 period, France pursued a relatively austere path with actual government purchases falling short of the forecast. Tax revenues were above forecast starting from 2011. In Germany, on the other hand, austerity only took the form of slightly higher-than-predicted tax revenues, whereas government purchases were above trend. Whether such differences in austerity "shocks" can explain the cross-sectional patterns of economic outcomes in Europe is the focus of the next section.

2.3 Measures of Economic Performance

We construct measures of economic performance in a similar manner to the fiscal measures described above. We construct forecast errors for real GDP, inflation, consumption, investment, net exports, the exchange rate, GDP growth, the unemployment rate and the debt-to-GDP ratio.

GDP, Consumption, Investment and GDP Growth We use the following forecast specification

$$\ln Y_{i,t} = \ln Y_{i,t-1} + g + \gamma \left(\ln \widehat{Y}_{EU,t-1} - \ln Y_{i,t-1} \right) + \varepsilon^{G}_{i,t}. \tag{2.5}$$

Equation (2.5) is written for real per capita GDP (Y). The same specification applies for real consumption and investment. As with the forecasts for government spending and tax revenues, this forecast specification accounts for both average GDP growth (the parameter g) and convergence dynamics (the parameter γ). The parameters g and γ are constructed just as they were in Section 2.2 and $\ln \widehat{Y}_{EU,t-1}$ is the fitted value from (2.2).[4] 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).[5]

To construct forecasts for GDP growth, we simply take the difference in the log-level forecasts. That is, $\Delta \ln \widehat{Y}_{i,t} = \ln \widehat{Y}_{i,t} - \ln \widehat{Y}_{i,t-1}$.

[4]There is a slight difference in the construction of g and γ 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 γ for consumption and investment because their share in GDP is likely affected by growth dynamics.

[5]To construct the forecast for $t = 2006Q1$, we use actual GDP in 2005Q4 in the forecast equation. However, for quarters after 2006Q1, we use forecasted lagged GDP. That is, for $t > 2006Q1$,

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

Inflation, Unemployment, Exchange Rates, Net Exports and the Debt-to-GDP ratio. For the remaining performance indicators, we impose pure random-walk specifications. As before, to reduce the sensitivity to the last observation, for each country we take an average of each variable for all quarters in the two years 2004 and 2005 as the last "observation." (See equation (2.4).)

We use "core inflation" (all items less energy and food) as reported by Eurostat. For each country we use the nominal effective exchange rate (the trade-weighted sum of bilateral nominal exchange rates). The net export measure is nominal exports in date t less nominal imports in date t divided by 2005Q1 nominal GDP. The debt-to-GDP ratio is end-quarter nominal public debt at date t divided by 2005Q1 nominal GDP.[6]

Summary Table 2b reports summary statistics for the nine measures of economic performance discussed above. On average, GDP, consumption, investment and GDP growth are all below forecast while the net export to GDP ratio, effective exchange rates, unemployment and debt-to-GDP are above average. There is considerable heterogeneity across countries as reflected in the standard deviations in the second row.

The table also reports the correlation coefficients for the performance measures. One correlation which is important to note is the strong positive correlation between inflation and GDP forecast errors.

2.4 Austerity and economic performance

We now turn our attention to estimating the relationship between austerity and economic performance. Below we report estimates from cross-sectional OLS regressions of the form

$$\frac{1}{5}\left(\sum_{t=2010}^{2014} \ln Y_{i,t} - \ln \widehat{Y}_{i,t}\right) = \alpha_0 + \alpha_1 \frac{G_i}{Y_i}\frac{1}{5}\left(\sum_{t=2010}^{2014} \ln G_{i,t} - \ln \widehat{G}_{i,t}\right) + \varepsilon_{i,t}. \tag{2.6}$$

Equation (2.6) is written for a regression of forecast errors in log real per capita GDP on forecast errors in government purchases but the same specification will be used for other measures of economic performance (e.g., inflation forecast errors, etc.) and other measures of austerity (e.g., tax changes, etc.). Note that the dependent variable is the *average* deviation of GDP from its forecast over 2010 - 2014. Similarly, the independent variable is the average

[6] For countries in the European Union, public debt is the definition of public debt under the Maastricht treaty.

deviation of government spending from its forecast for the same time period. Also, we multiply the austerity measures by the ratio G_i/Y_i (averaged over 2000 - 2010). This allows us to report the coefficient α_1 as a multiplier.[7]

Note, throughout the paper we often refer to the coefficients α_1 as "multipliers." We should caution the reader as to the precise interpretation of these estimates. The estimated coefficients are based entirely on cross-sectional variation in measures of austerity rather than time-series variation. Moreover, they include shocks to economic variables other than austerity.

Austerity, GDP and inflation We estimate equation (2.6) for GDP and inflation for each measure of austerity. Table 3a reports the estimated coefficients $\hat{\alpha}_1$ for government purchase shortfalls, shortfalls in total outlays and the primary balance. The top two rows focus on the effects of shortfalls in government purchases. For all countries, a shortfall in government purchases amounting to 1 percent of its GDP, is associated with a reduction in its GDP by 2.76 percent (relative to forecast). This "multiplier" is somewhat larger for countries with floating exchange rates fixed exchange rate countries (3.54 vs. 2.55), although the difference is statistically not significant. The estimate for inflation is -0.35 with a standard error of 0.10. So reducing government purchases by 1 percent of GDP is associated with a moderate reduction in inflation of 0.35 percentage points. The effect is somewhat larger (0.46 ppt.) in countries with floating exchange rates.

Shortfalls in total government outlays (purchases plus social benefits plus interest payments on debt) have similar effects to unanticipated changes in government purchases though the estimates are somehwat smaller. Austerity as measured by an increase in the primary balance is also associated with substiantial negative forecast errors in GDP and negative forecast errors in inflation. A one percentage point increase in the primary balance above forecast is associated with a reduction in GDP of 1.45 percent relative to forecast and a small (and statistically insignificant) drop in inflation.

Table 3b reports the estimates for government revenue and tax variables. In contrast to the estimates for government spending variations, we find little evidence that higher-than-

[7]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. Elasticities are likely to differ across countries if their fiscal sectors vary in size. For instance, government purchases account for an average of 14 percent of GDP in Switzerland for 2000 - 2005, but 29 percent in Sweden.

predicted revenue or unanticipated high tax rates are associated with low GDP or inflation. The one exception to this is for variations in the VAT. A one percentage point increase in the VAT is associated with a 3.24 percent negative forecast error in GDP and a 0.61 percentage points drop in inflation.

Although we do not report results for alternative forecast specifications here, House and Proebsting (2016) perform similar calculations using a wide array of forecast models. Broadly speaking, the results for government purchases are robust and quantitatively similiar across different forecast specifications while the results for tax revenues and tax rates are not. While there are specifications that attribute somewhat greater importance to variations in tax policy, there are other specifications that suggest that tax austerity may be expansionary. In addition, House, Proebsting and Tesar (2016) also report results from a multivariate regression which includes all of the austerity measures. In line with the findings in Tables 3a and 3b, the estimates from a mutivariate specification including all austerity measures indicate that variations in government spending are both economically and statistically significant while variations in the tax measures are not.

To summarize, we find clear, consistent results that indicate that unanticipated reductions in government purchases are associated with large negative forecast errors in GDP and substantial negative forecast errors in inflation. We find similar but smaller effects for total outlays and the primary balance. These results are robust to alternate forecast specifications. Among government revenue variables, only increases in VAT rates are associated with unpredicted falls in GDP and inflation, but we do not find any such patterns for government revenue on the whole. One possible interpretation of such findings 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).

Government purchases shortfalls and economic performance Because the results for government purchases are the most robust relative to the other austerity measures, we provide more detail on the economic impacts of government spending shortfalls.[8] Table 4 expands on the effects of government purchases austerity by including additional measures of economic performance.

According to the table, shortfalls in government purchases are associated with large reductions in consumption and investment. The implied consumption multiplier is -2.50 and the

[8]Results for the other government finance variables are provided in the Appendix.

investment multiplier is -7.14. The effect on investment is noteworthy because many textbook models would predict a crowding-out effect where reductions in government purchases would lead to increases in investment. Austere countries also saw reductions in GDP growth rates (by half a percentage point for a government purchases shortfall of 1 percent of GDP) and increases in unemployment (by 0.86 percentage points). Net exports react positively to government purchase shortfalls, although the effect is only statistically and economically significant for floating exchange rate countries. Austere countries tend to see a depreciation in their exchange rate, but the data is very noisy.

Lastly, there is little evidence that reductions in government purchases produced sizeable reductions in countries' debt levels. If anything, a shortfall in government purchases of 1 percent of GDP is associated with an increase in the debt-to-(constant)-GDP ratio of 2.36 percentage points (standard error of 1.47).

Fiscal spillovers We now analyze whether the effects of government purchases spillover to neighboring countries, following the approach taken in Auerbach and Gorodnichenko (2012). Specifically, we estimate the following regression

$$\frac{1}{5}\sum_{t=2010}^{2014} \ln Y_{i,t} - \ln \widehat{Y}_{i,t} = \alpha_0 - \alpha_1 \times Gshock_{i,t} - \alpha_1^* \times Gshock_{i,t}^* + \varepsilon_{i,t}, \tag{2.7}$$

where $Gshock_{i,t}$ is a measure of country i's domestic government spending at time t and $Gshock^*_{i,t}$ is a measure of government spending spillovers to country i at time t. Specifically, $Gshock_{i,t}$ is defined as

$$Gshock_{i,t} = dom_i \frac{G_i}{GDP_i} \left\{ \frac{1}{5} \sum_{t=2010}^{2014} \left(\ln G_{i,t} - \ln \widehat{G}_{i,t} \right) \right\}$$

and $Gshock^*_{i,t}$ is country i's spillover shock at time t:

$$Gshock^*_{i,t} = \sum_{j \neq i}^{N} imp^i_j \frac{G_j}{GDP_i} \frac{1}{5} \sum_{t=2010}^{2014} \left(\ln G_{j,t} - \ln \widehat{G}_{j,t} \right).$$

Country i's domestic austerity shock $Gshock_{i,t}$ is the average forecast residual of government purchases G_i, expressed in percent of domestic GDP. In contrast to our baseline regression (**??**), we multiply this austerity shock by dom_i, which is country i's share of final demand that is accounted for by domestic production:

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

where Imp_i are country i's imports, and C_i, X_i and G_i are its consumption, investment and government spending. 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:

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

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.[9] This specification completely distributes the effects of fiscal austerity in i to all its trading partners and itself because $dom_i + \sum_{j \neq i}^{N} imp_i^j = 1$. 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.

Table 5 display the results of regression (2.7) for a shortfall of government purchases. The estimated coefficient on domestic fiscal shocks, $\hat{\alpha}$, is around -4.17 for GDP, substantially higher than the estimate for the regression that does not correct for the domestic share. This coefficient can be interpreted as a closed economy multiplier under the assumption that the effect of fiscal policy shocks on GDP perfectly scales with the domestic share *dom*.

Figure 3 illustrates the regression for GDP. The vertical axes of the two scatter plots display average forecast residual for GDP (the dependent variable in regression (2.7), in log

[9] In contrast to Auerbach and Gorodnichenko (2012), our scaling factor is calculated as a share of j's final demand, not j's government purchases. This captures the idea that changes in fiscal policy might not only directly translate into imports from other countries, but also indirectly through changes in consumption and investment.

points times 100. The horizontal axes display either the domestic austerity shock, $Gshock$, or the spillover shock, $Gshock^*$, in the same units as the GDP forecast residual. For example, the value 2 on the horizontal axis in the left panel is a *reduction* in domestic government purchases, scaled by the domestic share of final demand, corresponding to 0.02 log points of GDP. As can be seen, variation in the spillover shocks is about a magnitude smaller than the variation in the domestic shock because export shares are somewhat lower than domestic shares. Also, 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, the Slovak Republic, Ireland, Slovenia and Cyprus. On the other end of the spectrum are Estonia and Latvia, which mainly export to Northern European markets and Germany.

The estimated results for the coefficient on the spillover shock in Table 5 does not support the view that austerity in export markets dampens economic activity at home. None of the results is statistically significant and the point estimates even have the "wrong" sign. Our results are also in contrast to Auerbach and Gorodnichenko (2012) who find strong and statistically significant positive spillover effects for the period before the great recession.[10]

3 Model

Here we present a multicountry business cycle model of the 29 countries in our data set. The model includes every country in the Eurozone (except for Malta) and is calibrated to roughly match both contemporaneous trade flows as well as recent long-run growth trajectories of certain nations particularly the former Eastern Bloc 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 and wage rigidity (ii) international trade in produc-

[10] Our results cannot directly be compared to those reported in Auerbach and Gorodnichenko (2012). Besides using a different data sample and forecast methods, we also use a different scaling factor imp^i_j. Using the same scaling factor as in Auerbach and Gorodnichenko (2012), our coefficients become smaller in magnitude, but do not tend to change signs. They also remain statistically insignificant.

tive intermediate goods, (iii) a net worth chanel for business investment and (iv) government spending shocks, consumption tax shock, monetary policy shocks and spread shocks.

3.1 Households

The world economy is populated by $n = 1...N$ countries denoted by subscript i. 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 simply scale by the population. Thus if $X_{n,t}$ is per capita investment in country n at time t, total investment is simply $\mathbb{N}_n X_{n,t}$. In each period t the economy experienes 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 $\pi(s^t)$.[11]

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 assume that utility is separable in consumption and labor. At date 0, the expected discounted sum of future period utilities for a household in country n is given by

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

where $\beta < 1$ is the subjective time discount factor, σ is the intertemporal elasticity of substitution for consumption, η is the Frisch labor supply elasticity and κ_n is a country specific weight on the disutility of labor. Households choose consumption $C_{n,t} \geq 0$, next period's capital stock $K_{n,t+1} \geq 0$ and current investment $X_{n,t}$ for all s^t and for all $t \geq 0$ to maximize the expected discounted sum of future period utilities subject to a sequence of budget constraints. Consumption is subject to a value added tax $\tau_{n,t}$. The allocation of labor $L_{n,t}$ is decided by monopolistically competitive labor supply unions (see below).

Households in each country own the capital stock $K_{n,t}$ of that country. They supply labor to the intermediate goods producing firms and capital to the entrepreneurs. In return, they earn nominal wages $W_{n,t} L_{n,t}$ and nominal payments for capital $\mu_{n,t} K_{n,t}$. Here $W_{n,t}$ is the nominal wage and $\mu_{n,t}$ is the nominal price of capital that prevail in country n at time t. Let

[11] Unless confusion arises, we write $X_{n,t}$ instead of $X_n(s^t)$.

$T_{n,t}$ denote nominal lump-sum taxes at time t. Finally, the household may also receive profits from domestic firms. Let $\Pi^f_{n,t}$ be nominal profits from intermediate good firms and Π^e be transfers from entrepreneurs paid to the household at time t.

Our specification of the payments associated with capital deserves some additional discussion. Rather 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.

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 $a\left(s^t, s_{t+1}\right)$ 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 which can be traded. Let $S^j_{n,t}$ 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 $1 + i_{n,t}$. The nominal exchange rate to convert country n's currency into the reserve currency is $E_{n,t}$.[12]

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

$$\begin{aligned}
&P_{n,t}\left[(1+\tau_{n,t})C_{n,t} + X_{n,t}\right] + (1-\delta)\,\mu_{n,t}K_{n,t} + \sum_{j=1}^{N}\frac{E_{j,t}S^j_{n,t}}{E_{n,t}} \\
&+ \mathbb{I}_{\text{comp}}\left[\sum_{s^{t+1}}\frac{a\left(s^t, s_{t+1}\right)b_n(s^t, s_{t+1})}{E_{n,t}} - \frac{b_n(s^{t-1}, s_t)}{E_{n,t}}\right] \\
&= \mu_{n,t}K_{n,t+1} + W_{n,t}L_{n,t} + \Pi^f_{n,t} + \Pi^e_{n,t} + \sum_{j=1}^{N}\frac{E_{j,t}\left(1+i_{j,t-1}\right)S^j_{n,t-1}}{E_{n,t}} - T_{n,t}
\end{aligned}$$

and

$$K_{n,t+1} = K_{n,t}\left(1-\delta\right) + \left[1 - f\left(\frac{X_{n,t}}{X_{n,t-1}}\right)\right]X_{n,t}$$

with $f(1) = f'(1) = 0$ and $f''(1) \geq 0$. As in Christiano et al. (2005), the function $f\left(\cdot\right)$ features higher-order adjustment cost on investment if $f''\left(1\right) > 0$.

[12]Technically, we assume that households also extend domestic loans to entrepreneurs, $B_{n,t}$, at a risky interest rate $(1+i_{n,t})F(\lambda_{n,t})e^{\epsilon^F_{n,t}}$. We later discuss these loans in more detail. We omit these loans for clarity reason in the budget contraint.

The indicator variable $\mathbb{I}_{\text{comp}}$ takes the value 1 if markets are complete and 0 otherwise.[13] The first order conditions for an optimum are as follows.[14] The household's Euler equation for purchases of state contingent bonds $b_n(s^t, s_{t+1})$ requires

$$\frac{a\left(s^t, s_{t+1}\right)}{E_{n,t}} \frac{1}{(1+\tau_{n,t})P_{n,t}} C_{n,t}^{-\frac{1}{\sigma}} = \beta\pi(s^{t+1}|s^t) \frac{1}{E_{n,t+1}} \frac{1}{(1+\tau_{n,t+1})P_{n,t+1}} C_{n,t+1}^{-\frac{1}{\sigma}} \quad \forall s_{t+1}$$

where for convenience we are omitting the argument s^t for state-contingent variables when there is no ambiguity (i.e., we will write $C_{n,t}^{-\frac{1}{\sigma}}$ rather than $C_{n,t}\left(s^t\right)^{-\frac{1}{\sigma}}$, $P_{n,t}$ rather than $P_{n,t}\left(s^t\right)$, etc.). There are also Euler equations associated with the uncontingent nominal bonds $S_{n,t}^j$. These require

$$\frac{C_{n,t}^{-\frac{1}{\sigma}}}{(1+\tau_{n,t})P_{n,t}} \frac{E_{j,t}}{E_{n,t}} = \beta\left(1+i_{j,t}\right) \sum_{s^{t+1}} \pi(s^{t+1}|s^t) \left[\frac{E_{j,t+1}}{E_{n,t+1}} \frac{C_{n,t+1}^{-\frac{1}{\sigma}}}{(1+\tau_{n,t+1})P_{n,t+1}}\right] \text{ for all } j = 1...N.$$

Finally, the optimal choice for investment and capital requires

$$\begin{aligned} C_{n,t}^{-\frac{1}{\sigma}} &= \mu_{n,t} \frac{C_{n,t}^{-\frac{1}{\sigma}}}{(1+\tau_{n,t})P_{n,t}} - \mu_{n,t} \frac{C_{n,t}^{-\frac{1}{\sigma}}}{(1+\tau_{n,t})P_{n,t}} \left[f_{n,t} + \frac{X_{n,t}}{X_{n,t-1}} f'_{n,t}\right] \\ &+ \beta \sum_{s^{t+1}} \pi(s^{t+1}|s^t) \left[\mu_{n,t} \frac{C_{n,t+1}^{-\frac{1}{\sigma}}}{(1+\tau_{n,t+1})P_{n,t+1}} f'_{n,t+1} \left(\frac{X_{n,t+1}}{X_{n,t}}\right)^2\right], \end{aligned}$$

where the notation $f_{n,t}$ denotes the value of f evaluated at $X_{n,t}/X_{n,t-1}$.

3.1.1 Wage Setting

We follow the treatment by Erceg et al. (2000) and Christiano et al. (2005) by assuming that the household supplies labor to firms through unions that have some market power. Specifically, we assume that *effective* labor is a CES mix of different labor types. These labor types are aggregated by aggregation firms that then supply the labor aggregate to the firms

[13]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.

[14]The reader will notice that the standard labor supply first order condition is "missing." The reason for this is that we appeal to market power on the part of labor suppliers (acting on behalf of the household) and thus, as in the typical sticky wage setting, wages are set above the market clearing level (i.e., workers are "off their labor supply curves").

at a nominal wage of $W_{n,t}$. Effective labor is given by

$$L_{n,t} = \left(\int_0^1 l_{n,t}\left(z\right)^{\frac{\psi_l - 1}{\psi_l}} dz \right)^{\frac{\psi_l}{\psi_l - 1}}$$

where $L_{n,t}$ is the effective amount of labor supplied to the firms in country n at time t and $l_{n,t}\left(z\right)$ is the amount of type s labor supplied. The parameter $\psi_l > 1$ governs the degree to which different labor types are substitutable. The labor aggregating firm behaves competitively and supplies effective labor to the firms at the flow nominal wage $W_{n,t}$ but hires labor by type according to the type-specific nominal wages $w_{n,t}\left(z\right)$. Demand for each labor type is

$$l_{n,t}\left(z\right) = L_{n,t} \left(\frac{w_{n,t}\left(z\right)}{W_{n,t}} \right)^{-\psi_l} \tag{3.1}$$

and the competitive aggregate nominal wage in country n at time t is

$$W_{n,t} = \left(\int_0^1 w_{n,t}\left(z\right)^{1-\psi_l} dz \right)^{\frac{1}{1-\psi_l}}.$$

Wages for each type of labor are set by monopolistically competitive worker-types. Given the elasticity of demand $-\psi_l$, workers desire a real wage $w_{n,t}\left(z\right)/P_{n,t}$ which is a constant markup over the marginal rate of substitution between consumption and leisure, $-U_{2,n,t+j}/U_{1,n,t+j}$ (i.e., the competitive wage). The desired markup is $\mu_w = \frac{\psi_l}{\psi_l - 1} > 1$.

As in Erceg et al. (2000), we model sticky wages with a Calvo mechanism. Let θ_w be the probability that a worker cannot reset his or her wage in a given period. Whenever possible, workers reset wages to maximize the utility of the representative household in country n. The marginal benefit of additional money at time $t+j$ is $C_{n,t+j}^{-\frac{1}{\sigma}}/(1+\tau_{n,t+j})P_{n,t+j}$ and the marginal disutility to the representative household from supplying additional labor is $\kappa_n L_{n,t+j}^{\frac{1}{\eta}}$. Workers take the demand curve (3.1) as given whenever they can choose a new reset wage. Denote the optimal reset wage in country n at time t as $w_{n,t}^*$. The optimal reset wage satisfies

$$w_{n,t}^* = \frac{\psi_l}{\psi_l - 1} \frac{-\sum_{j=0}^{\infty} \left(\theta_w \beta\right)^j \sum_{s^{t+j}} \pi(s^{t+j}|s^t) L_{n,t+j} W_{n,t+j}^{\psi_l} \kappa_n L_{n,t+j}^{\frac{1}{\eta}}}{\sum_{j=0}^{\infty} \left(\theta_w \beta\right)^j \sum_{s^{t+j}} \pi(s^{t+j}|s^t) L_{n,t+j} W_{n,t+j}^{\psi_l} \frac{C_{n,t+j}^{-\frac{1}{\sigma}}}{(1+\tau_{n,t+j})P_{n,t+j}}}. \tag{3.2}$$

Given (3.2), the nominal wage for effective labor evolves according to

$$W_{n,t} = \left[\theta_w \left(W_{n,t-1}\right)^{1-\psi_l} + (1-\theta_w)\left(w^*_{n,t}\right)^{1-\psi_l}\right]^{\frac{1}{1-\psi_l}}.$$

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 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. The intermediate goods are used in the production of the final good which is ultimately the source of consumption and investment for each country. The intermediate goods are the only goods that can be traded between countries. Production of the intermediate good occurs in two stages. As we did with the supply of labor above, 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

$$\max_{q_{n,t}(\xi)} \left\{ p_{n,t} Q_{n,t} - \int_0^1 \varphi_{n,t}(\xi)\, q_{n,t}(\xi)\, d\xi \right\}$$

subject to the CES production function

$$Q_{n,t} = \left[\int_0^1 q_{n,t}(\xi)^{\frac{\psi_q - 1}{\psi_q}}\, d\xi \right]^{\frac{\psi_q}{\psi_q - 1}}$$

where the parameter $\psi_q > 1$. Here $Q_{n,t}$ is the real quantity of country n's tradable intermediate good produced at time t. The indexing variable ξ indexes the continuum of differentiated types of sub-intermediate producers (thus ξ 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 $\varphi_{n,t}(\xi)$ and the quantity of each sub-intermediate is $q_{n,t}(\xi)$. It is straight-forward to show that the demand for each sub-intermediate has an iso-elastic form

$$q_{n,t}(\xi) = Q_{n,t} \left(\frac{\varphi_{n,t}(\xi)}{p_{n,t}} \right)^{-\psi_q}. \tag{3.3}$$

The competitive price of the intermediate $p_{n,t}$ is then a combination of the prices of the sub-intermediates. In particular,

$$p_{n,t} = \left[\int_0^1 \varphi_{n,t}(\xi)^{1-\psi_q}\, d\xi \right]^{\frac{1}{1-\psi_q}}. \tag{3.4}$$

First-Stage Producers The sub-intermediate goods $q_{n,t}(\xi)$ which are used to assemble the tradable intermediate good $Q_{n,t}$ are produced in the first stage. The first-stage producers hire workers at the nominal wage $W_{n,t}$ and rent capital at the nominal rental price $R_{n,t}$ for use in production. 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 (3.3) as given. These firms each have access to a Cobb-Douglas production function

$$q_{n,t}(\xi) = Z_{n,t} [k_{n,t}(\xi)]^{\alpha} [l_{n,t}(\xi)]^{1-\alpha}.$$

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 (3.3). Each type of sub-intermediate good producer ξ freely chooses capital and labor each period but there is a chance that their nominal price $\varphi_{n,t}(\xi)$ 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 $\varphi_{n,t}(\xi)$ as given. Cost minimization implies that

$$W_{n,t} = MC_{n,t}(1-\alpha) Z_{n,t} [k_{n,t}(\xi)]^{\alpha} [l_{n,t}(\xi)]^{-\alpha}$$

$$R_{n,t} = MC_{n,t} \alpha Z_{n,t} [k_{n,t}(\xi)]^{\alpha-1} [l_{n,t}(\xi)]^{1-\alpha}$$

where $MC_{n,t}$ is the marginal cost of production. The capital-to-labor ratios are constant for all of the sub-intermediate firms, in particular

$$\frac{k_{n,t}(\xi)}{l_{n,t}(\xi)} = \frac{\alpha}{1-\alpha} \frac{W_{n,t}}{R_{n,t}} = \frac{u_{n,t} K_{n,t}}{L_{n,t}}$$

This implies that (within any country n) the nominal marginal cost of production is constant across the sub-intermediate goods firms. Nominal marginal costs can be equivalently expressed in terms of the underlying nominal input prices $W_{n,t}$ and $R_{n,t}$

$$MC_{n,t} = \frac{W_{n,t}^{1-\alpha} R_{n,t}^{\alpha}}{Z_{n,t}} \left(\frac{1}{1-\alpha}\right)^{1-\alpha} \left(\frac{1}{\alpha}\right)^{\alpha}.$$

Pricing The nominal prices of the sub-intermediate goods are adjusted only infrequently according to the standard Calvo mechanism. We let $\varphi_{n,t}(\xi)$ denote the nominal price of sub-intermediate producer ξ that prevails at time t in country n. In particular, for any firm, there is a fixed probability θ_p 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 firms are competitive in the input markets, all firms ξ that can reset their price at time t optimally choose the same reset price $\varphi^*_{n,t}(\xi) = \varphi^*_{n,t}$. 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

$$\max_{\varphi^*_{n,t}} \sum_{j=0}^{\infty} (\theta_p \beta)^j \sum_{s^{t+j}} \pi(s^{t+j}|s^t) \frac{C_{n,t+j}^{-\frac{1}{\sigma}}}{P_{n,t+j}} \left(\varphi^*_{n,t} - MC_{n,t+j}\right) Q_{n,t+j} \left(\frac{\varphi^*_{n,t}}{p_{n,t+j}}\right)^{-\psi_q}$$

The solution to this optimization problem requires

$$\varphi^*_{n,t} = \frac{\psi_q}{\psi_q - 1} \frac{\sum_{j=0}^{\infty} (\theta_p \beta)^j \sum_{s^{t+j}} \pi(s^{t+j}|s^t) \frac{C_{n,t+j}^{-\frac{1}{\sigma}}}{P_{n,t+j}} \left(P_{n,t+j}\right)^{\psi_q - 1} MC_{n,t+j} Q_{n,t+j}}{\sum_{j=0}^{\infty} (\theta_p \beta)^j \sum_{s^{t+j}} \pi(s^{t+j}|s^t) \frac{C_{n,t+j}^{-\frac{1}{\sigma}}}{P_{n,t+j}} \left(P_{n,t+j}\right)^{\psi_q - 1} Q_{n,t+j}}.$$

Because the sub-intermediate goods firms adjust their prices infrequently, the nominal price of the tradable intermediate goods are sticky. In particular, using (3.4), the nominal price of the tradable intermediate good evolves according to

$$p_{n,t} = \left[\theta_p \left(p_{n,t-1}\right)^{1-\psi_q} + (1-\theta_p) \left(\varphi^*_{n,t}\right)^{1-\psi_q}\right]^{\frac{1}{1-\psi_q}}. \tag{3.5}$$

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

$$\max_{y^j_{n,t}} \left\{ P_{n,t} Y_{n,t} - \sum_{j=1}^{N} \frac{E_{j,t}}{E_{n,t}} p_{j,t} y^j_{n,t} \right\}$$

subject to the CES production function

$$Y_{n,t} = \left(\sum_{j=1}^{N} \omega_{n,j}^{\frac{1}{\psi_y}} \left(y_{n,t}^{j} \right)^{\frac{\psi_y - 1}{\psi_y}} \right)^{\frac{\psi_y}{\psi_y - 1}} \tag{3.6}$$

Here, $y_{n,t}^{j}$ is the amount of country-j intermediate good used in production by country n at time t. The parameter ψ_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 trade exposure.

Demand for country-specific intermediate goods is isoelastic

$$y_{n,t}^{j} = Y_{n,t}\omega_{n,j} \left[\frac{E_{j,t}}{E_{n,t}} \frac{p_{j,t}}{P_{n,t}} \right]^{-\psi_y}$$

The implied nominal price of the final good is

$$P_{n,t} = \left(\sum_{j=1}^{N} \omega_{n,j} \left[\frac{E_{j,t}}{E_{n,t}} p_{j,t} \right]^{1-\psi_y} \right)^{\frac{1}{1-\psi_y}}$$

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.[15]

Formally, at the end of period t, entrepreneurs purchase capital $K_{n,t+1}$ from the households at the nominal price $\mu_{n,t}$ 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 $NW_{n,t}$. Then to purchase capital, the entrepreneur will have to borrow $B_{n,t} = \mu_{n,t}K_{n,t+1} - NW_{n,t}$ units of their own currency (entrepreneurs borrow money from the households in their country). Both $B_{n,t}$ and $NW_{n,t}$ 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 $F(\lambda_{n,t})$, with $F(1) = 1, F'$ and $F'' > 0$. Here $\lambda_{n,t} = \frac{\mu_{n,t}K_{n,t+1}}{NW_{n,t}}$ is the leverage ratio.[16] The interest rate for securing next period capital is then $(1 + i_{n,t})\,F(\lambda_{n,t})e^{\epsilon^F_{n,t}}$, where $\epsilon^F_{n,t}$ is a shock to the interest rate spread. The function $F(\cdot)$ implies that entrepreneurs who are more highly levered pay a higher interest rate.

At the beginning of period $t+1$, entrepreneurs earn a utilization-adjusted rental price of capital $u_{n,t+1}R_{n,t+1}$ and then sell the undepreciated capital back to the households at the capital price $\mu_{n,t+1}$. Varying the utilization of capital requires $K_{n,t+1}a\,(u_{n,t+1})$ units of the final good. Each period, a fraction $(1-\gamma_n)$ of the entrepreneurs' net worth is transferred to the households.[17]

Each period, entrepreneurs choose $K_{n,t+1}$ and utilization $u_{n,t+1}$ to maximize expected net worth $NW_{n,t+1}$. Net worth evolves over time according to

$$NW_{n,t+1} = \gamma_n \left\{ K_{n,t+1}\left[u_{n,t+1}R_{n,t+1} + \mu_{n,t+1}(1-\delta) - P_{t+1}a\,(u_{n,t+1})\right] - (1+i_{n,t})F(\lambda_{n,t})e^{\epsilon^F_{n,t}}B_{n,t} \right\}.$$

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

$$R_{n,t} = P_{n,t}a'\,(u_{n,t})\,.$$

Following Christiano et al. (2005) we assume that the utilization cost function is $a\,(u) = \frac{\bar{R}}{P}\left[\exp\left\{h\,(u-1)\right\} - 1\right]\frac{1}{h}$ where the curvature parameter h governs how costly it is to increase

[15] 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.

[16] 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.

[17] We set $\gamma_n = \frac{\beta}{F_n}$ so that net worth is constant in a stationary equilibrium.

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 $K_{n,t+1}$ requires

$$(1 + i_{n,t})F(\lambda_{n,t})e^{\epsilon^F_{n,t}} = \frac{\sum_{s^{t+1}} \pi(s^{t+1}|s_t) \left[u_{n,t+1}R_{n,t+1} + \mu_{n,t+1}(1-\delta) - P_{t+1}a(u_{n,t+1}))\right]}{\mu_{n,t}}.$$

As is standard in financial accelerator models, the external finance premium $F(\lambda_{n,t})$ drives a wedge between the nominal interest rate on bonds and the expected nominal return on capital.[18] Notice that if $F(\lambda_{n,t}) = 1$ then we obtain the standard efficient outcome in which the market price of capital is the discounted stream of rental prices.

3.4 Government Policy

The model includes both fiscal and monetary policy variables. We assume that government spending is exogenous and financed by lump sum taxes on the representative households and a consumption tax. Government spending in country n is governed by a simple auto-regressive process

$$G_{n,t} = (1 - \rho_G) G_n + \rho_G G_{n,t-1} + \varepsilon^G_{n,t}.$$

We choose the parameter G_n to match observe ratio's of government spending to GDP for each country. The consumption tax rate follows a unit root process:

$$\tau_{n,t} = \tau_{n,t-1} + \varepsilon^\tau_{n,t}$$

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

$$i_{n,t} = \bar{\imath}_n + (1 - \phi_i)(\phi_{GDP} GDP_{n,t} + \phi_\pi \pi_{n,t}) + \phi_i i_{n,t-1} + \varepsilon^i_{n,t} \tag{3.7}$$

For simplicity we assume that the reaction parameters ϕ_{GDP}, ϕ_π and ϕ_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

[18] 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.

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 (3.7) 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 Eurozone and the weights are proportional to GDP relative to the total GDP in the Eurozone.

3.5 Aggregation and Market Clearing

For each country n, aggregate production of the tradable intermediate goods is (up to a first-order approximation[19]) given by

$$Q_{n,t} = Z_{n,t} \left(u_{n,t} K_{n,t} \right)^{\alpha} L_{n,t}^{1-\alpha}.$$

Final goods production is given by (3.6) and, since the final good is nontradable, the market clearing condition for the final good is

$$Y_{n,t} = C_{n,t} + X_{n,t} + G_{n,t} + a\left(u_{n,t}\right) K_{n,t}.$$

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

$$Q_{n,t} = \sum_{j=1}^{N} \frac{\mathbb{N}_j}{\mathbb{N}_n} y_{j,t}^{n}.$$

Finally, the bond market clearing conditions require

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

[19]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.

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

$$NX_{n,t} = p_{n,t}Q_{n,t} - \sum_{j=1}^{n} \frac{E_{j,t}}{E_{n,t}} p_{j,t} y_{n,t}^{j} = p_{n,t}Q_{n,t} - P_{n,t}Y_{n,t}$$

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

$$NGDP_{n,t} = p_{n,t}Q_{n,t} = NX_{n,t} + P_{n,t}\left[C_{n,t} + X_{n,t} + G_{n,t}\right]$$

Note, since the equilibrium price level in the steady state is $P = 1$, real GDP is $RGDP_{n,t} = Q_{n,t}$ (this is the real GDP calculation associated with a fixed price deflator in which the base year prices are chosen as corresponding to the steady state).

3.6 Steady state

We express each variable's stationary equilibrium in terms of the final good, Y_n.[20] We directly calibrate a certain number of steady-state variables to their empirical counterpart. Those are the shares of government purchases, G_n, net exports, NX_n, and the relative country sizes, $\frac{\mathbb{N}_n Y_n}{\mathbb{N}_m Y_m}$. We now derive the shares of the remaining variables, C_n and X_n, and later show that these non-targeted shares implied by our model match their empirical counterparts quite closely.

Steady-state inflation is zero, so that nominal prices are constant. We normalize the price level P_n to 1.

We first solve for the steady-state rental price of capital. Combining the Euler equation for capital with the Euler equation for domestic bonds gives an expression for the rental price of capital in terms of parameters

$$R_n = \frac{F(\lambda_n)}{\beta} - (1 - \delta).$$

The rental price of capital is the marginal product of capital, reduced by the inverse of the

[20]For any variable $X_{n,t}$, X_n denotes the corresponding steady-state value.

markup $\frac{\psi_q - 1}{\psi_q}$.

$$R_n = \frac{\psi_q - 1}{\psi_q} p_n \alpha Z_n \left(\frac{K_n}{L_n}\right)^{1-\alpha}.$$

We adjust the technology level Z_n so that all intermediate goods prices, expressed in the reserve currency, are 1 in steady state: $p_n E_n = 1$. Then, using the price index formula for the final good gives

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

Since the prices of all intermediate goods are $p_j E_j = 1$, one can easily verify that $E_n = 1$ solves this equation, that means the real exchange rate is unity. It follows from the demand equation for intermediate goods that $\omega_{n,j}$ is country n's import share of country j's good, measured in terms of the privately-produced good Y_n:

$$\omega_{n,j} = \frac{y_n^j}{Y_n}.$$

Later, we use data on imports to calibrate $\omega_{n,j}$. The implied net export share can be expressed in terms of country sizes and the import preference parameters. Inserting the market clearing condition for Q_n into the definition of net exports, $NX_n = Q_n - Y_n$, we have

$$\begin{aligned}
\frac{NX_n}{Y_n} &= \left(\sum_{j=1}^{N} \frac{\mathbb{N}_j}{\mathbb{N}_n} y_j^n\right) - 1 \\
&= \left(\sum_{j=1}^{N} \frac{\mathbb{N}_j Y_j}{\mathbb{N}_n Y_n} \omega_{j,n}\right) - 1.
\end{aligned}$$

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 β to imply a long run real annual interest rate of four percent. We set the intertemporal elasticity of substitution σ to 0.50 and the Frisch elasticity of labor supply η to 1. These values are comparable to findings in the microeconomic literature on preference parameters (e.g. Barsky et al., 1997)).

Trade and Country Size The preference parameters ω_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, wheras our model requires data in value added terms. We therefore use data from the OECD dataset on trade in value added (TiVA). 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 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 ω_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 ω_{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 ω_n^j.

The trade elasticity ψ_y is set to 1.5. This is comparable to calibrations used in international business cycle models with trade. In their original paper, Heathcote and Perri (2002) estimated $\psi_y = 0.90$. Backus et al. (1994) set the trade elasticity to 1.5. Using firm-level data, Cravino (2014) and Proebsting (2015) find elasticities close to 1.5.[21].

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

[21] 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.

Technology The capital share parameter α 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 1.7% 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 $f(.)$ implies a simple relationship between investment 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 $\mathbb{Q}_{n,t} = v_{n,t}/C_{n,t}^{-\frac{1}{\sigma}}$. It is straightforward to show that the change in investment growth over time obeys the equation

$$\left[\tilde{X}_{n,t} - \tilde{X}_{n,t-1}\right] = \frac{1}{\kappa}\tilde{\mathbb{Q}}_{n,t} + \beta\left[\tilde{X}_{n,t+1} - \tilde{X}_{n,t}\right]$$

where $\tilde{X}$ denotes the percent deviation from X from its steady state value. Thus the parameter κ is similar to a traditional inverse Q-elasticity. We adopt the value $\kappa = 2.48$ 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 $a(u) = \frac{\bar{R}}{P}\left[\exp\{h(u-1)\} - 1\right]\frac{1}{h}$, 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 $R_{n,t}/P_{n,t}$ causes an increase in the capital utilization rate of 0.286 percent.

Price and Wage Rigidity We calibrate the Calvo price and wage setting hazards to roughly match observed frequencies of price adjustment in the micro data. For price rigidity, 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 $\theta_p = 0.77$). The evidence on wage rigidity is somewhat more sparse. Perhaps the best study is Barattieri et al. (2014) who use a careful analysis of SIPP data to conclude that wages change on average once every 12 months (which corresponds to $\theta_w = 0.75$).[22] Our baseline calibration takes $\theta_p = 0.80$ and $\theta_w = 0.80$. These are somewhat higher than the

[22] If there are implicit wage contracts then the average frequency of wage adjustment may not be the relevant metric to guage how rapidly wage payments respond to economic conditions. See Basu and House (2016) for a review of the literature on wage adjustment in macroeconomic models.

empirical findings for U.S. price and wage 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.[23]

Financial Market Imperfections The steady state external finance premiums, $F_n(\lambda_s s)$, 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 across 2000 (or earliest available) through 2010. The data source for the spread data is the ECB for euro area countries, and 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 rom Brave et al. (2012). The elasticity of the external finance premium with respect to leverage F_ϵ 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 6. 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 $\rho_i = 0.75$.

4 Model and Data Comparison

We can now simulate the calibrated model's reaction to austerity shocks to compare the model's reaction to the observed patterns in the data. Our approach is to treat the austerity forecast deviations calculated in Section 2 as structural shocks. To incorporate the government purchase shocks, we interpolate the annual forecast errors using the Chow-Lin method (Chow and Lin, 1971). For the VAT shocks, we use quarterly data on VAT rates and calculate quarterly shocks based on the forecasting equation (2.4).

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 economicperformance can be traced to shocks other than austerity. We describe these additional shocks below.

[23]For purposes of comparison, Christiano et al. (2005) have $\theta_p = 0.6$ and $\theta_w = 0.64$, Del Negro et al. (2013) have $\theta_p = 0.6$ and $\theta_w = 0.64$ and Brave et al. (2012) have $\theta_p = 0.97$ and $\theta_w = 0.93$.

4.1 Forcing Variables

In addition to the austerity shocks, we will include shocks to monetary policy and shocks to the financial sector. Here we briefly describe how these shocks are constructed.

Monetary Policy Shocks To estimate monetary policy shocks we proceed as follows. We begin by estimating a generalized Taylor rule of the form suggested by Clarida et al. (1997).[24]

$$i_t = \rho_i i_{t-1} + (1 - \rho_i)\left[\pi_t + r + \phi_\pi (\pi_t - \pi^*) + \phi_{GDP}\%GDP_t\right] + \varepsilon_t^i$$

where i_t is the nominal interest rate, r is the long-run interest rate, π_t is inflation, π^* is the inflation target, $\%GDP_t$ are percent deviations of real GDP from its trend (i.e., the output gap), and ε_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 estimate this rule by first imposing the original estimate of $\rho = 0.79$ by Clarida et al. (1997) and then estimating ϕ_π and ϕ_{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 ϕ_π, ϕ_{GDP} and the constrained coefficient ρ 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 Eurozone, 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 $r - \pi$ in the Taylor rule). We can then recover the monetary policy shocks for each country n as $\hat{\varepsilon}_{n,t}^i = i_{n,t} - \hat{\imath}_{n,t}$.

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.

[24] 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 can now compare the benchmark model with the earlier empirical results. The left panel of Table 8 shows the empirical relationship between the negative shocks to government purchases and seven out of our nine measures of economic performance. These results are identical to the estimates in Table 4. The right panel of Table 8 shows the results for the same regression (**??**) but run on the simulated data. Several points are worth emphasizing. First, the estimated effects of the austerity shocks are substantially smaller than the estimates from the data. Empirically, the government purchase multiplier on GDP is 2.77. In contrast, the model estimates suggest a multiplier of only 0.76, less than a third the size. Similarly, the inflation reactions are also not of the same magnitude. A reduction in government purchases of one percent of GDP is associated with a small reduction in inflation of roughly 0.35 percent, with a somewhat stronger effect for floating exchange rate countries. The model implies a very weak reduction of 0.03 percent for fixed exchange rate countries, but a stronger reduction of 0.36 percent for floating exchange rate countries.

As one would anticipate, the benchmark model fails to generate movements in consumption in response to government purchase shocks. If anything, the model implies a crowding-out effect on consumption (at least for fixed exchange rate countries), with reductions in government purchases leading to slightly increased consumption. Interestingly, the model predicts a negative response of investment to government purchase reductions, although, again the response is less than a fifth as big as the one in the data. In contrast, net exports are positively associated with reductions in government purchases in both the data and the model.

Figures 4a - 4g show comparisons of scatterplots of the actual data (left panels) and the scatterplots of simulated data (right panels). For each panel, the log 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 figures reveal several differences between the actual data and the model. First and most importantly the actual data has substantially more noise than the model simulations. 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 Eurozone than the model permits. In the model, even though there are sharp differences in government spending 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 swings in inflation for countries that are not in the Eurozone while in the data, inflation does not differ radically from that of the Eurozone. This may be due to the fact that even though these countries technically have floating exchange rates and independent monetary policy, the monetary authorities in these countries do not depart from the policies enacted by the ECB. Third, the exchange rate data display only a very weak relationship to austerity shocks. In the model, exchange rates in the Eurozone display virtually no variation across countries (recall, these are trade-weighted exchange rates and thus countries in the Eurozone can have changes in their exchange rate).[25]

To understand the mechanisms operating in the model, we examine the model's reaction to variation in each of the four forcing variables—government purchases, VAT rates, monetary shocks, financial shocks—separately. Table 9 reports the results of such a decomposition. It displays the regression coefficients for the seven measures of economic performance. 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.

The decomposition reveals two things: First, the negative relationship between austerity and performance in the model is only partially driven by structural austerity shocks. Countries that are empirically identified as austere were also hit by contractionary VAT, monetary policy and spread shocks. For countries with a floating exchange rate, the negative austerity-performance relationship derives to an important extent from austere countries implementing contractionary monetary policy.

Second, while the benchmark model produces regression coefficients that are qualitatively consistent with those observed in the data, this is not true for the individual shocks. Both austerity and monetary policy shocks are needed to generate patterns as those observed in the data. Austerity shocks lead to declines in GDP and rising net exports as in the data, but also produce counterfactual inflation in floating exchange rate countries and a depreciation of their exchange rates. Monetary policy shocks help explain the pattern of inflation and exchange rates in floating exchange rate countries, but—not surprisingly—cannot explain the variation

[25]Slovakia is a clear outlier in the scatter plot in Figure 4f. This is because Slovakia was actively bringing its exchange rate into alignment with the Euro after 2005 (when our unit root forecast starts) and before it adopted the euro in 2009.

observed across fixed exchange rate countries. We now explain the effects of these two shocks in the model.

A reduction in government spending leads to a fall in GDP through a reduction in employment. Firms respond to the drop in demand for their goods by reducing their demand for labor. On the households' side, the contraction in government spending has a positive effect on wealth, and households respond by increasing their demand for goods and reducing their supply of labor. On net, the contraction in government expenditures results in excess supply of the home good; the real exchange rate depreciates and net exports increase.

The effect on inflation is ambiguous. Inflation is forward looking and depends on the future path of real marginal costs, including wages. Wages will be low if the reduction in labor demand outweighs the fall in labor supply. This is typically the case under fairly standard parameterizations of a closed economy New Keynesian model (including a closed economy version of our model), so that reductions in government spending cause deflation. In our open economy setting, however, reductions in government spending can cause inflation for countries with floating exchange rate (see the coefficient for inflation, 0.33, in Table 9 in the 'Only Govt' panel). This is because of the exchange rate: In response to a fall in government spending, the nominal exchange rate depreciates (see the coefficient -0.73). This raises the price of imports and stimulates demand for exports, which counterbalances the fall in labor demand and prevents wages from falling (too much). Both effects cause inflation.

Although our model features only limited risk sharing, increases in consumption translate into a depreciation of the real exchange rate in both fixed and floating exchange rate countries. For fixed exchange rate countries, the depreciation of the real exchange rate is achieved through deflation. For floating exchange rate countries, the depreciation of the real exchange rate comes from a depreciation of the nominal exchange rate (despite inflation).

As mentioned above, the implied response of inflation and exchange rates for floating exchange rate countries is counterfactual in the experiment with government spending shocks only. Adding monetary policy shocks improves the model's performance along these dimensions. In particular, in our dataset empirically austere countries tend to have interest rates above the level suggested by the Taylor rule. These high interest rates reduce consumption and output, push down inflation and lead to an appreciation of the nominal (and real) exchange rates.

4.3 Variations on the Benchmark Model

Table 10 reports simulated results under alternative model assumptions. Each column corresponds to a different set of parameter values but the shocks fed into the model are the same as those in the benchmark case. For each case, we report the cross-sectional multiplier for GDP and inflation as well as the rank correlation and the standard deviation of GDP relative to the data.

We consider the following alternative cases:

($i.$) *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 $\phi_{GDP} = \phi_{\pi} = 0.5$.

($ii.$) *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 that sets interest rates for the eurozone but doesn't trade with any other countries. The ZLB is assumed to persist indefinitely in this policy experiment.[26]

($iii.$) *Endogenous Desired Markups.* We introduce an endogenous counter-cyclical desired markup for price setting. In particular, we assume that demand elasticity ψ_q depends negatively on aggregate output, that is, we assume that for each country, $\psi_q' (Q_{n,t}) \frac{Q_n}{\psi_q} = \zeta$ where ζ governs the degree to which desired markups are counter-cyclical (recall the desired markup is $\mu_p = \frac{\psi_q}{\psi_q - 1}$). For this specification we set ζ to 8.

($iv.$) *Low Nominal Rigidities.* We reset the wage and price rigidity parameters to $\theta_w = \theta_p =$ 0.25 (quarterly).

($v.$) *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 80 basis points.

($vi.$) *High Capacity Utilization.* This parameterization featurs a greatly reduced cost of varying capital utilization. We set the curvature of the penalty function $a(u)$ to $a'' = 0.05$. This effectively makes the production of the home good nearly linear in labor.

($vii.$) *High Investment Adjustment Costs.* We increase the cost of adjusting investment by increasing the curvature of the function f to $f'' = 8$ relative to the benchmark parameter

[26] See House, Proebsting and Tesar (2016) for additional discussion of the ZLB solution.

value of 2.48.

(*viii.*) *High Trade Elasticity.* Setting the trade elasticity higher effectively increases the integration of the countries through international trade. The high trade elasticity sets the parameter $\psi_y = 5$ relative to the benchmark setting of 1.5.

(*viii.*) *Flexible Exchange Rates.* This specification allows the countries in the eurozone to have independent monetary policy and thus to react to local shocks.

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

While the multipliers vary with each model specification, the magnitudes of the GDP multiplier are typically close to or less than 1.00 and considerably less than the estimated "multipliers" in the data. The inflation multipliers are also typically less than the empirical estimates though quantitatively they are somewhat closer to those observed in the data.

The highest GDP multipliers are obtained in the model without trade, and thus no "leakage" of demand to foreign producers, and in the model with the endogenous desired markup. Notice, however, that in the case with the endogenous markup, the associated inflation multiplier has the wrong sign.

Interestingly, the GDP multiplier and the inflation multiplier for the countries with fixed exchange rates are uniformly lower than the multipliers for countries with floating exchange rates. Standard international monetary models would suggest that countries with floating exchange rates would be able to offset the impact of changes in fiscal policy with adjustments in monetary policy. The fact that the multipliers are higher for floaters suggests that those economies experienced both negative monetary and financial shocks in addition to negative spending shocks.

In a result that is reminiscent of the findings in Nakamura and Steinsson (2014), the model with the zero-lower-bound specification cannot explain the observed cross-sectional findings from the data. Typically, from an aggregate time-series perspective, models tend to produce a larger response of output to government expenditure shocks at the ZLB because monetary policy cannot buffer the impact of the fiscal shock (see e.g. Blanchard et al., 2016). Examination of the impulse responses produced by our model confirms the greater responsiveness of GDP to government expenditure shocks for countries at the ZLB. 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. For such countries, the monetary policy reaction is governed by the average GDP and inflation paths for the union as a whole. Differences in GDP and inflation (or other measures of economic activity) across countries that do not affect average economic activity for the currency union entail no monetary policy response and thus the equilibrium outcomes in this scenario are the same whether the country is or is not at the ZLB. In effect, at the ZLB, the countries in a currency union shift up or down together and therefore do not exhibit greater cross-sectional variation.

The general message from the table is that the model cannot generate correlations like those seen in the data even when we consider a wide range of model specifications.[27]

5 Counter-Factual Policy Simulations

We next use the model as a laboratory for considering some counterfactual scenarios 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. Table 11 shows the deviation from trend for GDP, inflation and consumption for the benchmark economy and for five counterfactual scenarios. In each case the results of the experiments will be discussed relative to the benchmark case (i.e. a decline in Eurozone output of 2.8 percent from trend).

The first experiment in column 2 shows the results from an alternative scenario in which there is no shock – positive or negative – to government expenditures. The experiment reveals that for the euroarea overall, fiscal policy was a drag on output. This is particularly true for the GIIPS economies, which would have had a decline of only 2.4 percent below trend, half of what actually occurred. Were countries to experience only the positive (stimulative) fiscal shocks, and no negative shocks (the "No Austerity" case), euroarea output would have fallen only 1.8 percent below trend. Column 4 shows the reverse experiment: negative fiscal shocks only.

Column 5, the "No Euro" case, shows the impact on output, inflation and consumption, had countries pursued actual policies over the period but were free to pursue independent monetary policy and allow their currencies to float. While there are many ramifications of such an "exit strategy" that are not captured in our model, the experiment does provide some

[27] In addition to the model variations considered here, we also explored the consequences of imposing incomplete financial markets. These results are nearly identical to the results in Table 10.

insight into the opportunity cost of a shared monetary policy. Under the full float scenario, GIIPS output would fall by 13 percent less relative to the benchmark while the EU10 would experience a larger output decline of 20 percent relative to the benchmark (see also Figure 5). Examination of the implied exchange rate changes in Figure 6 produces the obvious: the real exchange rate depreciates in the GIIPS region, stimulating exports and output. In contrast, 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 euroarea. Interestingly, the path for the euro area as a whole would barely be affected by this drastic policy change.

Finally, the "No Trade" experiment shows that, while direct spillover effects are small in the cross-section, trade does play a role in the transmission of shocks. The negative austerity shocks in the GIIPS region not only caused their output to fall, but pulled down output in the rest of Europe as well.

6 Conclusion

Since the end of the Great Recession in 2009, the advanced countries have experienced radically different recoveries. Some enjoyed a return to normal economic growth shortly 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 the cross-country dispersion in various measures of 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 austerity policies. In particular, the evidence suggests that contractions in government spending have played a surprisingly large role in reducing output for some countries. Evidence for tax policies and the primary balance is more mixed. Countries that increase taxes fare worse than otherwise but the effects of raising taxes are modest and not strongly statistically significant. In contrast, countries that reduce government spending experience sharp reductions in output and inflation.

We use a multi-country DSGE model to see whether standard macroeconomic theory can make sense of the observed changes in economic activity. The model features government spending shocks, shocks to a consumption tax, 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. While our preliminary findings suggest that standard Keynesian mechanisms are playing a strong role in shaping the behavior of countries across Europe, the quantitative predictions of the model for GDP are too small to fully match the empirical findings. This likely means that the magnitude of the demand multipliers in the model are simply too weak to match the data. Future work is needed to refine the model's performance along this dimension.

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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 Ilzetzki et al. (2004), *http://www.carmenreinhart.com/data/browse-by-topic/topics/11/*..

Table 2a: Summary Statistics of Forecast Deviations: Government Finance Variables

	Government Purchases	Total Outlays	Primary Balance	Total Revenue	VAT	Income Tax	Corporate Tax
Average	−5.60	−4.31	2.26	−2.17	1.41	−2.10	−2.84
Std. deviation	10.73	8.49	3.74	5.32	1.38	7.59	3.68
			Correlation matrix				
Gov't. Purchases	1.00						
Total Outlays	0.87	1.00					
Primary Balance	−0.54	−0.67	1.00				
Total Revenue	0.14	0.11	0.26	1.00			
VAT	−0.36	−0.18	0.28	0.17	1.00		
Income Tax	0.05	0.18	−0.14	0.42	0.16	1.00	
Corporate Tax	−0.00	0.10	−0.08	0.06	−0.16	0.02	1.00

Notes: Table displays statistics of the log-difference (*100) between the actual time series and the forecast, averaged over 2010 - 2014, for government purchases, total outlays, total revenue, the primary balance, the VAT, the personal income tax rate and the corporate tax rate. The first row displays the average of this difference across countries; the second row displays the standard deviation across countries. The remaining rows display the correlation across the various measures.

Table 2b: Summary Statistics of Forecast Deviations: Economic Performance Variables

	GDP	Con-sumption	Invest-ment	Inflation	NX to GDP	Exchange Rate	GDP Growth	Unem-ployment	Debt to GDP
Average	−11.93	−13.01	−31.61	−0.90	4.30	2.60	−1.60	1.92	18.12
Std. deviation	9.17	10.41	25.07	1.65	5.91	9.36	2.03	4.52	21.09
				Correlation matrix					
GDP	1.00								
Consumption	0.79	1.00							
Investment	0.88	0.80	1.00						
Inflation	0.40	0.42	0.54	1.00					
NX to GDP	0.08	−0.29	−0.06	−0.34	1.00				
Consumption	0.34	0.16	0.20	−0.01	0.10	1.00			
GDP Growth	0.79	0.56	0.68	0.33	0.23	0.00	1.00		
Unemployment	−0.65	−0.42	−0.62	−0.25	0.13	−0.21	−0.34	1.00	
Debt to GDP	−0.46	−0.34	−0.55	−0.26	0.04	−0.34	−0.14	0.62	1.00

Notes: Table displays statistics of the log-difference (*100) between the actual time series and the forecast, averaged over 2010 - 2014, for GDP, inflation, net exports over GDP, the nominal effective exchange rate, GDP growth, unemployment and the debt to GDP ratio. The first row displays the average of this difference across countries; the second row displays the standard deviation across countries. The remaining rows display the correlation across the various measures.

Table 3a: AUSTERITY, GDP AND INFLATION

	All countries		Fixed XRT		Floating XRT	
	α_1	R^2	α_1	R^2	α_1	R^2
	Government Purchases (Shortfall)					
GDP	−2.76	0.60	−2.55	0.59	−3.54	0.76
	(0.43)		(0.50)		(0.75)	
Inflation	−0.35	0.31	−0.33	0.37	−0.46	0.24
	(0.10)		(0.10)		(0.31)	
	Total Outlays (Shortfall)					
GDP	−2.06	0.48	−2.08	0.53	−2.27	0.53
	(0.41)		(0.46)		(0.81)	
Inflation	−0.19	0.12	−0.22	0.22	−0.11	0.02
	(0.10)		(0.10)		(0.27)	
	Primary Balance					
GDP	−1.45	0.35	−1.81	0.47	−0.98	0.24
	(0.38)		(0.46)		(0.66)	
Inflation	−0.07	0.03	−0.07	0.03	−0.09	0.03
	(0.08)		(0.10)		(0.17)	

Notes: Table displays the estimated coefficient and standard errors on the government finance variable from regression (2.6) as well as its R^2. Reported standard errors in parentheses are (untreated) OLS errors.

Table 3b: Austerity, GDP and Inflation

	All countries		Fixed XRT		Floating XRT	
	α_1	R^2	α_1	R^2	α_1	R^2
			Total Revenue			
GDP	−0.51	0.01	−0.46	0.01	0.21	0.00
	(1.01)		(1.10)		(3.24)	
Inflation	0.13	0.02	0.24	0.10	−0.75	0.14
	(0.18)		(0.17)		(0.69)	
			VAT			
GDP	−3.24	0.23	−3.12	0.22	−3.33	0.26
	(1.16)		(1.39)		(2.32)	
Inflation	−0.61	0.25	−0.39	0.13	−1.16	0.59
	(0.21)		(0.24)		(0.40)	
			Personal Income Tax Rate			
GDP	−0.12	0.01	−0.40	0.10	0.57	0.26
	(0.23)		(0.29)		(0.36)	
Inflation	0.05	0.05	0.00	0.00	0.16	0.38
	(0.04)		(0.05)		(0.08)	
			Corporate Tax Rate			
GDP	0.41	0.03	0.52	0.05	−0.09	0.00
	(0.47)		(0.56)		(0.99)	
Inflation	0.03	0.00	0.02	0.00	0.06	0.01
	(0.09)		(0.09)		(0.23)	

Notes: See Table 3a.

Table 4: Austerity and Economic Performance

	Government Purchases (Shortfall)					
	All countries		Fixed XRT		Floating XRT	
	α_1	R^2	α_1	R^2	α_1	R^2
GDP	−2.76	0.60	−2.55	0.59	−3.54	0.76
	(0.43)		(0.50)		(0.75)	
Inflation	−0.35	0.31	−0.33	0.37	−0.46	0.24
	(0.10)		(0.10)		(0.31)	
Consumption	−2.50	0.38	−1.59	0.36	−5.96	0.72
	(0.61)		(0.50)		(1.39)	
Investment	−7.14	0.54	−6.81	0.59	−8.22	0.57
	(1.27)		(1.33)		(2.72)	
Net Exports	0.46	0.04	0.20	0.01	1.46	0.64
	(0.43)		(0.56)		(0.41)	
Exchange Rate	−0.55	0.02	−0.27	0.02	−1.67	0.06
	(0.69)		(0.49)		(2.46)	
GDP Growth	−0.52	0.43	−0.55	0.46	−0.36	0.39
	(0.11)		(0.14)		(0.17)	
Unemployment Rate	0.86	0.24	0.86	0.27	0.82	0.25
	(0.29)		(0.33)		(0.54)	
Debt to GDP	2.36	0.09	2.40	0.10	2.22	0.07
	(1.47)		(1.69)		(3.39)	

Notes: See Table 3a.

Table 5: AUSTERITY AND SPILLOVERS

	Government Purchases (Shortfall)								
	All countries			Fixed XRT			Floating XRT		
	α_1	α_1^*	R^2	α_1	α_1^*	R^2	α_1	α_1^*	R^2
GDP	−4.17	6.47	0.63	−3.81	17.10	0.64	−5.69	−1.23	0.77
	(0.63)	(14.91)		(0.70)	(16.90)		(1.31)	(38.47)	
Inflation	−0.51	−2.54	0.31	−0.46	−0.33	0.35	−0.63	−17.91	0.43
	(0.15)	(3.66)		(0.15)	(3.68)		(0.47)	(13.89)	
Consumption	−3.62	−8.50	0.38	−2.40	6.09	0.39	−9.21	−15.77	0.70
	(0.92)	(21.99)		(0.72)	(17.46)		(2.59)	(76.06)	
Investment	−10.69	1.07	0.55	−10.04	31.81	0.62	−13.52	34.82	0.58
	(1.88)	(44.75)		(1.92)	(46.35)		(4.75)	(139.45)	
Net Exports	0.56	21.89	0.11	0.24	19.23	0.06	2.09	20.88	0.65
	(0.63)	(14.94)		(0.81)	(19.55)		(0.72)	(21.14)	
Exchange Rate	−0.86	26.82	0.07	−0.37	22.71	0.11	−3.25	32.43	0.09
	(1.02)	(24.18)		(0.69)	(16.77)		(4.30)	(126.31)	
GDP Growth	−0.76	−4.84	0.47	−0.81	−3.56	0.48	−0.51	−9.76	0.51
	(0.17)	(3.94)		(0.21)	(5.05)		(0.27)	(7.99)	
Unemployment Rate	1.34	1.06	0.27	1.31	−1.88	0.29	1.61	−27.53	0.40
	(0.43)	(10.33)		(0.49)	(11.85)		(0.85)	(25.05)	
Debt to GDP	3.96	28.53	0.13	3.95	45.62	0.16	6.07	−196.12	0.30
	(2.17)	(51.37)		(2.44)	(58.82)		(5.39)	(161.93)	

Notes: Table displays the estimated coefficients and standard errors on the austerity (α) and spillover shock (α^*) from regression (2.7) as well as its R^2. Reported standard errors in parentheses are (untreated) OLS errors.

Table 6: Calibration

Description	Parameter	Value	Source
Preferences			
Discount factor (quarterly)	β	0.99	Standard value
Coefficient of relative risk aversion	$\frac{1}{\sigma}$	2	Standard value
Frisch elasticity of labor supply	η	1	Barsky et al. (1997)
Trade and Country Size			
Trade preference weights	ω_n^j	x	OECD Trade in Value Added Dataset
Trade demand elasticity	ψ_y	1.5	e.g. Backus et al. (1994), Cravino (2014), Proebsting (2015)
Country size	$\mathbb{N}_n Y_n$	x	OECD Input-Output Tables
Technology			
Capital share	α	0.38	Trabandt and Uhlig (2011)
Depreciation (quarterly)	δ	0.022	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	ψ_q	10	Standard value
Price and Wage Rigidity			
Sticky price probability	θ_p	0.80	Alvarez et al. (2006)
Sticky wage probability	θ_w	0.80	Barattieri et al. (2014)
Financial Market Imperfections			
SS External finance premium	$F_n(\lambda_{ss})$	x	ECB, Global Financial Database and national sources
Elasitcity external finance premium	F_ϵ	0.20	Brave et al. (2012)
Persistence spread shock	ρ_F	0.99	Brave et al. (2012)
Fiscal and Monetary Policy			
Gov't purchases over final demand	$\frac{G_n}{Y_n}$	x	OECD and Eurostat
Persistence government spending shock	ρ_G	0.93	Del Negro et al. (2013)
Consumption tax rate	τ	x	European Commission (2015)
Taylor rule persistence	ϕ_i	0.75	
Taylor rule GDP coefficient	ϕ_{GDP}	0.5	
Taylor rule inflation coefficient	ϕ_π	0.5	

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

Table 7: SUMMARY STATISTICS OF EXOGENOUS PROCESS

	Gov	VAT	Mon	Spread
Average	−2.66	1.36	1.21	0.51
Std. deviation	14.94	1.38	2.03	1.20
	Correlation matrix			
Gov	1.00			
VAT	−0.03	1.00		
Mon	−0.22	0.34	1.00	
Spread	−0.30	−0.07	−0.08	1.00

Notes: Table displays statistics of the exogenous process for the model. 'Gov' refers to the log-difference of government purchases between the actual time series and the forecast. 'VAT' refers to percentage deviations of the average VAT rate between 2010 - 2014 to the average VAT rate in 2004 & 2005; 'Mon' refers to the (annualized) central bank interest rate less the rate implied by a monetary policy rule, in quarterly percentage points. 'Spread' is based on the raw spread data, which is calculated as lending rates to businesses less central bank interest rates, in annual percentage points. 'Spread' is this raw spread data less the country-specific spread averaged over 2000 (or earliest available date) - 2010. Statistics are averaged over 2010 - 2014.

Table 8: Comparison of Model and Data: Benchmark Calibration

	Data			Benchmark		
	All	Fix	Float	All	Fix	Float
GDP	-2.77	-2.54	-3.61	-0.78	-0.52	-1.80
	(0.43)	(0.50)	(0.76)			
Inflation	-0.35	-0.32	-0.47	-0.09	-0.03	-0.34
	(0.10)	(0.10)	(0.31)			
Consumption	-2.48	-1.58	-6.06	0.04	0.12	-0.24
	(0.61)	(0.49)	(1.42)			
Investment	-7.14	-6.78	-8.37	-1.14	-0.68	-2.96
	(1.26)	(1.32)	(2.76)			
Net Exports	0.45	0.19	1.48	0.59	0.65	0.41
	(0.43)	(0.55)	(0.42)			
Exchange Rate	-0.55	-0.27	-1.72	0.14	-0.04	0.79
	(0.69)	(0.49)	(2.50)			
GDP Growth	-0.52	-0.55	-0.37	-0.05	-0.06	0.01
	(0.11)	(0.14)	(0.17)			

Notes: Table displays data and model results for the multiplier α_1 in regression (2.6) See also Table 3a.

Table 9: Comparison of Model and Data: Individual Shocks

	Data			Benchmark			Only Govt			Only VAT			Only Money			Only Spread		
	All	Fix	Float	All	Fix	Float	All	Fix	Float	All	Fix	Float	All	Fix	Float	All	Fix	Float
GDP	-2.77	-2.54	-3.61	-0.78	-0.52	-1.80	-0.60	-0.59	-0.64	-0.02	-0.02	-0.02	-0.23	0.05	-1.34	0.00	0.01	-0.05
	(0.43)	(0.50)	(0.76)															
Inflation	-0.35	-0.32	-0.47	-0.09	-0.03	-0.34	0.03	-0.04	0.33	0.02	0.01	0.03	-0.17	0.00	-0.86	0.01	0.00	0.04
	(0.10)	(0.10)	(0.31)															
Consumption	-2.48	-1.58	-6.06	0.04	0.12	-0.24	0.14	0.12	0.22	-0.02	-0.02	-0.01	-0.11	-0.01	-0.48	0.02	0.03	-0.03
	(0.61)	(0.49)	(1.42)															
Investment	-7.14	-6.78	-8.37	-1.14	-0.68	-2.96	-0.76	-0.79	-0.63	-0.03	-0.02	-0.05	-0.54	0.05	-2.91	-0.18	-0.15	-0.29
	(1.26)	(1.32)	(2.76)															
Net Exports	0.45	0.19	1.48	0.59	0.65	0.41	0.68	0.55	1.23	-0.01	-0.01	0.00	-0.13	0.07	-0.91	0.04	0.05	-0.01
	(0.43)	(0.55)	(0.42)															
Exchange Rate	-0.55	-0.27	-1.72	0.14	-0.04	0.79	-0.15	-0.01	-0.73	0.03	-0.00	0.18	0.29	-0.03	1.54	-0.01	-0.00	-0.07
	(0.69)	(0.49)	(2.50)															
GDP Growth	-0.52	-0.55	-0.37	-0.05	-0.06	0.01	-0.07	-0.07	-0.05	-0.01	-0.01	-0.03	0.01	0.01	0.04	-0.00	-0.00	0.01
	(0.11)	(0.14)	(0.17)															

Notes: Table displays data and model results for the multiplier α_1 in regression (2.6). The benchmark calibration includes shocks to government spending ("Govt"), the VAT, 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 10: Robustness

	Data	Bench-mark	Passive Monetary	ZLB	Variable Markup	Low nom. rigidity	Strong fin. accelerator	Elastic utilization	High adj. costs	High Trade Elasticity	No Euro	No Trade
All												
GDP	−2.77	−0.78	−0.90	−0.70	−1.05	−0.67	−0.80	−0.85	−0.74	−0.78	−0.61	−1.20
Inflation	−0.35	−0.09	−0.24	−0.04	0.18	−3.26	−0.09	−0.09	−0.11	−0.09	0.10	−0.18
Fixed												
GDP	−2.54	−0.52	−0.50	−0.55	−0.84	−0.42	−0.55	−0.58	−0.51	−0.26	–	−0.96
Inflation	−0.32	−0.03	−0.02	−0.03	0.03	−0.03	−0.03	−0.03	−0.03	−0.02	–	−0.12
Floaters												
GDP	−3.61	−1.80	−2.51	−1.33	−1.88	−1.65	−1.79	−1.92	−1.65	−2.81	−0.61	−2.02
Inflation	−0.47	−0.34	−1.08	−0.05	0.79	−15.92	−0.35	−0.30	−0.41	−0.39	0.10	−0.39
Simualted GDP												
Rank Corr.	1.00	0.53	0.46	0.46	0.62	0.54	0.55	0.51	0.61	0.36	0.51	0.64
Rel. Std. Dev.	1.00	0.26	0.29	0.25	0.37	0.23	0.25	0.28	0.24	0.49	0.22	0.35

Notes: The table displays the estimated α_1 in regression (2.6) 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 11: COUNTERFACTUAL ANALYSIS

	Bench	No Fiscal	No Austerity	No Stimulus	No Euro	No Trade
Eurozone						
GDP	−2.58	−2.08	−1.82	−2.83	−2.60	−2.56
Inflation	−0.39	−0.49	−0.52	−0.35	−0.36	−0.47
Consumption	−0.36	−0.76	−0.96	−0.16	−0.33	−0.50
Floaters						
GDP	−0.51	−0.35	−0.13	−0.72	−0.50	−0.71
Inflation	−0.00	0.00	−0.02	0.02	0.00	−0.19
Consumption	0.02	−0.09	−0.27	0.20	0.02	0.10
GIIPS						
GDP	−4.33	−2.44	−2.40	−4.36	−3.78	−5.24
Inflation	−0.50	−0.40	−0.45	−0.44	0.25	−0.89
Consumption	−0.03	−0.72	−0.86	0.11	0.22	0.43
EU10						
GDP	−1.64	−1.89	−1.52	−2.01	−1.97	−1.03
Inflation	−0.33	−0.54	−0.56	−0.30	−0.70	−0.24
Consumption	−0.55	−0.78	−1.01	−0.33	−0.67	−1.05
Multiplier						
GDP	−0.78	−0.25	−0.33	−0.70	−0.61	−1.20
Inflation	−0.09	−0.14	−0.13	−0.10	0.10	−0.18
Consumption	0.04	−0.11	−0.08	0.02	0.11	0.39
Add'l Statistics						
Rank Correlation GDP	0.53	0.25	0.12	0.52	0.51	0.64
Rel. Std. Dev. GDP	0.26	0.17	0.20	0.24	0.22	0.35

Notes: Table displays average percent deviations from the steady state for simulated data over 2010 - 2014. The values for the multiplier refer to the estimated α_1 in regression (2.6) with regressors being shocks to government purchases 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. The standard deviation is the cross-country standard deviation of the simulated GDP data averaged over 2010 - 2104 relative to the standard deviation of the actual GDP data averaged over 2010 - 2014.

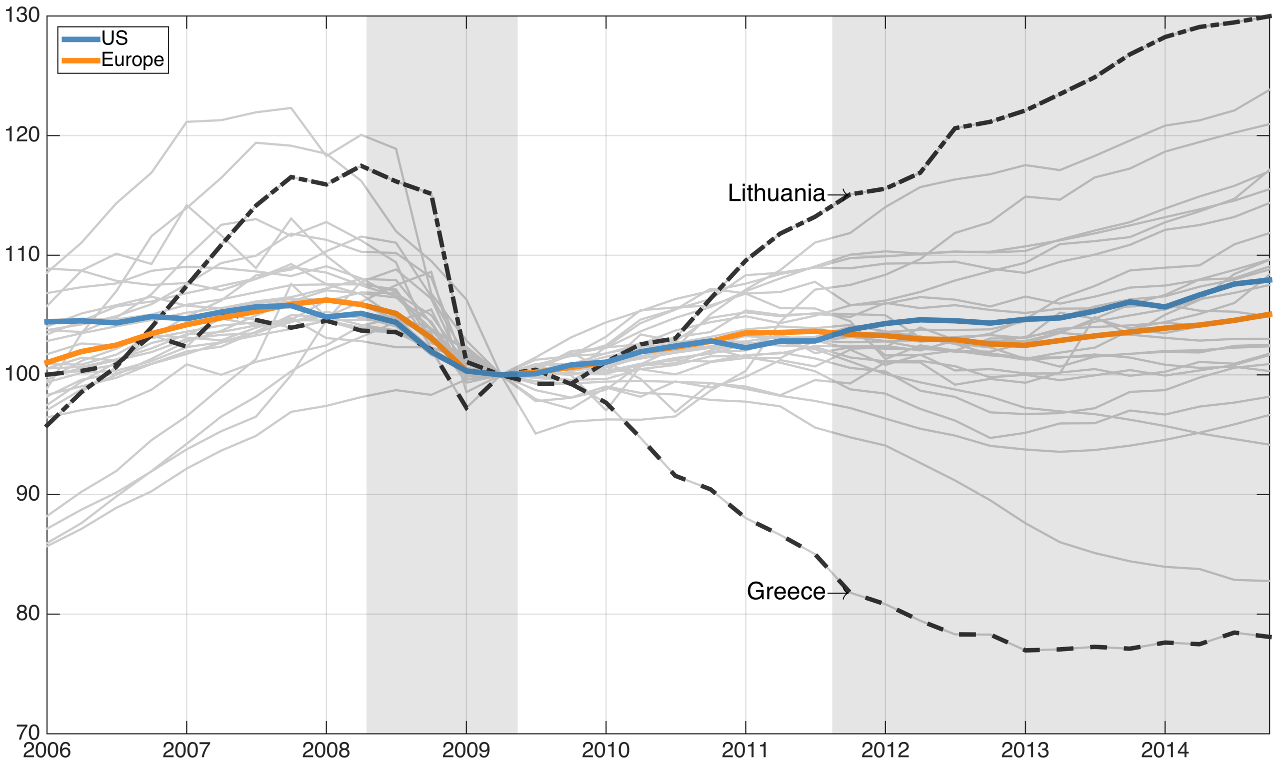


Figure 1: Real per Capita GDP Before, During and After the Crisis

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.

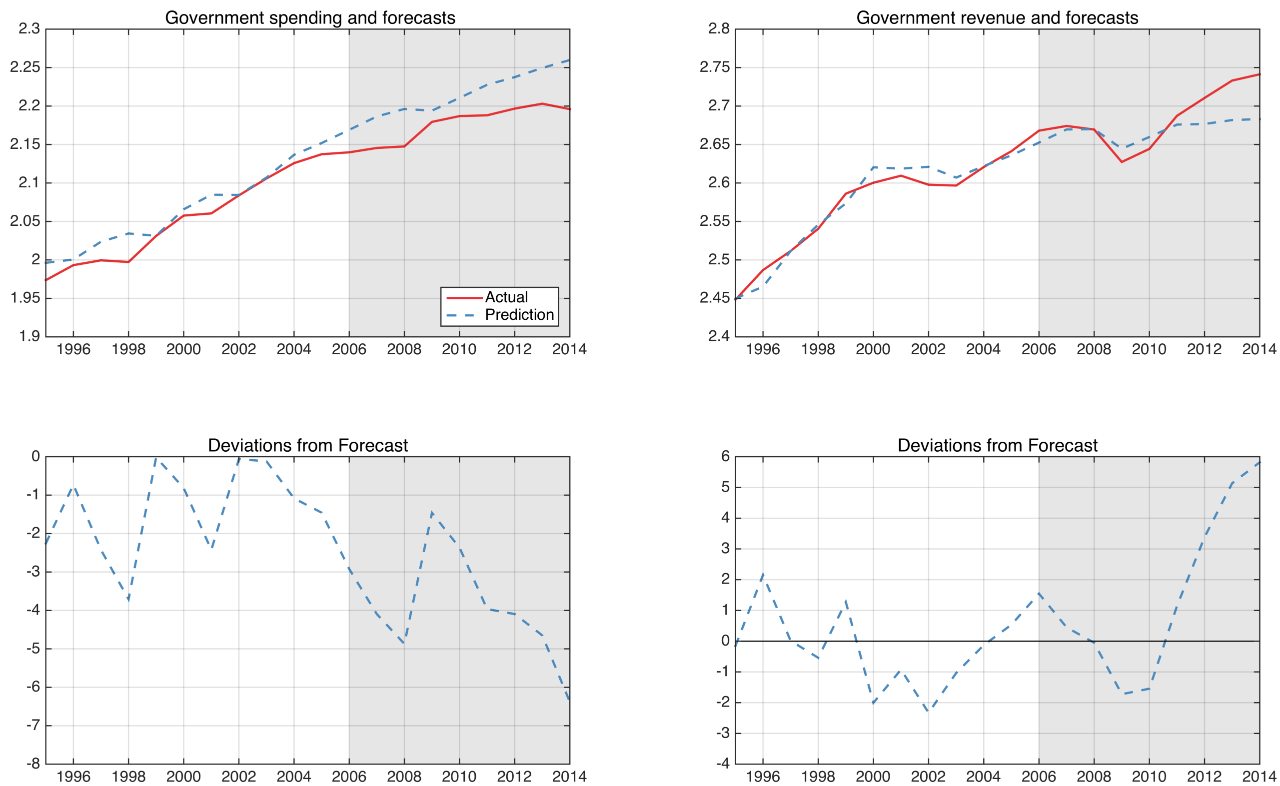


Figure 2a: MEASURES OF AUSTERITY FOR FRANCE

Note: Upper panels display nominal government purchases and government revenue for France on a log scale, together with their predicted values. Lower panels display the corresponding deviations of the actual series from their forecasts in log points.

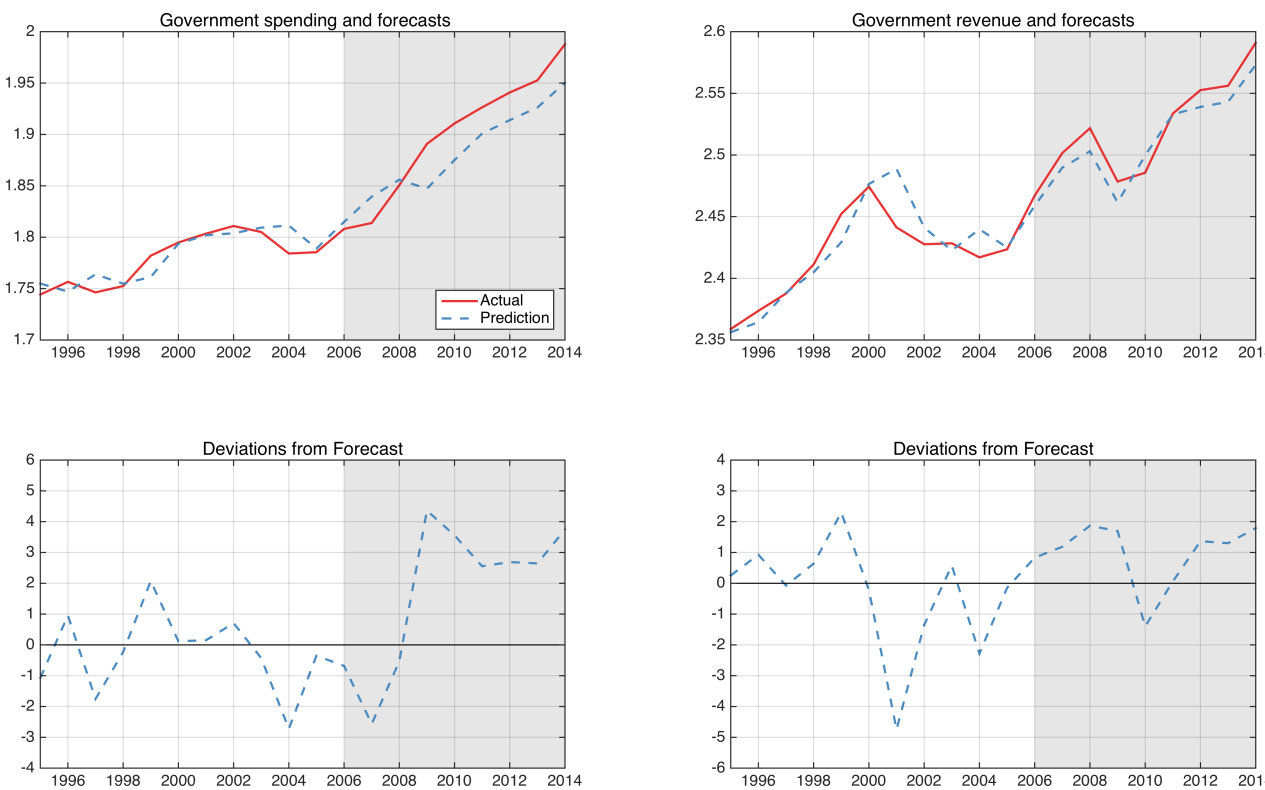


Figure 2b: Measures of Austerity for Germany

Note: See Figure 2a.

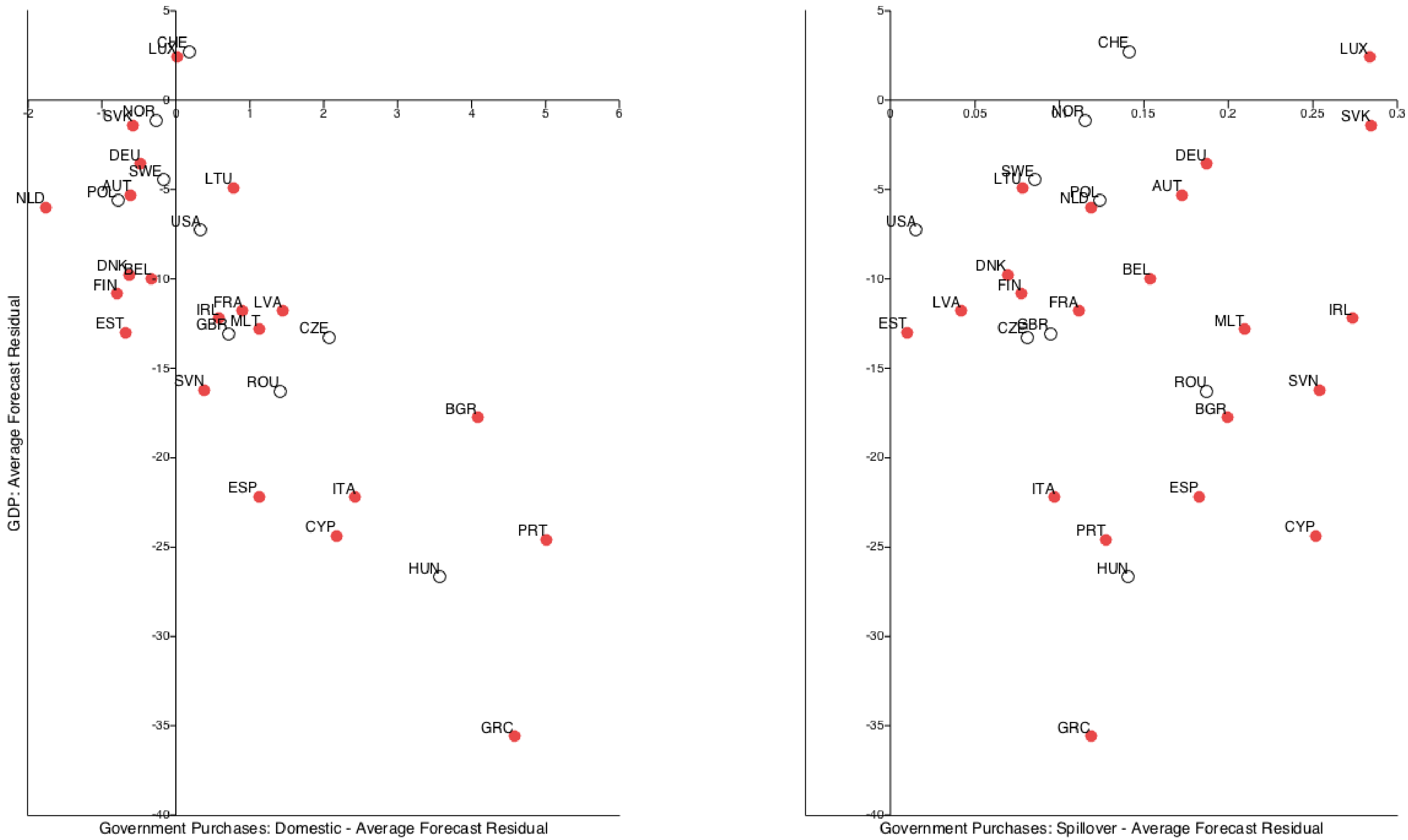


Figure 3: GDP and Austerity in Data: Domestic and Spillover Effect

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 government purchases, expressed in terms of a country's GDP and multiplied by a scaling factor. Left panel plots *Gshock*, the domestic austerity shock; right panel plots *Gshock**, the spillover shock. Countries are classified by their exchange rate regime (red: euro / pegged to euro; black: floating currency). See text for details on the forecast specification.

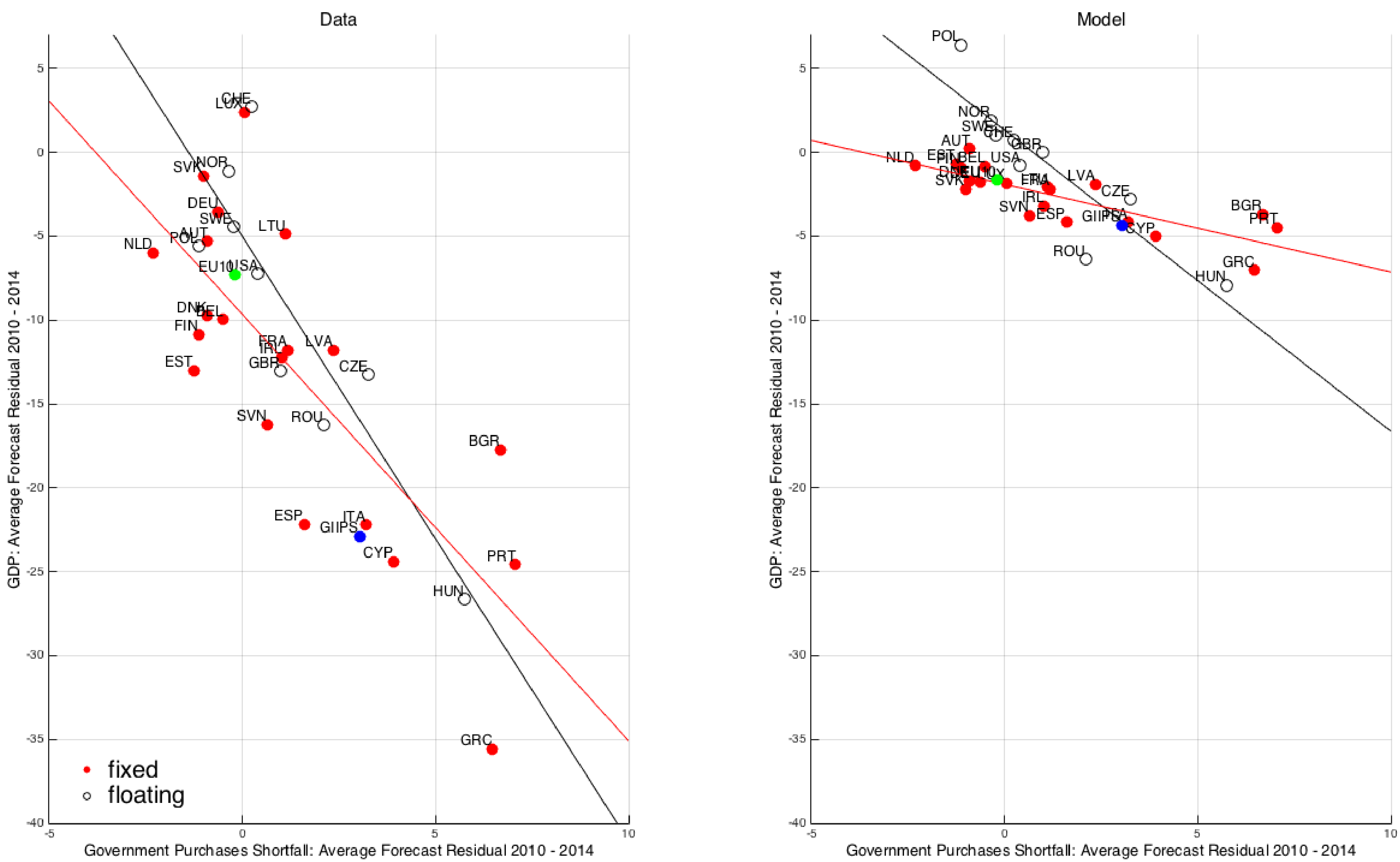


Figure 4a: GDP and Austerity: Data vs. Model

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; right panel refers to data from the simulated model. See text for details on the forecast specification.

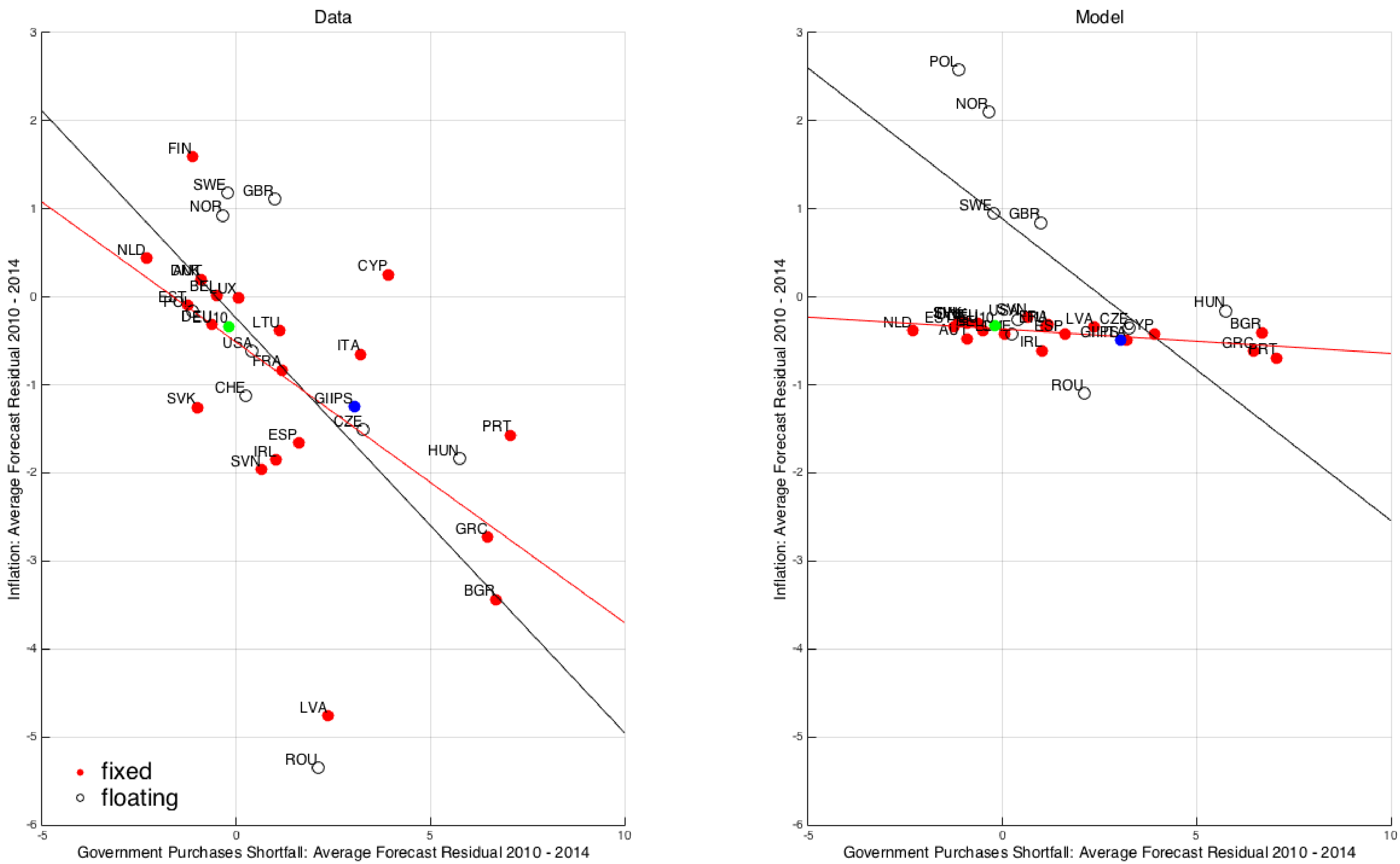


Figure 4b: Inflation and Austerity: Data vs. Model

Note: See Figure 4a.

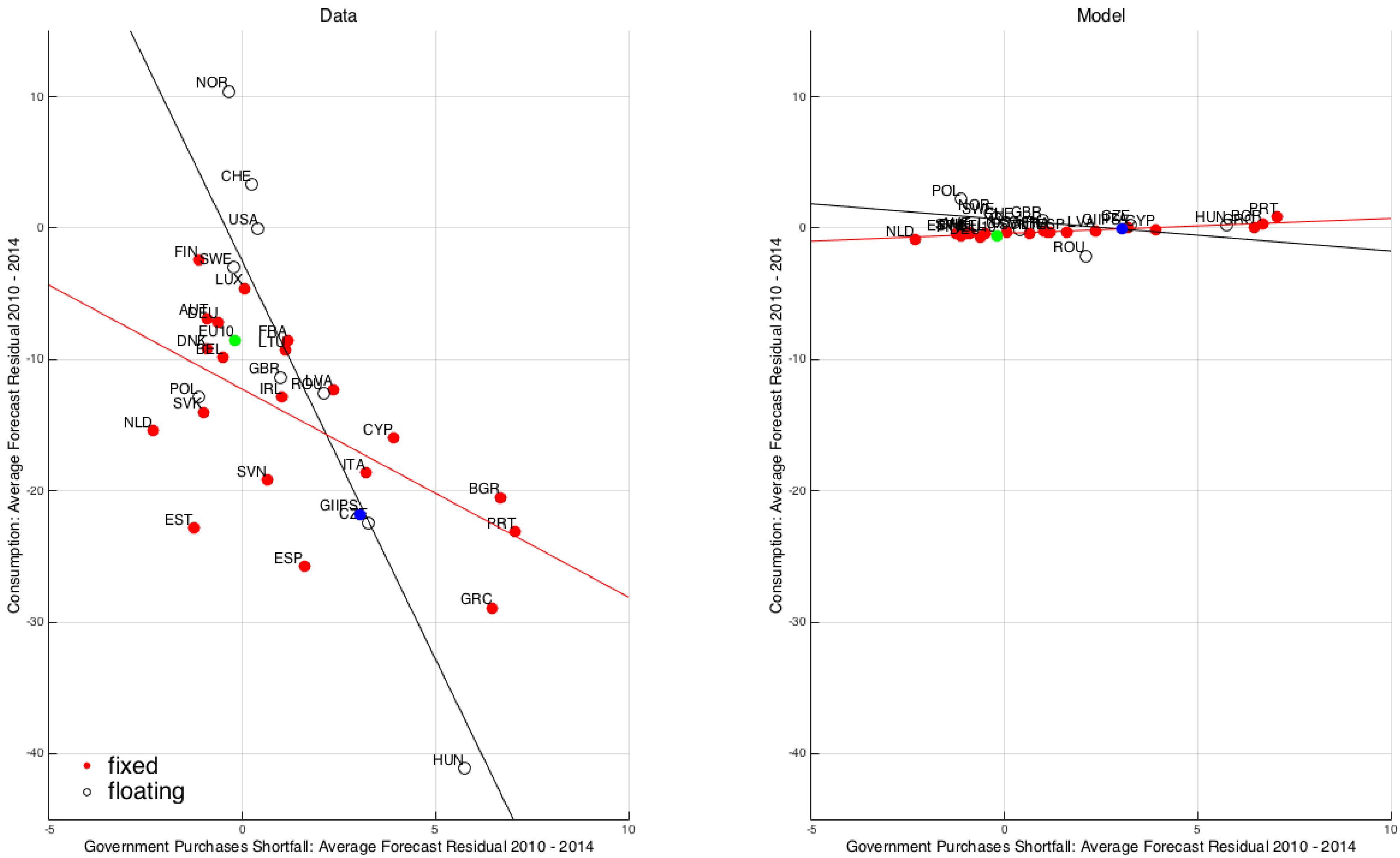


Figure 4c: Consumption and Austerity: Data vs. Model

Note: See Figure 4a.

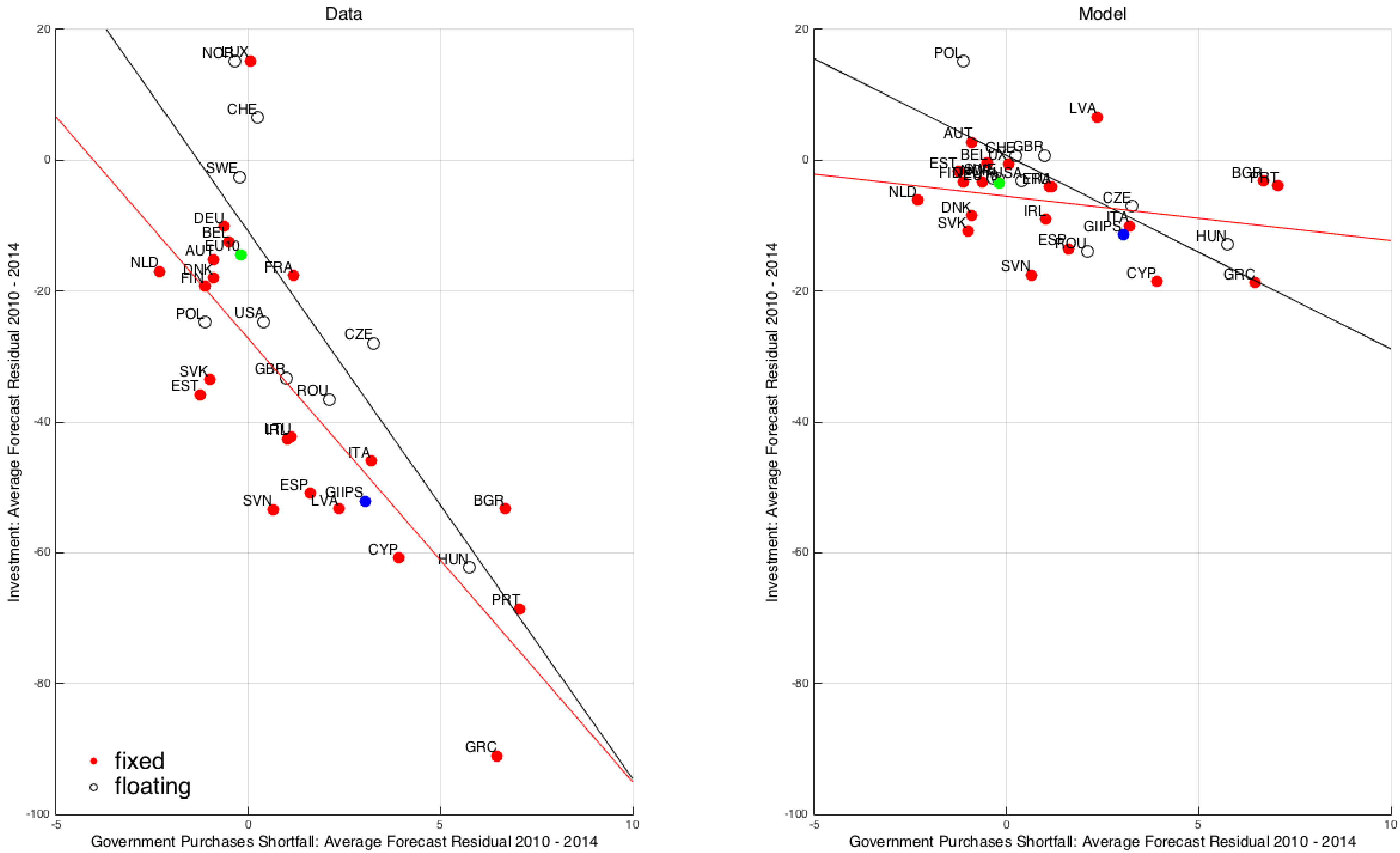


Figure 4d: Investment and Austerity: Data vs. Model

Note: See Figure 4a.

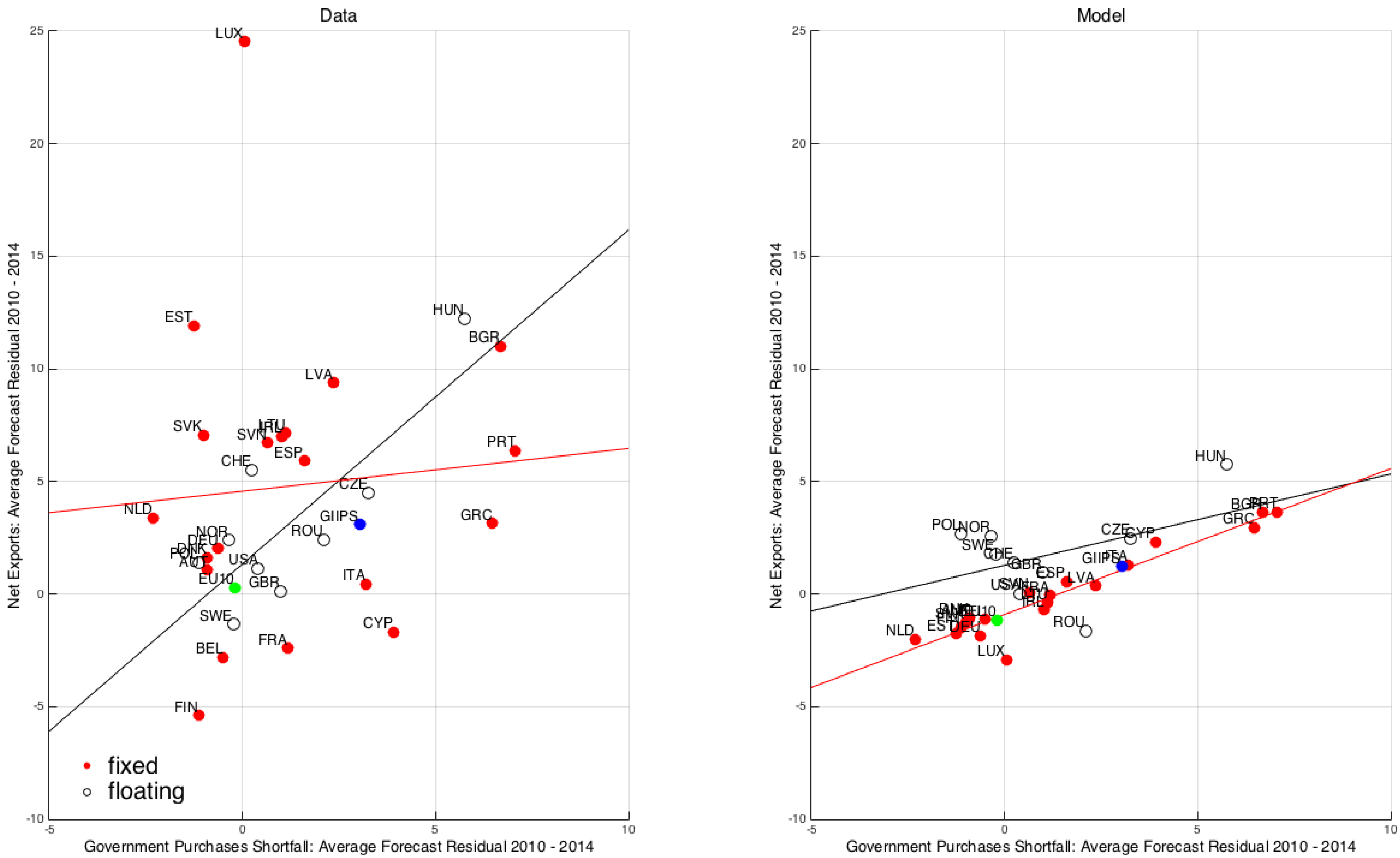


Figure 4e: Net Exports and Austerity: Data vs. Model

Note: See Figure 4a.

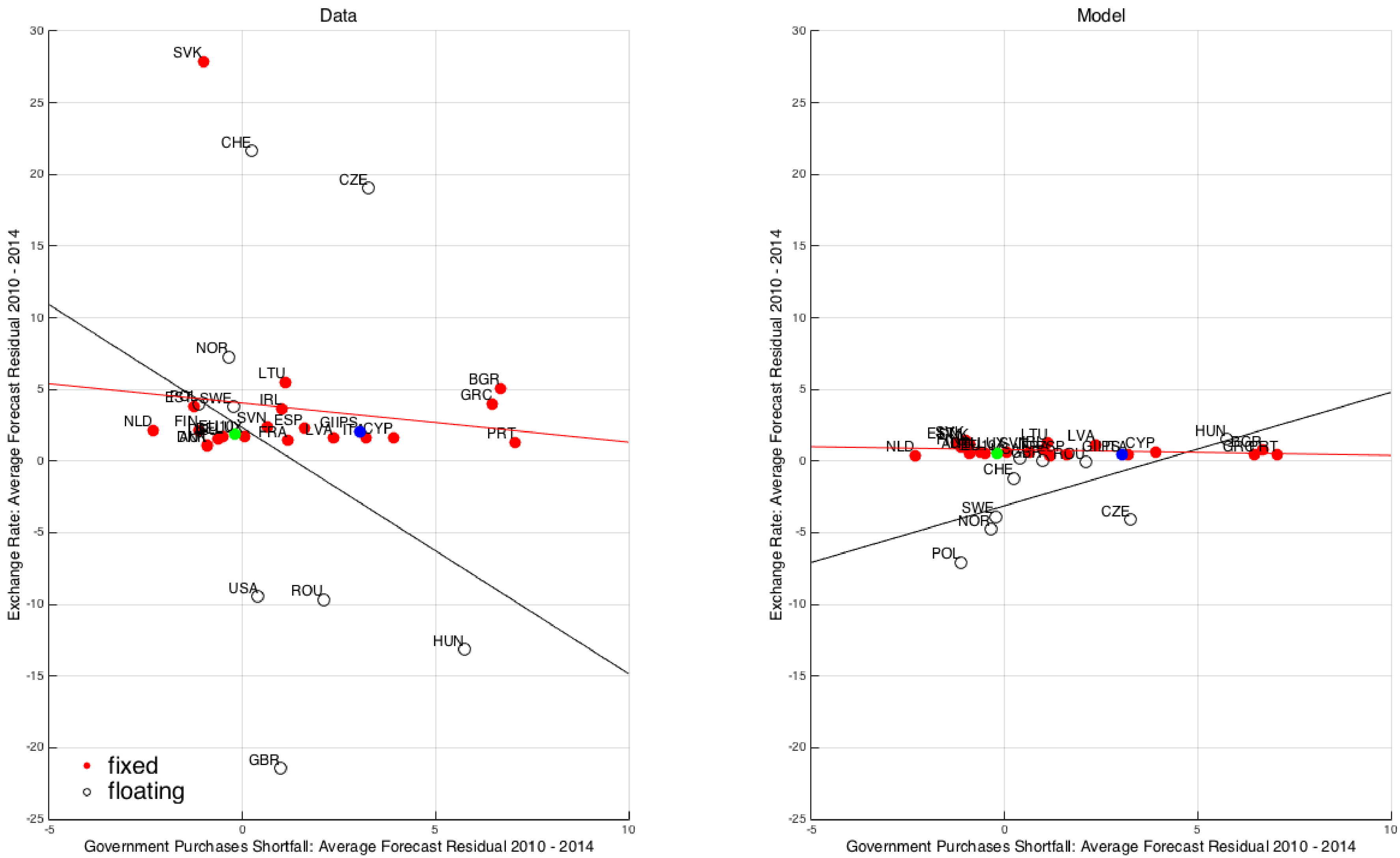


Figure 4f: Nominal Effective Exchange Rate and Austerity: Data vs. Model

Note: See Figure 4a.

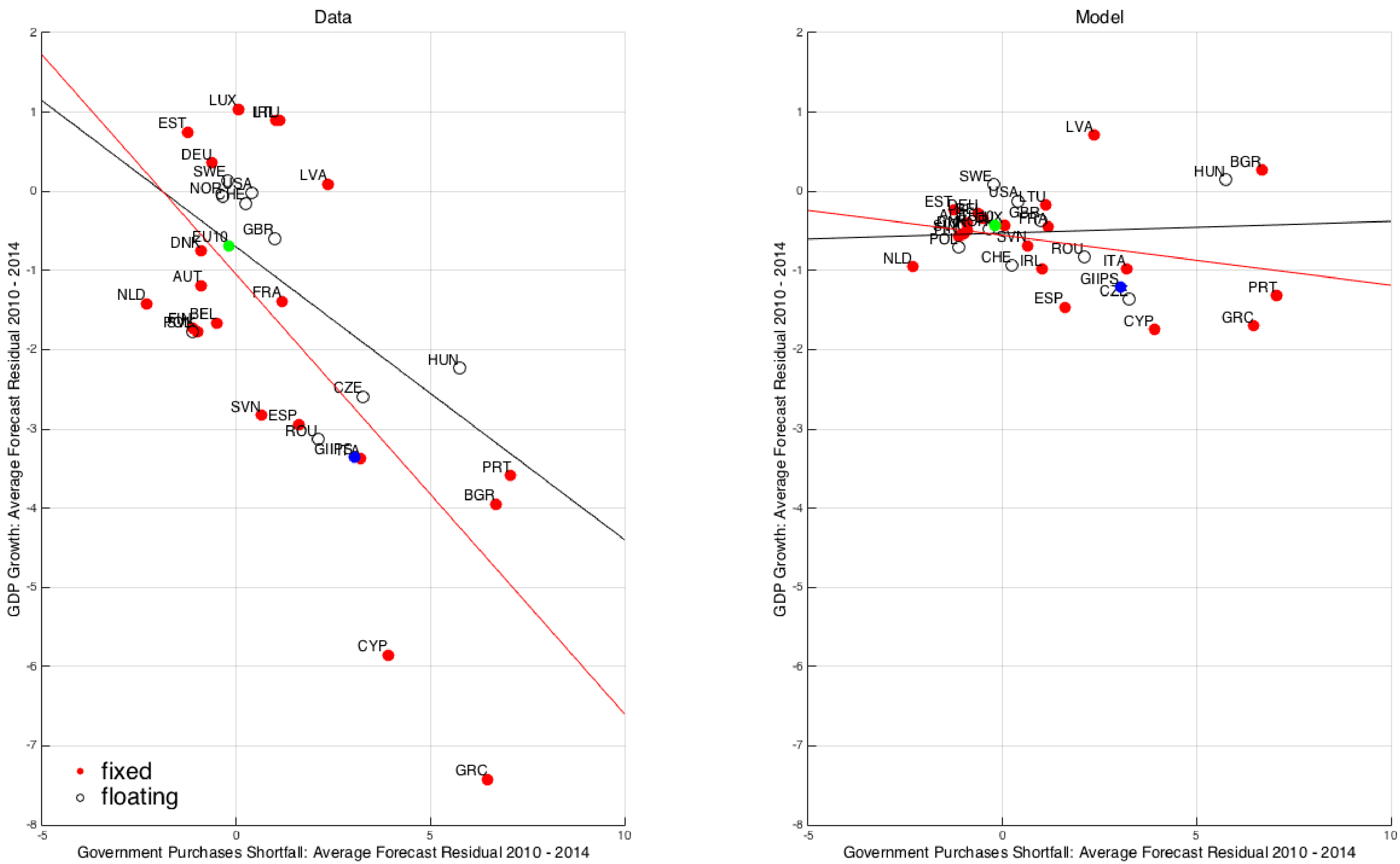


Figure 4g: GDP Growth and Austerity: Data vs. Model

Note: See Figure 4a.

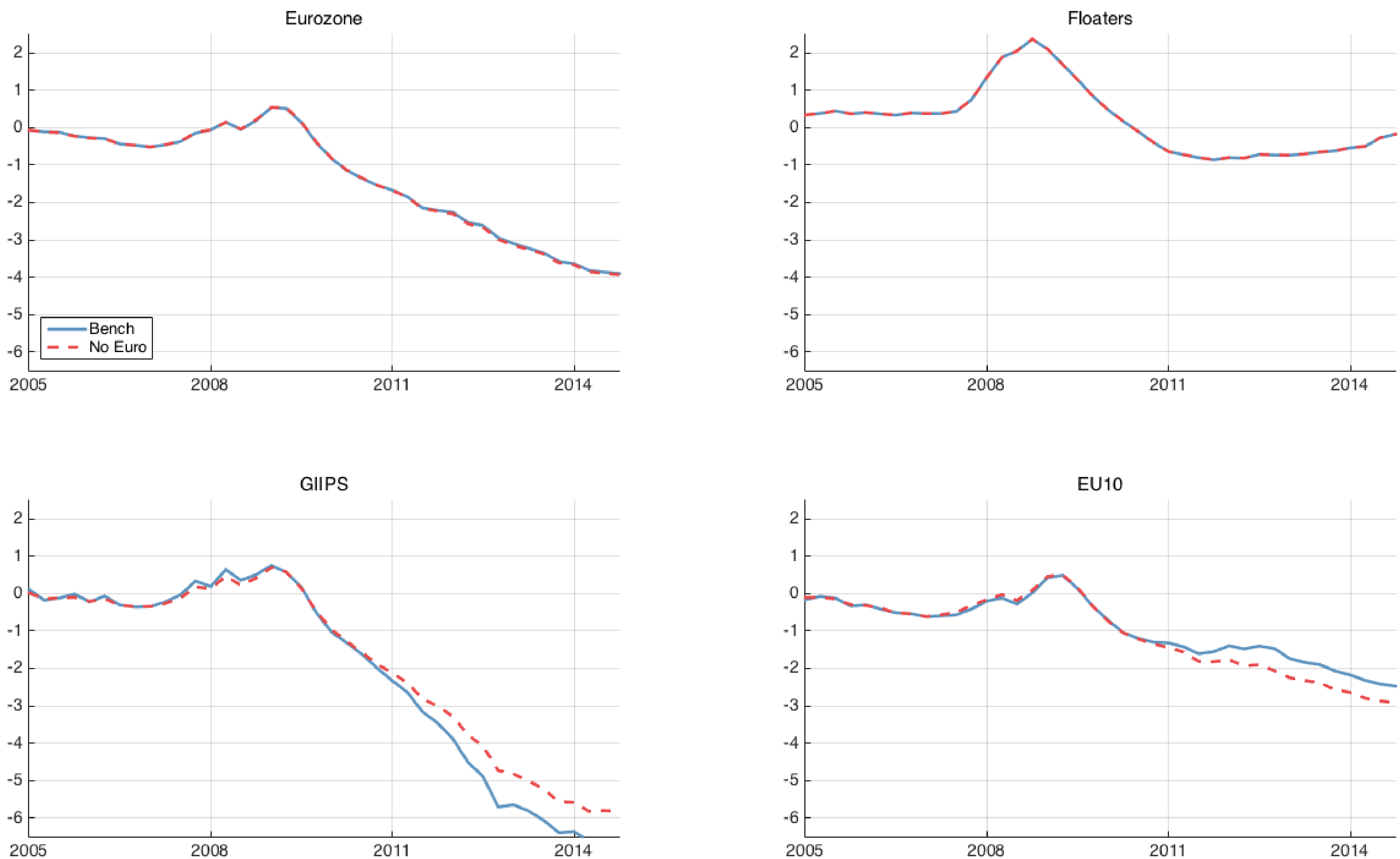
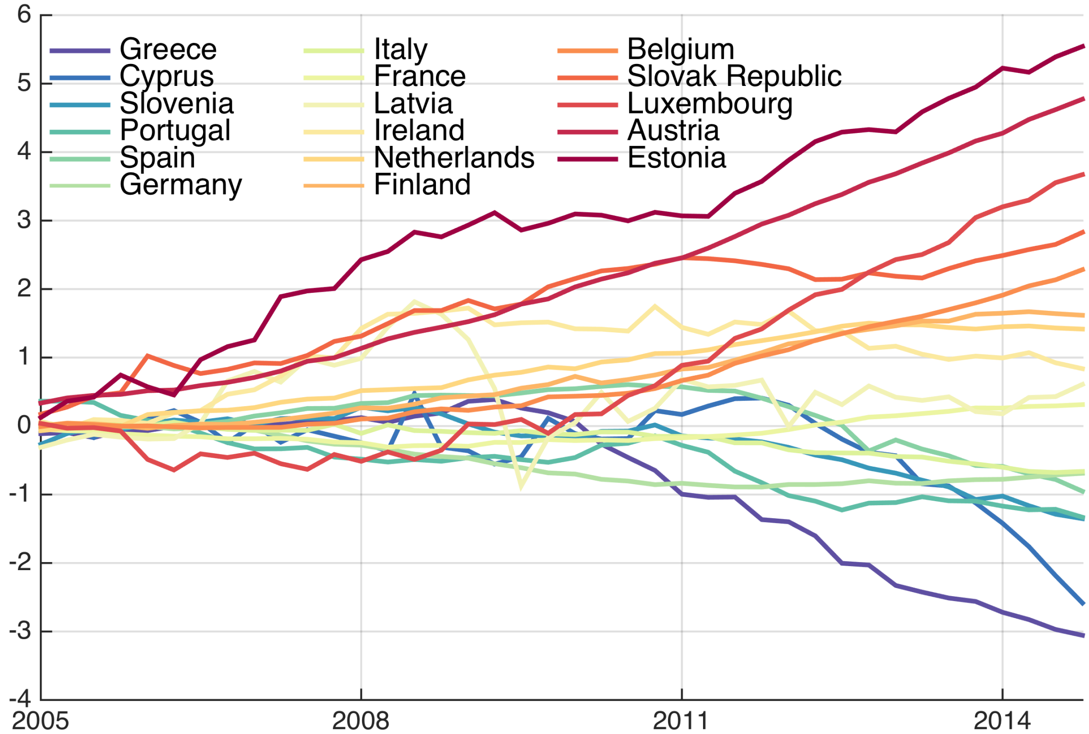
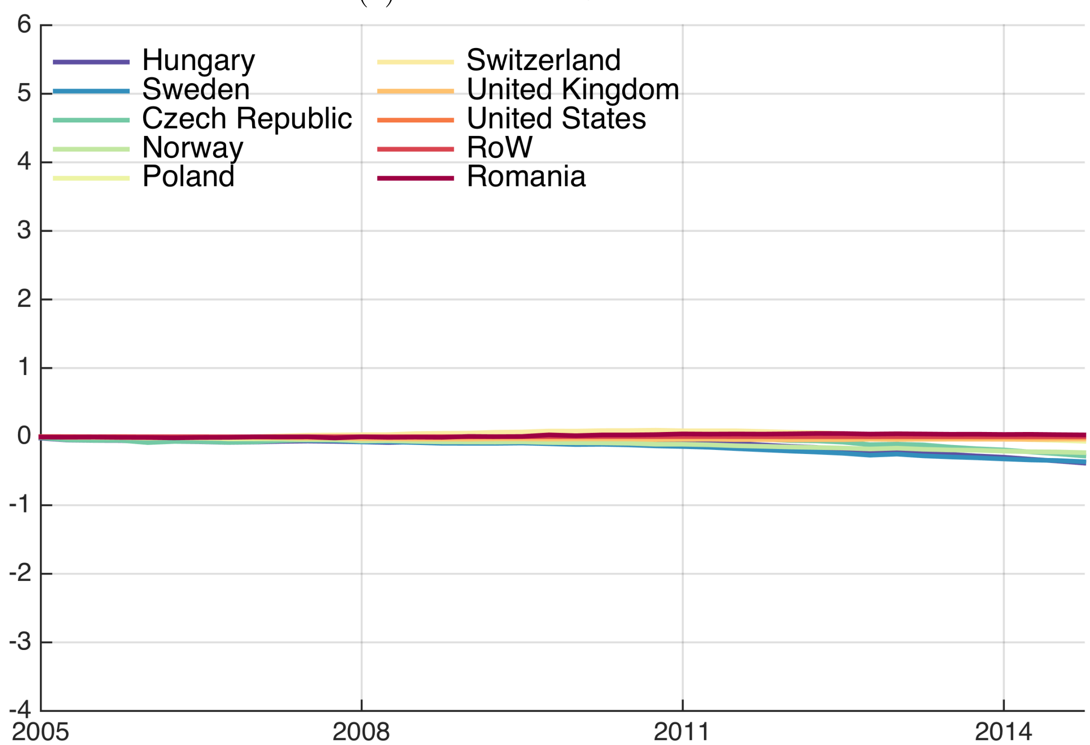


Figure 5: GDP: 'No Euro' and Benchmark

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



(a) Eurozone Countries



(a) Floating Countries

Figure 6: 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.

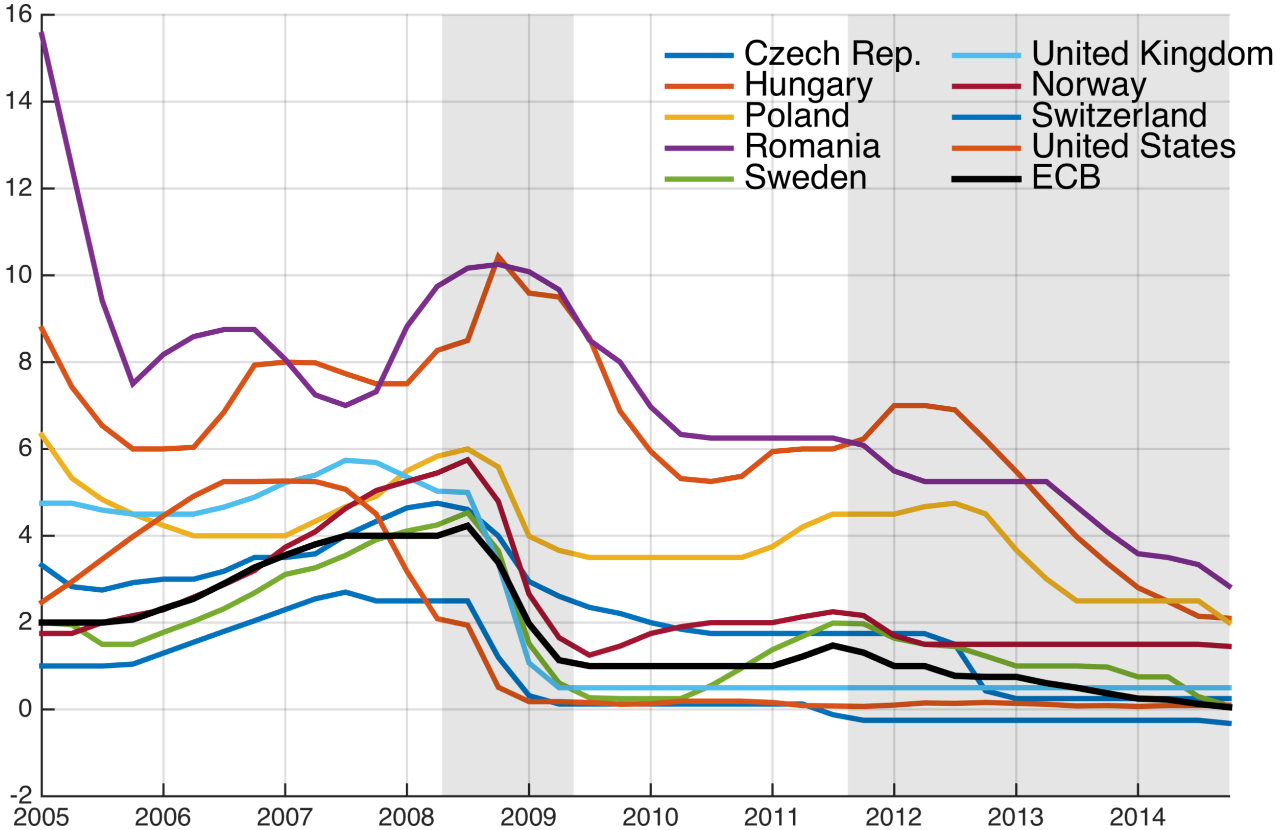


Figure 7: Central Bank Policy Interest Rates

Note: The figure plots the policy interest rates of the central banks in Europe and the U.S.