Austerity in the Aftermath of the Great Recession*†

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Abstract

Cross-country differences in austerity, defined as government purchases below forecast, account for over 70 percent of the observed cross-sectional variation in GDP in advanced economies during the period 2010-2014. Statistically, austerity is associated with lower real GDP, lower inflation and higher net exports. The cross-sectional multiplier is roughly 2. A multi-country DSGE model calibrated to 29 advanced economies generates a multiplier consistent with the data. Counterfactuals suggest that eliminating austerity would have substantially reduced output losses in Europe. Austerity in Europe was so contractionary that debt-to-GDP ratios in some countries increased as a consequence of endogenous reductions in GDP and tax revenue.

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1 Introduction

The economies in Europe contracted sharply and almost synchronously during the global financial crisis. Economic performance after the crisis, however, varied widely. Figure 1 plots real per-capita GDP for 29 countries including the U.S., the European Union, Switzerland, and Norway.[1] Taken as a whole, the recovery in Europe is similar to that of the U.S. This similarity, however, masks a tremendous amount of variation across Europe. At one end of the spectrum is Greece, where per capita income at the end of 2014 is more than 25 percent below its 2009 level. While Greece's GDP performance is exceptionally poor, a persistent contraction in GDP over this period is not unique. About a third of the countries have end-2014 levels of real per-capita GDP at or below their 2009 levels. At the other end of the spectrum is Lithuania. Like Greece, Lithuania experienced a strong contraction during the Great Recession. However, it then returned to a rapid rate of growth quickly thereafter.

We find that cross-country differences in austerity, defined as government purchases below forecast, account for roughly three quarters of the cross-sectional variation in GDP during the 2010-2014 period. At a time when faltering economies required stimulus, most countries in Europe cut government spending. Other austerity policies—such as cutting transfer payments or increasing taxes—do not explain the cross-sectional variation in output. There is little evidence that austerity in government purchases is a consequence of the run-up of government debt during the Great Recession. Austerity policies were pursued by almost all of Europe regardless of their debt to GDP ratios in 2009. The stark negative relationship between austerity in government purchases and GDP is robust to the method used to forecast both GDP and government purchases in the 2010-2014 period, and holds for countries with fixed, as well as flexible exchange rates. In our data sample, the cross-sectional multiplier is approximately 1.75. Statistically, austerity in government purchases is negatively associated with consumption, investment, GDP growth, and inflation. Austerity is associated with an increase in net exports, and this effect is larger for countries within the euro area and those with exchange rates fixed to the euro. Our cross-sectional multiplier of 1.75 is slightly higher than the "open-economy relative multiplier" found for the U.S. states by Nakamura and Steinsson (2014).[2] It is in line with recent estimates that suggest that government spending multipliers

[1] The data is normalized so that per-capita GDP is 100 in 2009:2 for every country.

[2] Ex ante it is not clear whether we should expect a higher or lower cross-sectional multiplier across euro area countries relative to U.S. states. While, as argued in Farhi and Werning (2015), multipliers are smaller in models where government spending is self-financed (as it is in Europe), other factors can predict larger multipliers in the euro area, such as less integrated goods and factor markets.

are substantially higher during recessions (see e.g. Auerbach and Gorodnichenko, 2012) and during periods in which nominal interest rates are at the ZLB (e.g. Miyamoto, Nguyen and Sergeyev, 2018).

We develop a multi-country DSGE model that generates cross-sectional patterns in macroeconomic variables that are consistent with that observed in the data. The model features trade in intermediate goods, sticky prices, hand-to-mouth consumers, and financial frictions. The model is calibrated to reflect relative country size, observed trade flows and financial linkages, as well as the country's exchange rate regime. The model incorporates shocks to government purchases and monetary policy. Consistent with our empirical findings, the model generates a positive relationship between austerity and net exports, and a strong negative relationship between austerity and inflation. In the model, a cut in government spending reduces aggregate demand; because prices do not adjust in the short run, there is downward pressure on wages and employment. Facing a reduction in income, hand-to-mouth consumers further reduce spending, amplifying the fall in aggregate demand. The reduction in aggregate demand also reduces the net worth of firms, raising leverage ratios and increasing the cost of capital. At the same time, a low trade elasticity limits the extent to which any excess supply of the home good can be exported. These effects combine to produce a fall in wages, deflation, a fall in consumption and output. The zero lower bound (ZLB) plays an important role in generating a large time-series multiplier but has little influence on the magnitude of the cross-sectional multiplier in a currency union.

Overall, our model corroborates our empirical finding that austerity played a major role in explaining the cross-sectional patterns of macroeconomic variables observed in Europe during the 2010-2014 period. In addition, we use our model to conduct a number of counterfactual experiments. We first use the model to generate macroeconomic outcomes in the absence of austerity. For the EU10, the model generates a seven percent drop in production relative to the non-austerity counterfactual.[3] Austerity resulted in even greater losses in the GIIPS economies (Greece, Ireland, Italy, Portugal and Spain). The model suggests that austerity fully accounts for the large drop in output for these countries.

Allowing European nations to pursue independent monetary policy in the face of austerity helps limit the drop in GDP. Relative to the benchmark model, the flexibility of independent monetary policy raises output for the GIIPS economies but reduces output for the EU10. This

[3]The EU10 consists of Belgium, Germany, Estonia, France, Luxembourg, Netherlands, Austria, Slovenia, Slovak Republic, and Finland.

is because the nominal exchange rate depreciates in the GIIPS region, stimulating exports and output. In contrast, under the euro, the EU10 already enjoys the export advantage of a relatively weak currency.

Finally, the model allows us to consider the dynamics of the debt-to-GDP ratio under different conditions. The main rationale for austerity was to reduce debt and bring debt-to-GDP ratios back to historical norms. However, our model suggests that reductions in government spending had such a severe contractionary effect on economic activity that debt-to-GDP ratios in many countries actually increased as a result. In addition, the model reveals that the austerity measures undertaken by countries' trading partners also contributed importantly to rising domestic debt-to-GDP ratios.

2 Related Literature

Our research relates to a large and growing body of work on the economic consequences of fiscal austerity and tax and spending multipliers in open economy settings.

Perhaps the most closely related paper is Blanchard and Leigh (2013). They regress errors from institutional sector forecasts of real GDP growth on forecasts of fiscal consolidation for the 2010 – 2011 period to argue that most analysts underestimated the size of the fiscal multiplier. They find that a $1 rise in fiscal consolidation was associated with a $1 real GDP loss relative to forecast and conclude that actual fiscal "multipliers were substantially above 1", with the exact size depending on the assumed multipliers in the GDP forecasts.[4,5]

Our approach differs in that we use a DSGE model to consider what would happen if the measured forecast errors were structural shocks. As Blanchard and Leigh point out, such forecast errors "are unlikely to be orthogonal to economic developments" and thus may not provide direct evidence on the magnitude of government spending multipliers. While Blanchard and Leigh are correct, examining the time series and covariance patterns in forecast errors does provide meaningful information regarding the type of underlying shocks experi-

[4]The forecasts of GDP used by Blanchard and Leigh already incorporate the expected effects of planned fiscal consolidation. Blanchard and Leigh believe that "a reasonable case can be made that [assumed] multipliers [were] about 0.5." In other words, had forecasters assumed a multiplier of zero, Blanchard and Leigh would have found a $1.5 GDP loss for every $1 of fiscal consolidation, close to our benchmark finding of a $1.77 loss.

[5]Blanchard and Leigh's baseline result measures fiscal consolidation in terms of the structural primary balance, whereas we focus on government purchases. As we do, they find stronger effects for spending cuts rather than revenue increases. Unfortunately, they do not report estimates for subcomponents of government outlays, such as government purchases.

enced by European economies. Three points are worth emphasizing in this regard. First, unlike Blanchard and Leigh, we examine many indicators of economic performance, not just GDP. Austerity shocks (like a reduction in government spending) should presumably be associated with negative forecast errors in inflation and positive forecast errors in net exports. If we did not find such associated forecast errors then this would be evidence against the view that government spending shocks played an important role in the European economic experience of 2010-2014.

Second, we control for many other potential sources of economic disturbances. We directly include measured tax changes, debt levels, interest rate spreads, and productivity in our cross-sectional regressions. To the extent that these alternative disturbances were actually to blame for limiting the European recovery, we should expect that the additional explanatory power of government spending shocks would disappear once we include the other forcing variables. As we shall see, this is not the case.

Finally, our objective is not to argue that the headline relationship between forecast errors in government spending and forecast errors in GDP provides an econometric estimate of a multiplier. Rather, we use a multi-country DSGE model to show that the measured shortfalls in government spending in 2010-2014 are sufficiently large to generate the changes in output, inflation and net exports that we observe in the data.

Alesina, Favero and Giavazzi (2015) and Alesina et al. (2016) examine the economic consequences of planned, multi-year, fiscal adjustments in OECD economies. Their identification strategy borrows from Romer and Romer (2010) by isolating fiscal consolidations motivated by long run budget concerns and excluding cyclical fiscal adjustments. According to their analysis, spending-based fiscal consolidations entail relatively small economic costs while tax-based consolidations are substantially more costly. Our analysis differs from theirs in several ways. While Alesina, Favero and Giavazzi (2015) base their conclusions on data since 1978, our paper focuses exclusively on the post-crisis period of 2010-2014. This is important because the 2010-2014 period was characterized by large contractions in government spending, unusually high debt, a preexisting currency union with coordinated monetary policy, interest rates that were essentially at the ZLB, and financial market failures. Another difference is that we focus on *actual* changes in spending and taxes rather than preannounced plans for fiscal consolidation. By measuring the cumulated effect of austerity over five years, we capture the full effect of any policy that was actually implemented, including anticipated or lagged effects of the policy. Finally, our conclusions are based on the wide variation in austerity observed *across countries* during this time period, rather than time-series variation. Cross-sectional multipliers are policy-relevant in their own right (e.g. they inform to what extent asymmetric fiscal policy goes counter the European Union's goal of economic convergence) and they also speak to the magnitude of time-series mutlipliers. Chodorow-Reich (2017) argues that a cross-sectional multiplier of 1.7 implies a closed-economy, deficit-financed zero-lower-bound multiplier of about 1.5 or above.

The setup of our model is similar to Blanchard, Erceg and Lindé (2016) who use a two-country DSGE model (based on Erceg and Lindé, 2013) to study how changes in spending by the core economies in Europe affect countries on the periphery. They find sizeable spillover effects when trade flows are large and countries are at the ZLB. We use a multi-country model that is calibrated to match relative country size, trade linkages, heterogeneous fiscal policy and actual differences in monetary policy regimes. The multi-country setting more precisely captures cross-country spillovers and produces more realistic counterfactuals. Because trade is widely dispersed throughout Europe, cross-country spillover effects are more muted in our multi-country framework relative to standard two-country models. Nevertheless, given the large austerity shocks observed in the data, our multi-country model produces important spillover effects for countries with large trade shares and for small open countries, particularly for countries in the currency union.

Martin and Philippon (2016) examine business cycle dynamics in seven euro area countries around the time of the financial crisis. In their model, fiscal consolidations are a consequence of the buildup in public debt prior to the crisis and the associated increase in credit spreads. Our results are similar to the extent that contractions in government spending are associated with large reductions in economic activity in the aftermath of the Great Recession. However, we find only a weak connection between pre-existing government debt and austerity in 2010-2014 in the full sample of European economies. Furthermore, we find clear evidence of negative effects of austerity, controlling for the level of debt and credit spreads. The data indicate that austerity was pursued across Europe, even in countries with relatively low levels of public debt. It is not debt that drives austerity in the aftermath of the Great Recession, but rather austerity that depresses GDP and generates rising debt/GDP levels.

3 The Empirical Relationship between Austerity and Economic Performance

Table 1 lists the countries in our data set together with each country's relative size, the share of imports in final demand and the country's exchange rate regime as of 2010.[6] Country size varies from less than one percent of the European aggregate (e.g. Cyprus and Luxembourg) to almost 100 percent (the U.S.).[7] 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 our sample of European countries is 32 percent. The model in Section 4 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.

3.1 Measuring Austerity

We measure austerity as a shortfall in government purchases relative to forecast. Our empirical approach borrows heavily from Blanchard and Leigh (2013), as discussed in the previous section. In contrast to Blanchard and Leigh (2013), rather than relying on forecasts generated by the IMF or national governments, we produce our own forecast measures. This has several advantages: First, institutional forecasts are typically not available for a horizon of five years. Second, we will understand the key driving factors in producing the forecasts themselves.[8] Third, we see how the results change as we change the forecast specification.[9] And fourth, we

[6]Our primary data sources are Eurostat and the OECD. The dataset includes all countries in the European Union with the exception of Croatia and Malta (excluded due to data limitations) and with the addition of Norway and Switzerland (outside of the European Union but members of the European Free Trade Association, EFTA). Our sample covers the period 1960 to 2014; it is an unbalanced panel due to limitations in data availability for some countries. Please see the Data Appendix for sources of all time series used.

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

[8]Among other things, this also avoids having to guess the multiplier assumed by forecasters to back out a fiscal multiplier (as Blanchard and Leigh do) because we know the multiplier implied by our forecasts. It is zero.

[9]During our analysis we considered a variety of forecast specifications. Our results were essentially invariant to the specification choice. In the paper we present results only for a single forecast specification that in our view is representative of the set of forecast specifications considered. Interested readers can contact the authors for details on the other specifications.

can consider additional variables for which institutional forecasts are not available, in terms of both fiscal and macroeconomic variables.

To illustrate our approach, the left column of Figure 2 shows real government purchases since 1996 for four countries: Germany, France, Greece and the U.S.[10] The years 2010-2014—our period of interest—is shaded. It is clear from the plots that government purchases declined significantly in Greece and the U.S. The decline was more modest in France and there is no discernable decline in Germany. This characterization of the data does not depend on a particular forecast method—a simple linear trend would yield essentially the same conclusion regarding the extent of austerity in government purchases.

We adopt the following forecast specification:

$$\ln G_{i,t} = \ln G_{i,t-1} + \hat{g}_{EU} + \hat{\gamma}\left(\ln \widehat{Y}_{EU,t-1} - \ln Y_{i,t-1}\right) + \varepsilon^{G}_{i,t}. \tag{3.1}$$

Here $\ln G_{i,t}$ is the log of real government purchases per capita in country i (deflated by the GDP deflator) at time t, $\ln Y_{i,t}$ is the log of real GDP per capita for country i at time t, and $g_{i,t}$ is the corresponding growth rate, calculated as the difference in log GDP. The "hat" indicates a predicted value of the variable. This forecast specification accounts for both average growth in GDP (the parameter g_{EU}) and convergence dynamics (through the parameter γ). This forecast method assumes that all countries are converging to a common growth rate g_{EU} and that growth rates in Central and Eastern European countries are expected to decline as their per-capita GDP approaches Western European levels. For countries other than Central and Eastern Europe, the inclusion of the convergence effect has a very small impact on the forecast.[11]

The forecasting equation (3.1) requires estimates of the average growth rate of GDP in Europe, g_{EU}, the convergence parameter γ and predicted values for average log real per capita output in Europe $\hat{Y}_{EU,t}$. These estimates are based on data up to 2005 – *prior* to the crisis.[12] To estimate g_{EU} and the predicted values $\ln \hat{Y}_{EU,t-1}$ we use annual data for twelve advanced

[10] Figures for the other 26 countries in our sample are in the Appendix (see Figures A3a to A3e).

[11] Specifically, removing the convergence term would yield larger shortfalls of government purchases, tax revenues etc. in initially poorer countries. Although we believe that the convergence term captures medium-run dynamics in Europe quite well and should be included in our medium-run forecast, our main conclusions on the relationship between austerity and economic performance hold without this term.

[12] We choose to exclude the boom just before the Great Recession and use data just up to 2005 in forming the forecast. The exact end date for the forecast has only a minimal impact on measured austerity.

euro area economies[13] over 1993-2005 using the specification

$$\ln Y_{EU,t} = \beta_{EU} + g_{EU} \cdot t + \varepsilon_{EU,t}. \tag{3.2}$$

The estimated value for g_{EU} is 0.018 (i.e., 1.8 percent annual growth) with a standard error of 0.0016. $\ln \widehat{Y}_{EU,t}$ are the fitted values from (3.2).

To estimate the convergence parameter γ we run the regression

$$g_{i,t} - \hat{g}_{EU} = \gamma \left(\ln \hat{Y}_{EU,t-1} - \ln Y_{i,t-1} \right) + \varepsilon^{\gamma}_{i,t}. \tag{3.3}$$

using a sample that includes all countries in Central and Eastern Europe[14] for the same time period. Our estimated value for γ is 0.024 with a standard error of 0.002.[15]

The forecast errors for 2010 through 2014 are the difference between predicted values based on (3.1 and the actual values. The predicted values are based on the forecasting parameters as well as information on government purchases up to 2009. For the year 2010, we therefore use the actual realizations of $\ln G_{i,2009}$ and $\ln Y_{i,2009}$ in (3.1). Starting from $t = 2011$, we replace $\ln G_{i,t-1}$ and $\ln Y_{i,t-1}$ with their predicted values (we describe the forecasts for $Y_{i,t-1}$ below). Thus, for 2010-2014, our forecasts use actual data on government purchases and GDP up to 2009. The predicted paths for government purchases and GDP are dotted lines in Figure 2. The cumulated forecast errors are consistent with the view that the fiscal stance was austere in Greece and the U.S., somewhat austere in France, and neutral in Germany.

We also construct forecasts for other fiscal policy measures. For social benefits and total revenue, we use a modified version of equation (3.1) that includes contemporaneous GDP. We do this because there is a mechanical link between income and tax revenues, and between income and social benefits. These feedback parameters are estimated using data up to 2005.[16] For statutory tax rates (the VAT, the top income tax rate, the top corporate tax rate) and

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

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

[15] This implies that a country with a GDP per capita of 10 log points below the core euro area value is predicted to have an annual growth rate of real GDP per capita of 0.24 percentage points above the growth rate for the core euro area countries.

[16] See Appendix Section A for more details on the estimation method. In previous versions of the paper, we included a similar adjustment for the forecasting equation for $\ln G_{i,t}$. We exclude contemporaneous GDP in the forecasting equation for $\ln G_{i,t}$ because we do not include a feedback mechanism for government spending in the DSGE model in Section 3. Whether we include GDP in the forecasts makes only modest changes to our estimates. Details are available from the authors on request.

for the ratio of primary balances to GDP, we adopt a random-walk specification. To reduce the sensitivity to the last observation, for each country we take an average of the variable to be forecasted for the two years 2008 and 2009 as the "last observation." That is, for dates t after 2009 our forecast for these variables is

$$\hat{x}_{i,t} = \frac{1}{2}\sum_{s=2008}^{2009} x_{i,s} \tag{3.4}$$

where $x_{i,t}$ is either a statutory tax rate or the ratio of primary balances relative to GDP.

3.2 Measures of Economic Performance

We construct measures of economic performance in a similar manner to the forecasting procedure for government purchases. The right column of Figure 2 shows the time paths of GDP for Germany, France, Greece and the United States. GDP declines sharply in 2007-2009 in all four countries (and indeed in almost all countries in our sample—see the Appendix). Our focus is on the role of austerity in the aftermath of the Great Recession. As is clear from the figure, Germany and the U.S. experienced a drop in GDP in the recession and then reverted back to their pre-recession trend (albeit at a lower level). On the other hand, GDP growth in France and Greece remained well below trend.

We adopt the following forecast specification for real GDP based on (3.3), which again allows for a convergence factor to capture the medium-run growth dynamics of the Central and Eastern European economies.

$$\ln Y_{i,t} = \ln Y_{i,t-1} + \hat{g}_{EU} + \hat{\gamma}\left(\ln \widehat{Y}_{EU,t-1} - \ln Y_{i,t-1}\right) + \varepsilon^{Y}_{i,t}. \tag{3.5}$$

As with the forecasts for government purchases, this specification accounts for both average GDP growth (the parameter g_{EU}) and convergence dynamics (the parameter γ). The parameters g_{EU} and γ are estimated over the time period 1993-2005 just as they were in Section 3.1 and $\ln \widehat{Y}_{EU,t-1}$ is the fitted value from (3.2).[17] As before, up to $t = 2010{:}1$, we use actual GDP data for $\ln Y_{i,t-1}$ in (3.5), and replace it by its forecast $\ln \widehat{Y}_{i,t-1}$ thereafter. We use the same procedure to forecast real consumption and investment. To construct forecasts

[17]There is a slight difference in the construction of g_{EU} 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_{EU} and γ when we forecast consumption and investment because their shares of GDP are likely affected by growth dynamics.

for GDP growth, we use the estimated growth rate $\hat{g}_{i,t} \equiv \hat{g}_{EU} + \hat{\gamma}\left(\ln \widehat{Y}_{EU,t-1} - \ln Y_{i,t-1}\right)$.

For the remaining performance indicators (inflation, net exports and the nominal effective exchange rate), we impose a random-walk specification as in (3.4).[18] Plots for all series, actual and forecasts, are provided in Figures A3a to A9e in the Appendix.

3.3 Austerity and Economic Performance in the Cross Section

Figure 3 is a scatter plot of austerity and the decline in GDP in our cross section of countries. Austerity (along the x-axis) is the shortfall in government purchases relative to forecast, averaged over 2010-2014. The y-axis is the shortfall in GDP relative to forecast, again averaged over 2010-2014. Austerity is expressed as a share of GDP so that the slope of the line can be interpreted as a multiplier. Dark circles indicate countries within the euro area or with a fixed exchange rate to the euro, while the open circles are countries with floating exchange rates. There is a strong negative relationship between the two variables: the more severe the austerity, the steeper the decline in output. A regression line fitted through the points in Figure 3 delivers a slope coefficient of -2.22 with a standard error of 0.25. This suggests that a shortfall in government purchases of one percent of GDP is associated with a decline in real GDP of 2.22 percent relative to forecast. The relationship between austerity and output is invariant to the exchange rate regime. Greece stands out as having both the sharpest decline in government purchases and the steepest fall in GDP. However, the relationship between austerity and economic activity is not driven by Greece. The estimated coefficient is -1.96 (standard error 0.33) when we exclude Greece and -2.05 (standard error 0.36) when we exclude all GIIPS economies.

The data indicate that it is austerity in the form of reductions in government purchases, and not increases in taxes or cuts to social benefits, that explain the decline in output. More formally, we repeat the analysis of Figure 3 and regress a number of alternative policy variables (each as a deviation from forecast and, if necessary, scaled by GDP) on the 2010-2014 decline in GDP:

$$\tilde{Y}_{i,2010-2014} = \alpha_0 + \alpha \tilde{G}_{i,2010-2014} + \varepsilon_i. \tag{3.6}$$

[18] We use "core inflation" (all items, less energy and food) as reported by Eurostat. The exchange rate is the nominal effective exchange rate (the trade-weighted sum of bilateral nominal exchange rates). The net export measure is real exports in date t, less real imports in date t divided by 2005:1 nominal GDP. We multiply real exports and real imports by their respective deflators for 2005:1, so that for 2005:1 our measure of net exports equals nominal net exports over nominal GDP.

Here $\tilde{Y}_{i,2010-2014}$ denotes the average forecast error for GDP, $\frac{1}{20}\sum_{t=2010:1}^{2014:4}\left(\ln Y_{i,t} - \ln \hat{Y}_{i,t}\right)$. Similarly, $\tilde{G}_{i,2010-2014}$ is the average forecast error for government purchases (or any of the other policy variables) expressed as a percent of GDP. By expressing policy variables as a share of output, the coefficient α can be interpreted as a multiplier.[19] Note that the estimated multiplier is based on cross-sectional variation in the data rather than time-series variation.

The first column in Table 2a reflects the slope coefficient in Figure 3 of -2.22. Reductions in social benefits and increases in the VAT have a comparable coefficient to government purchases, but the coefficients are estimated with large standard errors and explain little of the cross-country variation in GDP. We conclude that austerity, in the form of a shortfall in government purchases is the most significant fiscal policy for explaining output in the 2010-2014 period.[20] Based on these results, in what follows we use "austerity" to refer exclusively to reductions in government purchases.

Table 2b provides evidence on the significance of austerity after controlling for other variables in regression (3.6) that could explain cross-sectional variation in GDP. The table reports estimates of the effect of austerity on real GDP for eleven different econometric specifications when controlling for changes in total revenue, total factor productivity (TFP), and four measures of credit market conditions: the household debt-to-GDP ratio, the government debt-to-GDP ratio, the private credit spread and the government bond spread. Controlling for total revenue decreases the coefficient on austerity slightly. Stronger growth in TFP over 2010-2014 is associated with stronger economic performance. Including credit measures (columns (4) through (6)) have virtually no impact on the multiplier. The coefficient on the government debt ratio is close to zero. Columns (8) through (11) include total revenue and TFP together with each of the credit measures. Depending on the controls, the estimated multiplier is between -2.22 (specification 1) and -1.64 (specification 8). The coefficients change only slightly when the GIIPS countries are dropped from the sample (see Appendix Table A3b). We take specification (11) and the multiplier of -1.77 as our benchmark for assessing the performance of the model in Section 4. This specification has the virtue of producing an estimate roughly in the middle of the range of estimates and includes controls for productivity, taxes and credit

[19] 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. We also express transfers and total revenues in percent of GDP. The primary balance is expressed in percent of GDP and tax rates are expressed in percentage points.

[20] In the Appendix, we show that this conclusion is robust to different forecast specifications, allowing, for instance, for a linear time-trend specification or an AR(1) structure of economic and fiscal variables (see Table A2).

market stress.

One concern could be that austerity policies are motivated by the need to reduce debt, and therefore it is debt, not austerity, that depresses output. To evaluate this hypothesis, we regress the debt-to-GDP ratio in 2009 on our 2010-2014 average forecast errors for a number of fiscal policy measures, such as government purchases and tax rates. The coefficients reported in Table 3 are small and generally insignificantly different from zero, suggesting that in the cross-section, austerity policies are not correlated with the 2009 debt-to-GDP ratio. Put another way, austerity policies were pursued by most countries in Europe, including those that had not accumulated high levels of public debt.

We next extend our analysis to include additional macroeconomic variables. While these empirical results are interesting by and of themselves, they also provide additional information that we later use to ask whether the government spending shocks have effects on these variables that are broadly in line with standard macroeconomic theory. Table 4 reports the impact of austerity on these other macroeconomic variables.[21] In each regression, we include all of the control variables from specification (11) of Table 2b, though the table reports only the coefficients on government purchases shortfalls. The table also shows the results for subsamples of fixed and floating exchange rates. In particular, we interact the average forecast deviation of government purchases with a dummy for fixed exchange rate countries and report estimates of the corresponding coefficients α^{fix} and α^{fl}.[22]

The results in the table indicate that austerity is associated with declines in consumption, investment and GDP growth. These estimates are roughly the same across countries with fixed and floating exchange rates. This is somewhat surprising because models—including our own—typically predict that fiscal policy is more effective in currency unions (see e.g. Farhi and Werning, 2015). We will return to this point below. The decrease in investment is noteworthy because many textbook models would predict a crowding-out effect where decreases in government purchases would lead to an increase in investment. Austerity is also associated with lower inflation. Interestingly, this effect is independent of the exchange rate regime although the effect is stronger for fixed exchange rate countries. One possible interpretation of this finding is as evidence for a cross-sectional Phillips-Curve relationship similar to the findings in Beraja, Hurst and Ospina (2016), and Nakamura and Steinsson (2014). There

[21] For consumption and investment, we express the average forecast error in terms of GDP by pre-multiplying it by the average share of consumption and investment in GDP over the 2000-2010 period.

[22] The regression also allows for separate intercepts for each exchange rate regime, though the coefficients on the control variables are restricted to be the same for all countries.

is also a strong positive association between net exports and austerity, which, for floating exchange rate countries, is associated with a depreciation of the nominal effective exchange rate. We will return to the last six columns of Table 4 in Section 5 .

4 Model

Next we develop a multi-country business cycle model that can explain the associations between austerity and various macroeconomic variables found in Section 3 for fixed and floating exchange rate countries. In particular, the model will be able to generate a large cross-sectional multiplier for government purchases, match the simultaneous decline in consumption and investment together with an increase in net exports, and generate deflation in austere countries. We interpret these findings as additional evidence that government spending shocks played an important role in Europe during the 2010 - 2014 period. We will also use the model to perform counterfactual policy analysis.

The model is calibrated to match the economic size and bilateral trade flows of the 30 countries in our sample and incorporates many features from modern monetary business cycle models (e.g. Smets and Wouters, 2007; Christiano, Eichenbaum and Evans, 2005), international business cycles models (e.g. Backus, Kehoe and Kydland, 1992, 1994; Chari, Kehoe and McGrattan, 2000; Heathcote and Perri, 2002), and financial accelerator models (e.g. Bernanke, Gertler and Gilchrist, 1999; Brave et al., 2012; Christiano, Motto and Rostagno, 2014). The main ingredients of the model are (i) price rigidity, (ii) international trade, (iii) hand-to-mouth consumers, (iv) a net worth channel for business investment, and (v) government purchases and monetary policy shocks.

4.1 Households

The world economy is populated by $n = 1...N$ countries. Every country has a representative household, firms that produce the country-specific intermediate good, and firms that produce the final good. As in Heathcote and Perri (2002), intermediate goods are tradable across countries, but final goods are nontradable. In each country, the representative household owns all of the domestic firms.

All variables in the model are expressed in per-capita terms. To convert any variable to a national total, we scale by the population of country n, $\mathbb{N}_n$. In each period t the economy experiences one event s_t from a potentially infinite set of states. We denote by s^t the history of events up to and including date t. The probability at date 0 of any particular history s^t is given by $\pi\left(s^t\right)$.

We adopt the specification of Greenwood, Hercowitz and Huffman (1988) (GHH hereafter) in assuming that consumption and labor are complements for the household. As shown by Nakamura and Steinsson (2014) among others, GHH preferences play an important role for the transmission of austerity shocks by eliminating the reaction of labor supply to changes in household income and creating complementarities between consumption and labor.[23] At date 0, the expected discounted sum of future period utilities for a household in country n is given by

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

where $c_n\left(s^t\right)$ denotes state-contingent consumption allocations and $L_n\left(s^t\right)$ denotes state-contingent labor allocations. We set the flow utility function $U\left(\cdot\right)$ to

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

where $\beta < 1$ is the subjective time discount factor, 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.

A key feature of the model is a hand-to-mouth restriction on a fraction χ of a household's members in the economy.[24] These household members receive income in proportion to their consumption share of total income and spend the entire amount on current consumption. That is, hand-to-mouth consumption each period is given by $c_n^{htm}\left(s^t\right) \equiv \frac{\bar{C}_n}{\bar{Y}_n} Y_n\left(s^t\right)$ where the bars indicate steady-state values.[25] The remaining $1-\chi$ members of the representative household choose consumption optimally and thus behave in accordance with the permanent income

[23] Nakamura and Steinsson (2014) cite several papers that present empirical evidence for such complementarities, as e.g. Aguiar and Hurst (2005).

[24] Notice that we maintain the terminology "representative" household, and distinguish between hand-to-mouth consumers and unconstrained consumers who are both members of the representative household.

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

hypothesis.[26] *Aggregate* consumption is then given by

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

This specification allows us to introduce hand-to-mouth behavior while leaving the other first-order conditions unchanged.

Households in each country own the capital stock in their country. They supply labor to the intermediate goods producing firms and capital to the entrepreneurs. Households choose consumption $c_n\left(s^t\right)$, labor $L_n\left(s^t\right)$, next period's capital stock $K_n\left(s^t\right)$ and current investment $X_n\left(s^t\right)$ to maximize the expected discounted sum of future period utilities subject to a sequence of budget constraints.

The nominal budget constraint for the representative household in country n is

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

The left side of the budget constraint reflects household expenditures on the final consumption good, inclusive of a constant value-added consumption tax τ_n^c, and on investment. The household also participates in international financial markets and has access to 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 $\varrho\left(s^t, s_{t+1}\right)$ 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 that can be traded. Let $S_n^j\left(s^t\right)$ 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 $1 + i_n\left(s^t\right)$.[27] The nominal exchange rate

[26] Alternative specifications of hand-to-mouth consumers assume that a fraction of households is credit-constraint because they are impatient (see e.g. Martin and Philippon, 2016). In that framework, impatient households only receive labor income (net of taxes) and the tax incidence is crucial. In our formulation, hand-to-mouth consumers receive the same income as unconstrained consumers in steady state, which is in line with evidence on "wealthy" hand-to-mouth consumers (see Kaplan, Violante and Weidner, 2014).

[27] From a risk-sharing point of view, the noncontingent nominal bonds are a redundant security. However,

to convert country n's currency into the reserve currency is $E_n(s^t)$.

The right side of the budget constraint reflects the household's income. The household earns nominal wages net of labor taxes $(1-\tau_n^L)W_n(s^t)L_n(s^t)$ and nominal payments for sales of capital $\mu_n(s^t)K_n(s^{t-1})$. Here $W_n(s^t)$ is the state-contingent nominal wage, τ_n^L is a constant labor tax rate, and $\mu_n(s^t)$ is the state-contingent nominal price of capital.[28] The household also receives lump-sum transfers $\mathbb{T}_n(s^t)$. This transfer includes nominal profits from intermediate goods firms and entrepreneurs, $\Pi_n^f(s^t)+\Pi_n^e(s^t)$, nominal lump-sum taxes or transfers $T_n(s^t)$, profits or losses from the financial sector $\Pi_n^{fin}(s^t)$, and the nominal amount consumed by hand-to-mouth consumers, $P_n(s^t)c_n^{htm}(s^t)$ where $P_n(s^t)$ is the date t nominal price of the final good.[29] Thus,

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

The household also faces the capital accumulation constraint:

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

with $f(1)=f'(1)=0$ and $f''(1)\geq 0$. As in Christiano, Eichenbaum and Evans (2005), the function $f(\cdot)$ features higher-order adjustment costs on investment if $f''(1)>0$.

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

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

and

$$\frac{U_1\left(c_n\left(s^t\right),L_n\left(s^t\right)\right)}{E_n\left(s^t\right)P_n\left(s^t\right)}=\frac{U_1\left(c_m\left(s^t\right),L_m\left(s^t\right)\right)}{E_m\left(s^t\right)P_m\left(s^t\right)}$$

where $U_j(\cdot)$ denotes the derivative of the function $U(\cdot)$ with respect to its j^{th} argument.

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the nominal interest rate will be an important policy instrument for the monetary authority and will affect financing costs for the entrepreneurs.

[28] We assume that households sell capital to entrepreneurs and then subsequently repurchase the undepreciated capital. This assumption is convenient when we introduce financial market imperfections later.

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

The labor supply condition is

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

Finally, the optimal choice for investment and capital requires

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

4.2 Firms

There are three types of firms in the model. The first type are firms that combine tradable intermediate inputs to produce a final nontraded good for private consumption and investment and for government purchases. We refer to these firms as “final goods producers.” The two remaining types of firms produce tradable intermediate goods. Production of the tradable intermediate goods occurs in two stages. In the first stage, monopolistically competitive domestic firms use capital and labor to produce input varieties. Prices of the input varieties are set according to a Calvo pricing mechanism. We refer to the firms that produce input varieties as “first-stage intermediate producers.” In the second stage, competitive firms combine the input varieties into the tradable intermediate good (domestic producers of the tradable intermediate in country n use only varieties from country n as inputs). We refer to the firms that assemble the tradable intermediate good as “second-stage intermediate producers.” Neither capital nor labor can be moved across countries. Below, we describe the production chain of these three types of firms in detail. We begin by describing the production of the tradable intermediate goods.

4.2.1 Tradable Intermediate Goods

Each country produces a single (country-specific) type of tradable intermediate good in two stages.

Second-Stage Intermediate Producers The second-stage producers assemble the tradable intermediate good from domestically-produced input varieties. The second-stage producers solve

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

subject to the CES production function

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

Here $Q_n\left(s^t\right)$ is the real quantity of country n's tradable intermediate good produced at time t. The variable ξ indexes the continuum of differentiated varieties (thus ξ is one of the varieties) and the parameter $\psi_q > 1$ governs the degree of substitutability across varieties. The date t nominal price of each variety is $\varphi_n\left(\xi, s^t\right)$ and the quantity of each variety is $q_n\left(\xi, s^t\right)$. Demand for each variety has an iso-elastic form

$$q_n\left(\xi, s^t\right) = Q_n\left(s^t\right) \left(\frac{\varphi_n\left(\xi, s^t\right)}{p_n\left(s^t\right)}\right)^{-\psi_q}. \tag{4.1}$$

The competitive price of the intermediate $p_n\left(s^t\right)$ is a combination of the prices of the varieties,

$$p_n\left(s^t\right) = \left[\int_0^1 \varphi_n\left(\xi, s^t\right)^{1-\psi_q} d\xi\right]^{\frac{1}{1-\psi_q}}. \tag{4.2}$$

First-Stage Intermediate Producers The varieties $q_n\left(\xi, s^t\right)$ used to assemble the tradable intermediate good $Q_n\left(s^t\right)$ are produced in the first stage. First-stage intermediate producers hire workers at the nominal wage $W_n\left(s^t\right)$ and rent capital at the nominal rental price $R_n\left(s^t\right)$. First-stage firms are monopolistically competitive and take the demand curve for their product (4.1) as given. These firms have Cobb-Douglas production functions

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

Because first-stage producers are monopolistically competitive, they typically charge a markup for their products. The desired price naturally depends on the demand curve (4.1). Each variety good producer ξ freely chooses capital and labor each period. Cost minimization implies that the nominal marginal cost is

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

Pricing The nominal prices of input varieties are adjusted only infrequently according to the standard Calvo mechanism. For any firm, there is a probability θ that the firm cannot change its price that period. When a firm can reset its price it chooses an optimal reset price. Formally, the maximization problem of a firm that can reset its price at date t is

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

We denote the optimal reset price as $\varphi_n^*\left(s^t\right)$.

Because the first-stage intermediate producers adjust their prices infrequently, the nominal price of the tradable intermediate goods is sticky. In particular, using (4.2), the nominal price of the tradable intermediate good evolves according to

$$p_n\left(s^t\right) = \left[\theta p_n\left(s^{t-1}\right)^{1-\psi_q} + (1-\theta)\,\varphi_n^*\left(s^t\right)^{1-\psi_q}\right]^{\frac{1}{1-\psi_q}}. \tag{4.3}$$

Our specification of price setting assumes that firms set prices in their own currency. As a result, when exchange rates move, the implied import price moves automatically (there is complete pass-through).

4.2.2 Final Goods Producers

Final goods are assembled from a (country-specific) CES combination of tradable intermediates produced by the various countries in the model. The final good producers are competitive in both the global input markets and the final goods market. The final goods producers solve

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

subject to the CES production function

$$Y_n\left(s^t\right) = \left(\sum_{j=1}^{N} \left(\omega_n^j\right)^{\frac{1}{\psi_y}} y_n^j\left(s^t\right)^{\frac{\psi_y - 1}{\psi_y}} \right)^{\frac{\psi_y}{\psi_y - 1}} \tag{4.4}$$

Here, $y_n^j\left(s^t\right)$ 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 the preference weights satisfy $\omega_{n,j} \geq 0$ with $\sum_{j=1}^{N} \omega_n^j = 1$ for each country n. Notice that the weights ω_n^j are country-specific so each country n requires a different mix of the various country-specific intermediate goods as inputs. We later calibrate the ω_n^j parameters to match data on bilateral import shares.

Demand for country-specific intermediate goods is isoelastic:

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

The implied nominal price of the final good is

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

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 good producers have constant returns-to-scale production functions and behave competitively, profits are zero in equilibrium.

4.3 Financial Market Imperfections and the Supply of Capital

The model incorporates a financial accelerator mechanism similar to Carlstrom and Fuerst (1997) and Bernanke, Gertler and Gilchrist (1999). Entrepreneurs buy capital goods from households using a mix of internal and external funds (borrowing). The entrepreneurs rent purchased capital to the first-stage intermediate good 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.[30]

Formally, at the end of period t, entrepreneurs purchase capital $K_n\left(s^t\right)$ from the households at the nominal price $\mu_n\left(s^t\right)$ per unit. Entrepreneurs finance these purchases with their own internal funds (net worth) and intermediated borrowing. Let end-of-period nominal net worth be $P_n(s^t)NW_n\left(s^t\right)$, denominated in country n's currency. Then, to purchase capital, the entrepreneur borrows $B_n\left(s^t\right) = \mu_n\left(s^t\right)K_n\left(s^t\right) - P_n(s^t)NW_n\left(s^t\right)$ units from the households in their country. The nominal interest rate on business loans equals the nominal

[30]See Brave et al. (2012) for the same approach.

interest rate on government bonds times an external finance premium $F(\lambda_n(s^t))$ with F' and $F'' > 0$. Here, $\lambda_n(s^t) = \frac{\mu_n(s^t)K_n(s^t)}{P_n(s^t)NW_n(s^t)}$ is the leverage ratio.[31] The interest rate is then $(1+i_n(s^t))\,F(\lambda_n(s^t))e^{\epsilon_n^F(s^t)}$, where $\epsilon_n^F(s^t)$ is a shock to the interest rate spread. The function $F(\cdot)$ implies that entrepreneurs who are more highly leveraged pay a higher interest rate.

At the beginning of period $t+1$, entrepreneurs earn a utilization-adjusted rental price of capital net of capital taxes $(1-\tau_n^K)u_n(s^{t+1})\,R_n(s^{t+1})$ and then sell the undepreciated capital back to the households at the capital price $\mu_n(s^{t+1})$. Depreciation costs are tax deductible. Varying the utilization of capital requires $K_n(s^t)\,a(u_n(s^{t+1}))$ units of the final good. Each period, a fraction $(1-\gamma_n)$ of the entrepreneurs' net worth is transferred to the households.[32]

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

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

The utilization choice requires the first-order condition

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

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

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

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

As is standard in financial accelerator models, the external finance premium $F(\lambda_n(s^t))$ drives a wedge between the nominal interest rate on bonds and the expected nominal return on capital. Notice that if $F(\lambda_n(s^t)) = 1$ then we obtain the standard efficient outcome in

[31] We assume that $F(1)=1$. Technically, we also 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.

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

which the market price of capital is the discounted stream of rental prices.

4.4 Government Policy

Government purchases are exogenous and follow an auto-regressive process

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

where $\bar{G}_n$ indicates the steady-state level of government purchases. The government raises revenue by imposing taxes on consumption and on labor and capital income. All tax rates are constant. In periods where revenue falls short of expenditures, the government imposes a lump sum tax on households.[33]

The government splits its purchases across the final good and the domestically produced intermediate good. We denote by υ_n the share of government purchases that falls on the intermediate good. If $\upsilon_n > 0$, government purchases exhibit a stronger home bias than private consumption and investment. For $\upsilon_n = 1$, government purchases fall only on domestically produced goods. Below, we calibrate υ_n to match the oberseved (country-specific) home bias of government purchases.

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 has the form

$$i_n\left(s^t\right) = \bar{\imath}_n + \phi_i i_n\left(s^{t-1}\right) + \left(1-\phi_i\right)\left(\phi_{GDP} GDP_n\left(s^t\right) + \phi_\pi \pi_n\left(s^t\right)\right) + \varepsilon_n^i\left(s^t\right), \tag{4.5}$$

where $GDP_n(s^t)$ is country n's real GDP and $\pi_n(s^t)$ is country n's inflation. 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, 2005)).

Countries in the euro area have a fixed nominal exchange rate for every country in the union and a common nominal interest rate. The monetary authority for the countries within the euro area (the ECB) has a Taylor Rule similar to (4.5) with the exception that monetary

[33] According to our specification for hand-to-mouth consumers, a fall in government spending is not directly offset by lower taxes for hand-to-mouth consumers. We believe that this is a reasonable depiction of fiscal policy during the austerity period in Europe 2010-2014. Table A1a in the Appendix shows that forecast errors of government purchases were not positively, and if anything, were negatively correlated with forecast errors of tax rates.

policy reacts to the weighted average of innovations in GDP and inflation for the countries in the union. The weights are proportional to GDP relative to the total GDP in the euro area. By definition, the countries that peg their exchange rate to the euro adjust their policy to keep the bilateral exchange rate towards the euro constant.

4.5 Aggregation and Market Clearing

For each country n, aggregate production of the tradable intermediate goods is (up to a first-order approximation[34]) given by

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

Final goods production is given by (4.4) and, since the final good is nontradable, the market clearing condition for the final good is

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

Market clearing for the intermediate goods produced by country n is

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

Finally, the bond market clearing conditions require

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

Since final goods are not traded, net exports are comprised entirely of intermediate goods. For each country n, nominal net exports are[35]

$$NX_n\left(s^t\right) = p_n\left(s^t\right)\left(Q_n\left(s^t\right) - \upsilon_n G_n(s^t)\right) - P_n\left(s^t\right)Y_n\left(s^t\right)$$

[34] 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.

[35] Net exports are equal to the nominal value of exports less the nominal value of imports, or, equivalently, the nominal value of production less the nominal value of domestic absorption. The nominal value of production is $p_n(s^t)Q_n(s^t)$. The nominal value of domestic absorption is $P_n(s^t)Y_n(s^t) + p_n(s^t)\upsilon_n G_n(s^t)$.

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

$$NGDP_n\left(s^t\right) = p_n\left(s^t\right) Q_n\left(s^t\right) = NX_n\left(s^t\right) + P_n\left(s^t\right)\left[C_n\left(s^t\right) + X_n\left(s^t\right) + G_n\left(s^t\right) + a\left(u_n\left(s^t\right)\right) K_n(s^t)\right]$$

Real GDP is $GDP_n\left(s^t\right) = p_n Q_n\left(s^t\right)$ (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).

4.6 Steady state and Calibration

We solve for the model's non-stochastic steady state with zero inflation. A summary of parameters used in the benchmark model is provided in Table 5. We use the notation $\bar{X}_n$ to denote the steady state value of the variable X for country n.

Preferences Because inflation is zero, the Euler equations associated with the noncontingent nominal bonds imply that the nominal interest rate is $1 + \bar{\imath}_n = \frac{1}{\beta}$ for all n. 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) and are fairly standard in the macroeconomic literature (e.g. Nakamura and Steinsson, 2014; Hall, 2009). We set the share of hand-to-mouth consumers to $\chi = 0.5$. This is the value proposed by the original study by Campbell and Mankiw (1989) and is consistent with the calibration in Martin and Philippon (2016).

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 2.8 percent to match the share of private investment in final demand, X_n/Y_n. The average value is 19.7 percent across all countries in our sample for the years 2000-2010.

In the steady state, the nominal price of capital and the nominal price of the final consumption good are equal. The entrepreneurs' optimal choice for capital implies that

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

where we have defined the steady state interest rate spreads $\bar{F}_n \equiv F_n\left(\bar{\lambda}_n\right)$. Below we calibrate these spreads to match their observable counterparts. Once we have calibrated $\bar{F}_n$, the equation above determines the real rental price of capital $\bar{R}_n/\bar{P}_n$ in each country. The utilization cost function $a\left(u\right)$ is chosen to ensure that $\bar{u}_n = 1$ and $a\left(\bar{u}_n\right) = 0$.

The form of the investment adjustment cost $f\left(\cdot\right)$ implies a 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 $\mathbb{Q}_n(s^t) = v_n(s^t)/U_{1,n}(s^t)$. It is straightforward to show that the change in investment growth over time obeys the equation

$$\left[\widetilde{X}_n(s^t) - \widetilde{X}_n(s^{t-1})\right] = \frac{1}{\vartheta}\widetilde{\mathbb{Q}}_n(s^t) + \beta\left[\widetilde{X}_n(s^{t+1}) - \widetilde{X}_n(s^t)\right]$$

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

For the utilization cost function $a\left(u\right) = \frac{\bar{R}}{P}\left[\exp\left\{h\left(u-1\right)\right\} - 1\right]\frac{1}{h}$, 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/P_n causes an increase in the capital utilization rate of 0.286 percent.

Trade and Country Size We choose parameters to ensure that all real exchange rates $\bar{e}_{j,n} \equiv \frac{\bar{E}_j}{\bar{E}_n}\frac{\bar{p}_j}{\bar{p}_n}$ are 1 in steady state. With $\bar{e}_{j,n} = 1$ for all j, n it is straightforward to show that the price of the final consumption good and the price of the tradable intermediate good are equal, $\bar{P}_n = \bar{p}_n$. With zero inflation, the price of intermediates is a constant markup over nominal marginal cost, $\bar{p}_n = \frac{\psi_q}{\psi_q - 1}\overline{MC}_n$. Bilateral import ratios satisfy $\frac{\bar{y}_n^j}{\bar{Y}_n} = \omega_n^j$, and are calibrated to the share of imports y_n^j in the production of the final good, Y_n. We use data from the OECD on trade in value added (TiVA). The definition of imports and exports in TiVA correspond to those used in national account data and therefore capture trade in both goods and services. TiVA 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 for all country pairs. TiVA is available for 1995, 2000, 2005, and 2008 through 2011. We take an average of 2005 and 2010 to calibrate ω_n^j.[36]

In addition to matching the import ratios, we also calibrate the model to match observed relative country sizes, $\frac{\mathbb{N}_j \bar{Y}_j}{\mathbb{N}_n \bar{Y}_n}$ taken from the TiVA tables. Taken together this ensures that we match the shares of net exports relative to domestic absorbtion $\overline{NX}_n / \bar{Y}_n$ where $\overline{NX}_n = \bar{Q}_n - \bar{Y}_n$.

The trade elasticity ψ_y is set to 0.5. This is comparable to parameter values used in international business cycle models with trade. In their original paper, Heathcote and Perri (2002) estimated $\psi_y = 0.90$. Using firm-level data, Cravino (2014) and Proebsting (2015) find elasticities close to 1.5.[37] We consider higher trade elasticities in the sensitivity analysis below.

Price Rigidity We calibrate the Calvo price setting hazard to roughly match observed frequencies of price adjustment in the micro data. Nakamura and Steinsson (2008) report that prices change roughly once every 8 to 11 months; Klenow and Kryvtsov (2008) report that prices change roughly once every 4 to 7 months. Evidence on price adjustment in Europe suggests somewhat slower adjustment. Alvarez et al. (2006) find that the average duration of prices is 13 months (for a quarterly model this corresponds to $\theta = 0.77$). Our baseline calibration takes $\theta = 0.80$. This is somewhat higher than the empirical findings for U.S. price adjustment. Our main reason for adopting this calibration is to match the data indicating slightly more sluggish price adjustment in European countries compared to the U.S.[38]

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

[36] The TiVA dataset is derived from input-output tables, which themselves are based on national account data. We use the data series FD_VA ('Value added content of final demand'). TiVA also has data for a 'rest of the world' aggregate. We combine the TiVA measure of the rest of the world with the sum of the countries not in our sample to construct the preference parameters $\omega_{RoW,j}$ for the rest of the world aggregate for our analysis.

[37] The literature on international trade outside of business cycle analysis typically adopts higher elasticities. For instance Broda, Greenfield and Weinstein (2006) find a long-run trade elasticity of 6.8.

[38] For purposes of comparison, Christiano, Eichenbaum and Evans (2005) use $\theta = 0.6$, Del Negro et al. (2013) have $\theta = 0.88$ and Brave et al. (2012) have $\theta = 0.97$.

The elasticity of the external finance premium with respect to leverage F_ϵ is 0.025, implying that an increase in the leverage ratio of 10 percent raises the annual spread by 1 percentage point. This value is in the middle range of values used in the literature.[39] For the leverage ratio lev_n, we adopt the calibration from Brave et al. (2012) for the U.S ($lev = 2.11$).

Fiscal and Monetary Policy For each country, we set the steady state ratio of government purchases to GDP, $\bar{G}_n$, to match the average ratio from 2000-2010 in the data provided. The share of government purchases that directly falls on the intermediate good, υ_n, is chosen to match the observed import shares of government purchases. This information is not available in the TiVA database used to calculate bilateral trade flows. Instead, we use data from the World Input Output database to calculate each country's import share of government purchases relative to its total import share. On average, government purchases exhibit a stronger home bias than private purchases. On average, the value for υ_n is 0.86.

The persistence of the government purchase shock is set to 0.93, which corresponds to a half life of 2.5 years. This is in line with fiscal consolidation plans laid out by governments around 2009, where most consolidation measures were to be implemented until 2012 (see Forthun, Park and Lucas, 2011). We choose our Taylor rule parameters to be $\phi_\pi = 1.5$, $\phi_{GDP} = 0.5$ and $\phi_i = 0.75$, which is in line with estimates by Clarida, Gali and Gertler (2000).

Tax Rates We use implicit tax rates to calibrate the values for τ_n^C, τ_n^L and τ_n^K. Calculation of tax rates for consumption, labor and capital builds on Mendoza, Razin and Tesar (1994) and Eurostat (2014). The principal idea is to classify tax revenue by economic function using data from the National Tax Lists and then approximate the base with data from the national sector accounts. Compared to statutory tax rates, the advantages of these rates are that they take into account the net effect of existing rules regarding exemptions and deductions, and also incorporate social security contributions in labor taxes. We use the average over 2005 through 2009. Table A8 in the Appendix includes a list of all countries and steady-state implicit tax rates.

[39] In Bernanke, Gertler and Gilchrist (1999), the calibration of parameters implies an elasticity of 0.05. Del Negro et al. (2013) estimate an elasticity of 0.08, whereas Brave et al. (2012) estimate an elasticity of 0.002.

4.7 Forcing Variables

Our approach is to treat the austerity forecast deviations calculated in Section 3 as structural shocks. In addition to the austerity shocks, we also include shocks to monetary policy.

Austerity Shocks Government purchase shocks are based on forecast errors from equation (3.1). To convert the annual forecast errors to a quarterly series to feed into the model we interpolate them using the Chow-Lin method (Chow and Lin, 1971).

Monetary Policy Shocks To measure monetary policy shocks we estimate a generalized Taylor rule of the form suggested by Clarida, Gali and Gertler (1997):

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

where $i_{n,t}$ is the nominal interest rate, r_n is the long-run interest rate, $\pi_{n,t}$ is inflation, π_n^* is the inflation target, $\ln GDP_{n,t} - \ln \overline{GDP}_{n,t}$ is the percent deviations of real GDP from its trend, and $\varepsilon_{n,t}^i$ is a structural shock. Inflation is measured by the core CPI. The interest rate and the inflation rate are measured in annual percent. We impose a value for $\rho^i = 0.79$ (see Clarida, Gali and Gertler, 1997) and estimate 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^i for each of the countries in Europe that have an independent monetary policy. We do not estimate separate Taylor rules for each central bank primarily because of data limitations. For the euro area, we assume that the ECB reacts to the weighted average of inflation and output over all countries in the euro. With these coefficients we then estimate country-specific intercepts (corresponding to the parameters $r_n - \phi_\pi \pi_n^*$ in the Taylor rule). We can then recover the monetary policy shocks for each country n as $\hat{\varepsilon}_{n,t}^i = i_{n,t} - \hat{\imath}_{n,t}$. These shocks are the same for all euro area countries.

5 Model and Data Comparison

In this section we simulate the calibrated model's reaction to austerity shocks. We feed the estimated structural shocks for the 2005-2014 period into the model and compare the simulated data with the actual data. Throughout, we treat the simulated data (in terms of detrending, scaling and definitions of variables, etc.) in the same way as we treat the actual data.[40]

5.1 Benchmark Model Performance

The benchmark model includes austerity shocks and monetary policy shocks for the baseline calibration given in Table 5. Table 4 shows a comparison of the cross-sectional multipliers for the period 2010-2014 generated by the model and the data. Overall, the implied regression coefficients from the model (the middle set of columns labeled "Benchmark") are consistent with the estimates from the data in terms of magnitude and sign. Empirically, the government purchases multiplier for GDP is 1.77; the corresponding multiplier in the model is 1.95. Both in the data and the model the response of GDP to austerity is somewhat weaker for floating exchange rate countries. The response of inflation to government purchases is 0.46 in the data and 0.40 in the model (that is, austerity is associated with deflation). The inflation response is somewhat greater for fixed exchange rate countries and weaker for floating exchange rate countries in both the data and the model. The model also does a reasonable job at explaining consumption and investment behavior, although the magnitudes in the model fall a bit short of the empirical estimate for investment. In both the model and the data, austerity shocks generate a positive response of net exports.[41]

Figures 4a - 4c compare scatterplots of actual data (the left panels) with scatterplots of simulated data (the right panels).[42] In each panel, the austerity shocks (i.e., forecast errors) are on the horizontal axis. The units of both axes are log points times 100, so they can be interpreted as roughly corresponding to percent changes. The panels include the regression

[40] In the empirical section, we mentioned that Eastern European countries displayed convergence dynamics in the 90s and 2000s that we took into account when constructing our forecasts for the 2010-2014 period. Our forecast errors are therefore "cleaned" from these convergence dynamics. We therefore do not include any convergence dynamics in the model and directly calculate deviations from steady state that we then compare to our empirical forecast errors. Also, our "investment" variable in the model includes utilization costs.

[41] The multipliers of the demand components of GDP—consumption, investment, government spending and net exports—do not perfectly add up to the multiplier for GDP. In the data, the added-up multiplier is 2.23 (vs. 1.98); in the model, the added-up multiplier is 1.91 (vs. 1.98). This not surprising. For the actual data, we construct separate forecasts for all demand components and we do not impose that they must be consistent with our forecast for GDP (and the discrepancy between 2.23 and 1.98 show that they are not). For the simulated data, the added-up multiplier is somewhat smaller because part of output pays for variations in utilization costs, which we do not count towards investment.

[42] Note, the plot of the actual data conditions on total revenue, TFP and government debt to GDP (i.e., specification 11 in Table 2b). That is, we plot $\left(\tilde{G}_n, \tilde{Y}_n - \hat{\Gamma} \cdot \text{controls}_n\right)$. We do not include the controls in the model regressions because the model does not include shocks to TFP, shocks to tax rates, or endogenous responses of policy to debt-to-GDP ratios.

line for the entire sample.

The scatterplots reveal several differences between the actual data and the simulated data. First, the actual data have more noise than the simulated data. This is due to the fact that the model includes only a limited number of shocks. Given this limited number of shocks, it is almost surprising that our model can generate dispersion in inflation, especially across countries that share the same currency. Part of this dispersion stems from the household's and particularly the government's home bias in their domestic final good, which breaks the law of one price; part of it can also be attributed to asymmetries in steady-state relationships across countries (e.g. tax rates and bilateral trade flows).

Second, while our model does a reasonably good job replicating the *cross-sectional* dispersion in GDP—as illustrated by the same slope of the regression line in the data and the model—it underestimates the overall drop in GDP in Europe observed in the data: In other words, while the slope of the regression line is the same in the data and the model, the intercept in Figure 4a is higher for the data generated by the model. One possible reason for this difference could be due to the monetary policy response in the model. The model assumes that monetary authorities lower nominal interest rates in response to falling GDP and prices, thereby counteracting austerity. If instead, monetary authorities were bound by a zero lower bound (ZLB) on interest rates, they could not implement this policy to offset the impact of the austerity shock. Such a ZLB constraint would amplify the effects of austerity on GDP, as discussed e.g. by Eggertsson (2011), Christiano, Eichenbaum and Rebelo (2011) and Blanchard, Erceg and Lindé (2016). We return to the issue of the ZLB later. Alternatively, the general fall in GDP across European countries could be attributed to faltering economic conditions outside of Europe or other conditions that affected all European countries across the board, but are not captured by our model.

Next, we explore how much of the cross-sectional relationship between austerity and economic performance can be attributed to the austerity shocks themselves, as opposed to the monetary policy shocks. If observed austerity shocks and monetary policy shocks were independent of each other, then removing the latter should have little effect on the estimated relationship between austerity and economic performance. The last three columns of Table 4 report the cross-sectional multipliers when we remove the monetary policy shocks. Monetary policy shocks leave the cross-sectional multiplier virtually unchanged for countries in the euro area and those with fixed exchange rates. Since these monetary policy shocks are the same across all of these countries, they cannot explain the dispersion in economic performance across the euro area. This finding is reminiscent of Nakamura and Steinsson (2014), who emphasize that cross-sectional multipliers are unaffected by the stance of monetary policy. Removing the monetary policy shocks for floating exchange rate countries, however, reduces the cross-sectional multiplier across this country group by more than a third. This indicates that countries with floating exchange rates that implemented austere policies also conducted contractionary monetary policy, further deepening the recessionary effect. Without monetary policy shocks, the cross-sectional multiplier for floating exchange rate countries falls to 1.00, half the size of the multiplier for fixed exchange rate countries. This is in line with studies emphasizing that fiscal policy is particularly effective in currency unions (see e.g. Farhi and Werning, 2015). Countries with independent monetary policy can offset austerity shocks by letting their currency depreciate, both stimulating demand for exports and raising the price of imports. This currency depreciation explains the smaller multiplier and the weaker, and actually positive response of inflation to austerity (0.06). Overall, these results show that the positive correlation of austerity and contractionary monetary policy can rationalize the empirical finding that the decline in GDP associated with austerity was similar across fixed and floating exchange rate countries.

As a final remark, it is noteworthy that our model can generate positive comovements between GDP, consumption and investment in response to austerity shocks in form of cuts to government purchases. This is surprising because generating these positive comovements has proven difficult in business cycle models that are not driven by shocks to total factor productivity (see Barro and King, 1984).

Summing up our results thus far, our benchmark model including both austerity shocks and monetary policy shocks can replicate the cross-sectional patterns of observed macroeconomic aggregates and prices. Monetary policy shocks are only important for explaining the variation among floating exchange rate countries. The model underestimates the general fall in GDP observed in Europe between 2010 and 2014.

5.2 Inspecting the Mechanism

Several features of the model work together to generate the relatively large austerity multiplier observed in the data. Here we analyze the mechanisms in the model that produce this effect. Table 6 reports results for nine different model specifications and compares the results with the data. The table reports results for all countries as well as results for fixed and floating exchange rate countries separately. The empirical estimates are reported in column (1) in the table. Column (2) reports the results for our benchmark model. Columns (3) - (10) report results for other model specifications.

A reduction in government purchases reduces demand for the domestic final good. In many models, reductions in government purchases cause output to fall by less than the reduction in spending; i.e., the spending multiplier is often less than one. Here, because prices do not adjust in the short run, there is downward pressure on wages and employment. Hand-to-mouth consumers, in particular, reduce consumption sharply with the drop in GDP. There is a small positive wealth effect from the reduction in government spending that stimulates consumption by unconstrained household members. However, on balance, aggregate consumption falls. By eliminating the wealth effect on labor supply, GHH preferences further amplify the contraction in demand. Consumption and labor both fall—as households consume less, they also work less, further stifling demand. The reduction in income also increases the external finance premium for investment spending. As the premium increases, the effective cost of capital rises and investment demand falls. In an open economy, some of the excess supply of the home good is exported - hence the increase in net exports - but this effect is limited by the fact that government spending is biased toward the domestic good and the elasticity of substitution between home and foreign goods is relatively low. In the table, we examine the effect of each of these features on the multiplier.

Column (3) shows the results when we relax the assumption of GHH preferences, and instead assume preferences that are separable in consumption and leisure.[43] Under separable preferences the multiplier falls from 1.97 to 1.62, with most of the difference due to a weaker response of consumption spending.[44] This finding echoes the analysis in Nakamura and Steinsson (2014) who, among others, emphasize the role of GHH preferences in generating large cross-sectional multipliers.[45] The impact on the multiplier is smaller in our setting

[43] We assume the utility function is

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

Notice that we maintain our assumption that hand-to-mouth consumers supply the same amount of labor as unrestricted consumers.

[44] Notice that the weaker consumption response is somewhat offset by a weaker net export response. Intuitively, keeping prices constant, a weaker consumption response directly translates into a weaker response of imports.

[45] Other studies emphasizing the consequences of GHH preferences for government spending multipliers include Monacelli and Perotti (2008) and Bilbiie (2011).

relative to Nakamura and Steinsson (2014) for two reasons. First, the labor-consumption complementarities are weakened by steady-state distortions in the form of taxes on consumption and labor. These taxes reduce the fall in consumption demand by households in response to the drop in employment, as emphasized most recently by Auclert and Rognlie (2017).[46] Second, labor-consumption complementarieties have a weaker effect in our model because aggregate demand also depends on the response of investment while in Nakamura and Steinsson (2014) all of net output is used for consumption.

Like GHH preferences, the hand-to-mouth restriction helps the model produce a negative response of consumption to austerity. In the model, a decrease in government purchases leads to a drop in income, which directly reduces hand-to-mouth consumption.[47] Eliminating the hand-to-mouth constraint (column (4)) lowers the multiplier to 1.40, again mainly due to a weak response in consumption.

The financial accelerator allows us to match the observed fall in investment. As output falls, entrepreneurs' net worth declines, which in turn increases the external finance premium they face for purchases of new capital. Column (5) shows that investment is nearly unresponsive to austerity shocks in the absence of the financial accelerator mechanism. Without the financial accelerator, the coefficient on investment would be -0.11 instead of -0.97 in our benchmark specification.

So far, our discussion has abstracted from international trade. In a closed economy, all of the adjustment to changes in government spending must be borne by domestic firms and consumers. In an open economy, some of the adjustment is absorbed by foreign trading partners, reducing the multiplier. The strength of this effect depends on both trade openness and the degree to which home and foreign goods are substitutes. Column (6) considers a higher elasticity of substitution between home and foreign goods (5 instead of 0.5). This makes it easier to export excess supply of the home good, reducing the effect on GDP and increasing the effect on net exports.

A second important factor is that our benchmark specification assumes that government purchases are primarily comprised of domestic goods and services. In contrast, private con-

[46]Auclert and Rognlie (2017) show that in a closed-economy New Keynesian model without capital, the government spending multiplier under a constant real interest rate rule equals the inverse of the labor wedge. In our model, the labor wedge equals $1 - \frac{1-\tau_n^l}{1-\tau_n^c}\frac{\psi_q - 1}{\psi_q}$, which, for the average country in our model, equals 0.5. This implies a multiplier of 2. Adding capital and adopting a Taylor rule as in our model would yield a multiplier significantly smaller than 1.

[47]See also Galí, López-Salido and Vallés (2007) for a discussion of the role of hand-to-mouth consumers in shaping the response of consumption to unanticipated changes in government spending.

sumption and investment goods have higher import shares. In column (7), we assume that the home bias of government expenditures is the same as for consumption and investment ($\upsilon = 0$). For this experiment, we reduce the import shares for consumption and investment keeping the overall import shares the same. With the change in composition, the multiplier falls from 1.97 to 1.66.

Column (8) shows the results of the benchmark model under the assumption of incomplete markets. Under complete markets, households trade state-contingent assets to insure themselves against shocks to government purchases. Cuts in government spending are positive shocks to the optimizing household members because, together with the market clearing condition for the final good, they imply higher household consumption, all else being equal. Households will therefore purchase state-contingent bonds that require them to pay when their government cuts spending (see also Farhi and Werning, 2015). These transfers then finance net imports in countries with less austerity. This is in line with the large positive coefficient on net exports in our benchmark model (1.22, column (2)), meaning that austere countries export on average more than they import.[48] These transfer payments from austere to non-austere countries imply a reduction in life-time wealth for austere countries, which further depresses consumption and contributes to the reduction in consumption associated with cuts in government purchases (-1.21, column (2)). In a model with incomplete markets, these transfer payments from austere to non-austere countries do not occur and thus the response of both consumption and net exports to austerity is more muted (-0.56 and 0.75, respectively, column (8)).[49]

Columns (9) and (10) illustrate the influence of monetary policy on the cross-sectional multiplier. Column (9) shows results for a case of more accomodative monetary policy in which we reduce the Taylor rule parameters to $\phi_{GDP} = \phi_\pi - 1 = 0.1$ (compared to the benchmark setting of $\phi_{GDP} = \phi_\pi - 1 = 0.5$). The austerity multipliers for the fixed exchange rate countries are essentially unchanged. As emphasized by Nakamura and Steinsson (2014), the stance of monetary policy has little effect on the cross-sectional multiplier *in a monetary*

[48]Technically, the annuity value of the transfer payments implied by complete markets is given by the annuity value of *all* future, discounted net imports. The Table just displays the response of net exports over the first years. When we calculate the actual transfer value in our model, we still observe that it is negative in response to a cut in government spending, i.e. austere countries pay transfers under complete markets.

[49]Note that these transfer payments typically would also affect labor supply and counterbalance (and potentially overturn) this wealth effect on consumption, but this channel is absent under GHH preferences. With separable preferences, multipliers under incomplete markets can be larger than under complete markets, as shown in Nakamura and Steinsson (2014).

union. For countries outside the currency union, the change to the Taylor rule increases the cross-sectional multiplier from 1.62 to 2.61. This is because the monetary authorities outside the euro area are now less responsive to country-specific austerity shocks; this results in larger output losses and more deflation.

Finally, column (10) examines the case where the ECB is constrained by a zero lower bound (ZLB) on the nominal interest rate. To introduce a constant nominal interest rate for the ECB, we add a (large) fictional country to the model. This fictional country does not participate in the market for tradable goods but it does have a fixed exchange rate with the euro. Importantly, this external economy follows a Taylor rule and sets interest rates for itself and all the countries in the euro area. This country is sufficiently large to ensure that changes in inflation and output within the euro area do not have a perceptible feedback on the interest rate, thus even though there are significant fiscal shocks in the euro area, the interest rate for the euro does not react.[50] The monetary policy rules for the countries outside the euro remain the same. The ZLB specification has essentially no effect on the cross-sectional multipliers for the countries within the euro. On the other hand, the ZLB does imply that the countries in the euro area suffer greater output losses as a group. Figure 5 shows scatter plots of austerity and GDP for both our benchmark model (solid dots) and the specification with the ZLB (open dots) for the fixed exchange rate countries. The reaction of GDP to austerity in each country is indeed greater under the ZLB. For instance, Portugal (PRT) experienced a reduction in government spending of roughly 6 percent of GDP. Away from the ZLB, Portugal's GDP falls by roughly 11 percent (a multiplier of just under 2). At the ZLB, the decline is roughly 16 percent (a multiplier of nearly 3). On the other hand, the cross-sectional multiplier is unchanged.

To summarize, several amplification mechanisms generate large cross-sectional austerity multipliers. Labor-consumption complementarities, hand-to-mouth consumers, and the financial accelerator make aggregate consumption and investment demand more responsive to changes in current income. A low trade elasticity together with a realistic home bias in government purchases means that domestic production bears the brunt of austerity shocks. Variations in monetary policy (including the ZLB) play only a limited role in the cross-section.

[50] We set the size of this fictional country to be 1 million times the size of Europe. As discussed in Nakamura and Steinsson (2014), this specification is not the same as a ZLB in a closed economy model. While the fictional external economy does eliminate movements in the nominal interest rate across countries, it does not feature a long-run drop in the nominal price level. That is, prices in the euro area must return to the steady state after the shocks have subsided. In a specification of the ZLB that did allow for long-run deflation, the effects of the ZLB would be even more pronounced.

6 Counterfactual Policy Simulations

We next use the model to analyze two counterfactual scenarios. The first experiment considers the effect of eliminating austerity in Europe. The second examines the effect of eliminating the common currency and instead having country specific monetary policy with floating exchange rates.

Europe Without Austerity We begin by examining the case in which there is no austerity in Europe. Specifically, this "No Austerity" experiment removes all negative government spending shocks from our benchmark model.[51] For this experiment, we impose the ZLB in both the benchmark model and the counterfactual simulation. We do this because, while the ZLB has only a minimal impact on the cross-sectional performance of the model, it has a much larger impact on the simulated time series paths.

The two leftmost panels of Figure 6 show the actual and simulated time paths for GDP for the EU10 (the upper panel) and GIIPS (the lower panel). We include results for both the benchmark specification and the "No Austerity" counterfactual. The figure underscores our main result that fiscal austerity has large contractionary effects on output. The benchmark model under the ZLB tracks the data reasonably well, particularly for the GIIPS economies. Actual GDP falls by almost 18 percent in the GIIPS economies and by 15 percent in the benchmark model. When the austerity shocks are eliminated, output in the GIIPS group would have increased by roughly one percent rather than falling by 15 in the benchmark specification.[52] EU10 output in the "No Austerity" counterfactual exceeds EU10 output in the benchmark by roughly 8 percent.

Notice that in the figures, the actual data display sharp downturns in GDP in 2008-2009 while the model predicts expansions. The expansion in the model is due to stimulative monetary and fiscal policy shocks which are reflected in the forcing variables we feed in to the simulation. The model does not include the collapse in house prices, and credit market failures that caused the Great Recession. Our focus is on the post crisis period starting in 2010.

A significant motivation for austerity policies was to slow the escalation of debt-to-GDP

[51] During the 2010-2014 period, with the exception of Switzerland, there were virtually no positive fiscal shocks in Europe. For the "No Austerity" experiment, we retain the positive government spending shocks in Switzerland and set the other spending shocks to zero.

[52] While we do not include an explicit sovereign risk premium in the model, the financial accelerator creates interest rate spreads in the countries that experienced austerity, exacerbating any reductions in output.

ratios that occurred across the euro area. While reductions in government expenditures should, all else equal, reduce deficits and debt levels over time, the impact on the debt-to-GDP *ratio* is not obvious. As our previous analysis shows, reductions in government expenditures have a considerable negative impact on economic activity, and this will in turn reduce tax revenues. Furthermore, trade linkages and shared monetary policy in Europe mean that fiscal actions in one country will be transmitted to neighboring countries, affecting their fiscal positions.

Strictly speaking, the model does not feature any government debt because we assume that the government balances its budget through lump-sum taxes every period. We can however, report the cumulative change in tax liabilities implied by the model during the 2010-2014 period. Debt in each period is the difference between government expenditures and tax revenue collected through the VAT, the labor tax and the capital tax. For the average country in our sample, these tax rates—reported in Table A8 in the Appendix—are 18 percent, 39 percent and 25 percent, respectively. For each period, we cumulate all of the debt from the start of the simulation and report it as a ratio to GDP. Notice that this is the debt-to-GDP ratio *excluding* interest payments.[53]

The middle panels in Figure 6 show the actual and simulated time paths for the debt-to-GDP ratio for the EU10 (the upper panel) and GIIPS (the lower panel). These figures report changes in the debt-to-GDP ratio relative to its average value over 2008-2009. The grey line shows the actual path of the debt-to-GDP ratio in the data. The light, dotted line is a "static" estimate that assumes that GDP and tax revenue are unaffected by changes in government purchases, and thus reflects only reductions debt associated with reduced government spending. According to this static measure, austerity undertaken by the GIIPS countries should have resulted in a decline in the debt-to-GDP ratio by more than 20 percentage points from 2008 to 2014 for the GIIPS region.

In contrast, our benchmark model with the ZLB predicts an *increase* in the debt-to-GDP ratio in the GIIPS region (45 percentage points), even somewhat larger to that observed in the data (20 percentage points).[54] The strong discrepancy of 65 percentage between the "static" debt-to-GDP ratio and the benchmark debt-to-GDP ratio by the end of 2014 is driven by two forces: (i) a reduction in GDP by about 18 percent (see the leftmost panel) and (ii) a fall in

[53]Austerity might affect the debt-to-GDP ratio through its effect on sovereign risk premia. Since our model ignores this channel, we prefer to exclude interest payments (both in the data and the simulated data) from the definition of the debt-to-GDP ratio.

[54]The fact that our model somewhat overstates the increase in debt might stem from the fact that in the data, most countries raised tax *rates* after the recession, while our model assumes that these tax rates did not change over time.

cumulative tax revenue by about 47 percentage points, which, itself, is induced by the decline in GDP.

Our model suggests that austerity is "self-defeating" in the sense that, in response to a cut in government spending, the primary balance turns negative and the debt level rises. This is reminiscent of DeLong and Summers (2012) and Denes, Eggertsson and Gilbukh (2013) who have shown that a cut in government spending can perversely boost debt levels during a liquidity trap. The response of the debt level to austerity depends on the reaction of tax revenues to austerity, which can be broken down into the response of GDP to austerity, measured by the *time-series* multiplier, and the response of tax revenues to a fall in GDP. If we impose the ZLB, the time-series multiplier is slightly above 2, that is a 1 euro cut in government spending leads to a 2 euro drop in GDP. This fall in GDP will translate into a loss in tax revenue. In our simulated data, a fall in GDP by two euros lowers tax revenues by about 1.5 euros.[55] This fall in tax revenues more than outweighs the fall in government spending and the primary balance becomes negative.[56]

GDP, and hence the debt level, does not only react to domestic austerity, but also austerity by their trading partners. To measure the magnitude of this effect, we simulate our benchmark model for each country assuming that all other countries pursue austerity but the country itself does not. E.g., for Greece we would eliminate austerity in Greece but continue to have austerity in the other countries. (We maintain the ZLB for this experiment). Figure 7 plots the resulting debt-to-GDP ratios, again normalized to 2008-2009, with each grey line corresponding to a different country-simulation. The highest line depicts Luxembourg's debt-to-GDP ratio in which Luxembourg is the only country that does not receive any austerity shocks. The fifteen grey lines correspond to the ten EU10 economies and the five GIIPS economies. The figure also depicts the (weighted) average response of the EU10 group and the GIIPS group.

The first striking result is that the average euro area country would have seen its debt-to-GDP ratio rise by about 16 percentage points relative to 2008-2009, even if it hadn't implemented any austerity measures itself. This is entirely due to negative spillover effects from trading partners who implement austerity. For the GIIPS countries, roughly a third of the increase in their debt-to-GDP ratio stems from austerity measures implemented abroad.

[55]We obtain this value by regressing simulated tax revenue on simulated GDP.

[56]Without the ZLB, the *time-series* multiplier is about 1.5 and the debt level is rather unresponsive to austerity. DeLong and Summers (2012) assume a value of 1/3 for the "marginal tax rate", that is half the size of the value implied by our simulations. DeLong and Summers (2012) therefore require a larger multiplier of 3 to generate self-defeating austerity.

The ZLB assumption plays a key role in the size of these negative spillover effects. Under our benchmark Taylor rule the ECB would have lowered nominal interest rates to counterbalance the austere policies in the euro area. These lower interest rates would help countries in the euro area irrespective of whether they implemented austerity.

A second striking result is the variation in predicted debt-to-GDP ratios in the Figure 7. This variation ranges from an increase of less than 12 percentage points in Greece to an increase of more than 21 percentage points in Luxembourg. This partially reflects the different intensity of austerity across countries, but also reflects differences in exposure to trade and differences in country size (Luxembourg is affected more simply because it is relatively small and open compared to other European nations). This finding is consistent with estimated regional spillover effects of government spending, particularly during recessions (see e.g. Auerbach and Gorodnichenko, 2013).

Europe Without the Euro The third set of panels in Figure 6 show output trajectories for a "No Euro" experiment. In this counterfactual, the countries experienced austerity shocks but were free to pursue independent monetary policy and allow their currencies to float. Unlike the previous counterfactual, we do not impose the ZLB for this experiment.[57] While there are many ramifications of such an "exit strategy" from the euro that are not captured in our model, the experiment does provide some insight into the opportunity cost of a shared monetary policy. Although the effects of allowing countries to pursue independent monetary policy are more modest than eliminating austerity, they do suggest that both the EU10 and the GIIPS economies in particular would benefit from moving to an independent, unconstrained monetary policy. By the end of 2014, their GDP would have been 5 and 10 percentage points, respectively, higher relative to the benchmark. In this scenario, central banks in both regions would lower their nominal interest rates to counterbalance austerity. The consequent fall in nominal exchange rate would stimulate exports and output.[58]

[57]Although the euro area itself was close the ZLB during the European debt crisis, we assume here that, after a breakup of the euro area, monetary authorities would be able to devalue their currencies. Amador et al. (2017) show that monetary authorities can devalue their currencies at the ZLB by intervening in the foreign exchange market.

[58]See Figure A11 in the Appendix for the path of implied effective exchange rates for this experiment.

7 Conclusion

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

We use a multi-country DSGE model to see whether standard macroeconomic theory can explain the observed changes in economic activity. The model features government purchases shocks and monetary shocks 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, trade flows and exchange rate regimes. The model output broadly matches the patterns observed in the data. In particular, the model successfully reproduces a large cross-sectional multiplier of austerity shocks on output.

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

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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 Itzetzki, Reinhart and Rogoff (2004), *http://www.carmenreinhart.com/data/browse-by-topic/topics/11/*..

Table 2a: Austerity and GDP (1)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Gov't. Purchases	−2.22						
	(0.25)						
Social Benefits		−2.60					
		(1.29)					
Primary Balance			−0.41				
			(0.62)				
Total Revenue				−1.55			
				(0.93)			
Stand. VAT					−2.42		
					(0.74)		
Top Income Tax Rate						−0.36	
						(0.24)	
Top Corp. Tax Rate							0.97
							(0.43)
R^2	0.74	0.13	0.02	0.09	0.29	0.08	0.16
Obs.	29	29	29	29	28	29	29

Notes: Table displays the regression coefficient α of univariate regressions (3.6). Each column represents a separate regression. The dependent variable is the average deviation of real GDP per capita from its forecast over 2010 - 2014. The independent variables are the average deviations of various fiscal variables from their forecast over 2010 - 2014. Sample includes all countries (U.S. missing for regression on VAT rates). All variables are expressed in percent. Untreated OLS standard errors in parentheses.

Table 2b: Austerity and GDP (2)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Gov't. Purchases	−2.22	−2.15	−1.79	−2.20	−2.06	−2.19	−2.10	−1.64	−1.76	−1.93	−1.77
	(0.25)	(0.24)	(0.24)	(0.26)	(0.24)	(0.47)	(0.25)	(0.22)	(0.24)	(0.40)	(0.24)
Total Revenue		−0.90						−0.82	−0.64	−0.58	−0.68
		(0.48)						(0.38)	(0.41)	(0.45)	(0.48)
TFP			0.39					0.42	0.31	0.36	0.37
			(0.11)					(0.10)	(0.12)	(0.11)	(0.12)
HH Debt to GDP				0.02				0.04			
				(0.02)				(0.01)			
Credit Spread 2010-2014					−1.00				−0.43		
					(0.43)				(0.42)		
Gov't. Bond Rate						−0.02				0.21	
						(0.54)				(0.46)	
Gov't Debt to GDP							−0.04				0.00
							(0.02)				(0.02)
R^2	0.74	0.77	0.83	0.75	0.79	0.75	0.77	0.88	0.85	0.84	0.84
Obs.	29	29	29	29	29	28	29	29	29	28	29

Notes: Table displays the regression coefficients of a multivariate regression along the lines of (3.6). Each column represents a separate regression. The dependent variable is the average deviation of real GDP per capita from its forecast over 2010 - 2014. For the independent variables: 'Gov't Purchases' is the average deviation of real government purchases per capita (deflated by the GDP deflator) from their forecast over 2010 - 2014, 'Total Revenue' is the average deviation of real government revenue per capita (deflated by the GDP deflator) from its forecast over 2010 - 2014, 'TFP' is the change in TFP between 2009 and 2014, 'HH Debt to GDP' is the level of nominal household debt at the end of 2007 over 2005 nominal GDP, 'Credit Spread' is the spread of lending rates to non-financial corporations and the central bank interest rates, averaged over 2010 - 2014, less its average over 2000 - 2005, 'Gov't Bond Rate' is the nominal interest rate on 10-year government bonds, averaged over 2010 - 2014, less its average over 2000 - 2005 (no data for Estonia), and 'Gov't Debt' is the end-of-2009 nominal government debt level (normalized by 2005 nominal GDP). All variables are expressed in percent. Untreated OLS standard errors in parentheses.

Table 3: FISCAL POLICY AND DEBT TO GDP

	Debt to GDP 2009					
	All Countries		Fixed XRT		Floating XRT	
	α	R^2	α^{fix}	R^2	α^{fl}	R^2
Gov't. Purchases	0.02	0.05	0.02	0.13	−0.02	0.07
	(0.01)		(0.01)		(0.03)	
Social Benefits	0.00	0.00	0.00	0.01	−0.01	0.04
	(0.01)		(0.01)		(0.01)	
Total Revenue	0.02	0.26	0.02	0.33	0.01	0.07
	(0.01)		(0.01)		(0.02)	
Stand. VAT	0.01	0.02	0.01	0.04	0.04	0.09
	(0.01)		(0.01)		(0.05)	
Top Income Tax Rate	0.03	0.03	0.05	0.18	−0.05	0.03
	(0.03)		(0.02)		(0.10)	
Top Corp. Tax Rate	−0.02	0.06	−0.03	0.08	0.00	0.00
	(0.02)		(0.02)		(0.02)	

Notes: Table displays the estimated coefficient of regression (3.6) without any controls as well as its R^2. The explanatory variable is the government debt to GDP ratio at the end of 2009. The explained variables are forecast errors of GDP, government purchases, social benefits, total outlays, total revenue, VAT, top income tax rates and top corporate tax rates. Regressions are run for the whole set of countries, only fixed exchange rate countries, or only floating exchange rate countries. Reported standard errors in parentheses are (untreated) OLS errors.

Table 4: COMPARISON OF MODEL AND DATA

	Data			Benchmark			Only aust. shocks		
	All	Fix	Float	All	Fix	Float	All	Fix	Float
GDP	-1.77	-1.79	-1.66	-1.95	-2.00	-1.62	-1.76	-2.01	-1.00
	(0.19)	(0.23)	(0.41)						
Inflation	-0.46	-0.60	-0.18	-0.40	-0.47	-0.20	-0.35	-0.48	0.06
	(0.10)	(0.11)	(0.20)						
Consumption	-1.17	-1.17	-1.07	-1.20	-1.21	-1.07	-1.08	-1.21	-0.70
	(0.17)	(0.21)	(0.36)						
Investment	-1.36	-1.43	-1.13	-0.96	-0.96	-0.80	-0.80	-0.97	-0.26
	(0.14)	(0.16)	(0.29)						
Net Exports over GDP	1.47	1.56	1.11	1.22	1.19	1.26	1.14	1.19	0.97
	(0.17)	(0.19)	(0.34)						
Exchange Rate	-0.77	0.42	-3.04	-0.19	-0.11	-0.54	-0.29	-0.10	-0.90
	(0.35)	(0.28)	(0.49)						
GDP Growth	-0.53	-0.51	-0.51	-0.42	-0.48	-0.23	-0.38	-0.49	-0.07
	(0.08)	(0.10)	(0.17)						

Notes: Table displays the regression coefficients on government purchases (α in regression (3.6) and for the multipliers α^{Fix} and α^{Fl} for the regression with separate coefficients for fixed and floating exchange rate countries, after controlling for government revenue, government debt and TFP as is done in specification (11) of Table 2b. Each row represents a separate regression. The dependent variables are average forecast errors in real GDP per capita, the inflation rate based on the Harmonized Index for Consumer Prices excluding Food and Energy, real consumption per capita, real investment per capita, real net exports over nominal 2005Q1 GDP and the nominal effective exchange rate. The coefficients α^{Fix} and α^{Fl} are estimated in a single regression, which also allows intercepts to differ across currency regimes, but forces the coefficients on the control variables to be the same across currency regimes. The benchmark calibration includes shocks to government spending and the Taylor rule. The last three columns display the results if only government spending shocks are fed into the model.

Table 5: Calibration

Description	Parameter	Value	Source / Target
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)
Share of hand-to-mouth consumers	χ	0.5	Campbell and Mankiw (1989), Martin and Philippon (2016)
Trade and Country Size			
Trade preference weights	ω_n^j	x	OECD Trade in Value Added Dataset
Trade demand elasticity	ψ_y	0.5	e.g. Heathcote and Perri (2002), 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	0.028	Average private investment share, $X/Y = 0.197$, 2000 - 2010
Utilization cost	a''	0.286	Del Negro et al. (2013)
Investment adjustment cost	f''	2.48	Christiano, Eichenbaum and Evans (2005)
Elasticity of substitution between varieties	ψ_q	10	Standard value
Price Rigidity			
Sticky price probability	θ	0.80	Alvarez et al. (2006)
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	0.025	Spread increases by 1 pp for 10% higher leverage
SS Leverage ratio	$\lambda - 1$	2.11	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	Half-life of 2.5 years
Import share of gov't purchases	υ_n	x	World-Input Output Database
Consumption, Labor, Capital tax rates	τ^C, τ^L, τ^K	x	Authors' calculations based on Eurostat's National Tax Lists
Taylor rule persistence	ϕ_i	0.75	Clarida, Gali and Gertler (2000)
Taylor rule GDP coefficient	ϕ_{GDP}	0.5	Clarida, Gali and Gertler (2000)
Taylor rule inflation coefficient	ϕ_π	1.5	Clarida, Gali and Gertler (2000)

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

Table 6: Alternative Model Specifications

	(1) Data	(2) Bench-mark	(3) Separable preferences	(4) No rule of thumb	(5) No financial accelerator	(6) High trade elasticity	(7) High trade share for G	(8) Incomplete markets	(9) Passive mone-tary policy	(10) ECB at ZLB
All										
GDP	−1.77	−1.97	−1.62	−1.40	−1.16	−0.83	−1.66	−1.47	−2.20	−2.07
Inflation	−0.44	−0.40	−0.13	−0.29	−0.42	0.01	−0.45	−0.35	−0.80	−0.43
Consumption	−1.18	−1.21	−0.55	−0.36	−0.71	−0.82	−1.06	−0.56	−1.38	−1.31
Investment	−1.29	−0.97	−0.76	−0.70	−0.11	−0.54	−0.82	−0.65	−1.14	−1.03
Net Exports over GDP	1.43	1.22	0.70	0.67	0.67	1.54	1.23	0.75	1.33	1.29
Fixed										
GDP	−1.79	−2.03	−1.58	−1.38	−1.17	−0.62	−1.71	−1.44	−1.95	−1.99
Inflation	−0.57	−0.49	−0.24	−0.32	−0.43	−0.11	−0.49	−0.32	−0.45	−0.47
Consumption	−1.20	−1.22	−0.52	−0.37	−0.70	−0.69	−1.07	−0.53	−1.23	−1.27
Investment	−1.43	−0.98	−0.69	−0.64	−0.09	−0.34	−0.82	−0.58	−0.91	−0.92
Net Exports over GDP	1.61	1.18	0.65	0.64	0.63	1.42	1.19	0.69	1.20	1.21
Floaters										
GDP	−1.70	−1.62	−1.55	−1.29	−1.10	−1.14	−1.34	−1.41	−2.61	−1.65
Inflation	−0.17	−0.21	0.15	−0.25	−0.36	0.18	−0.36	−0.40	−1.74	−0.21
Consumption	−1.04	−1.08	−0.57	−0.31	−0.73	−1.08	−0.95	−0.65	−1.69	−1.09
Investment	−0.92	−0.81	−0.79	−0.72	−0.16	−0.89	−0.70	−0.70	−1.54	−0.84
Net Exports over GDP	0.91	1.27	0.80	0.74	0.78	1.82	1.31	0.93	1.61	1.27
Simulated GDP										
Corr.	1.00	0.83	0.82	0.81	0.86	0.58	0.81	0.84	0.79	0.74
Rel. Std. Dev.	1.00	1.01	0.84	0.73	0.58	0.61	0.88	0.75	1.19	1.23

Notes: See Table 4. Specifications: (3) separable preferences, (4) $\chi = 0$, (5) $F_\varepsilon = 0$, (6) $\psi_y = 5$, (7) $\upsilon = 0$, (8) only state non-contingent bonds are traded, (9) $\phi_{GDP} = 0.1, \phi_\pi = 1.1$, (10) ECB at zero lower bound (see text).

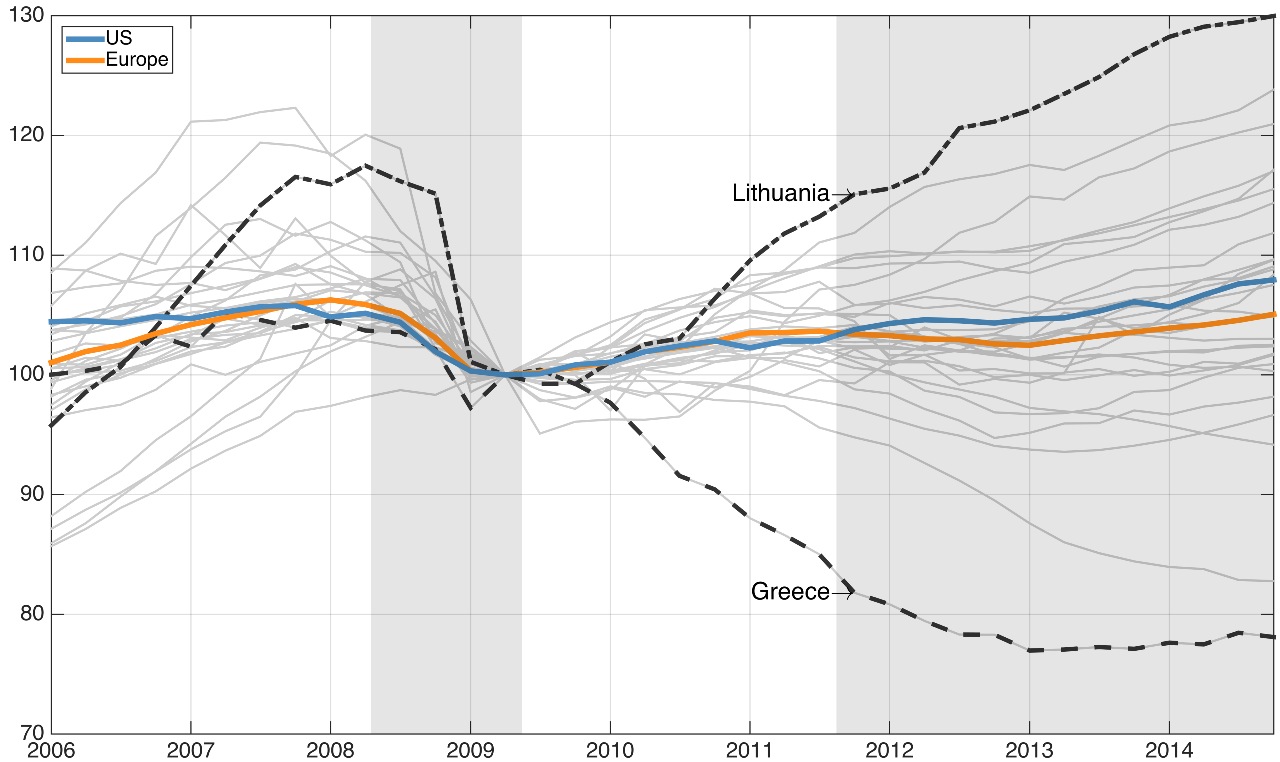

Figure 1: Real per Capita GDP Before, During and After the Crisis

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

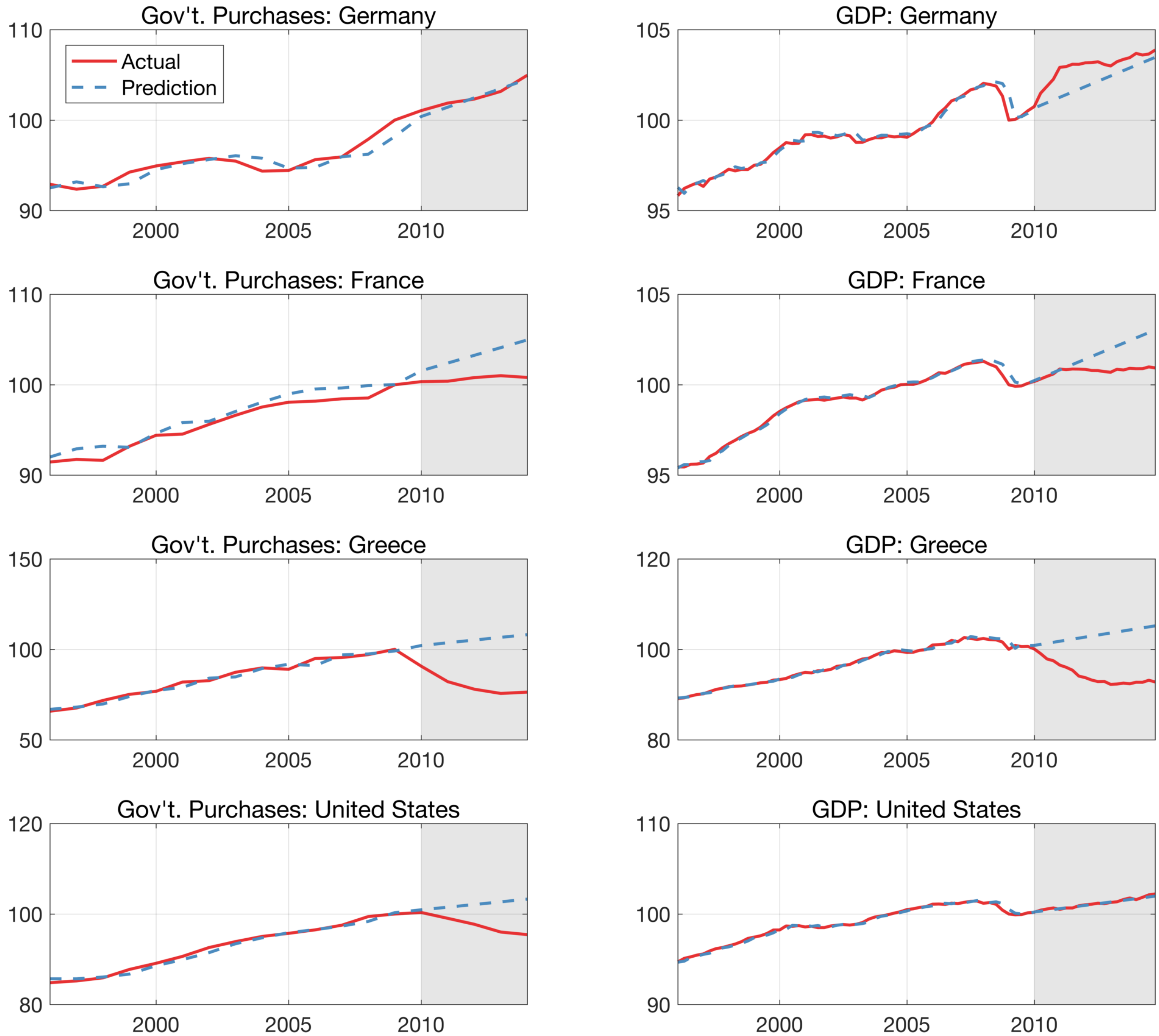

Figure 2: Government Purchases and GDP

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

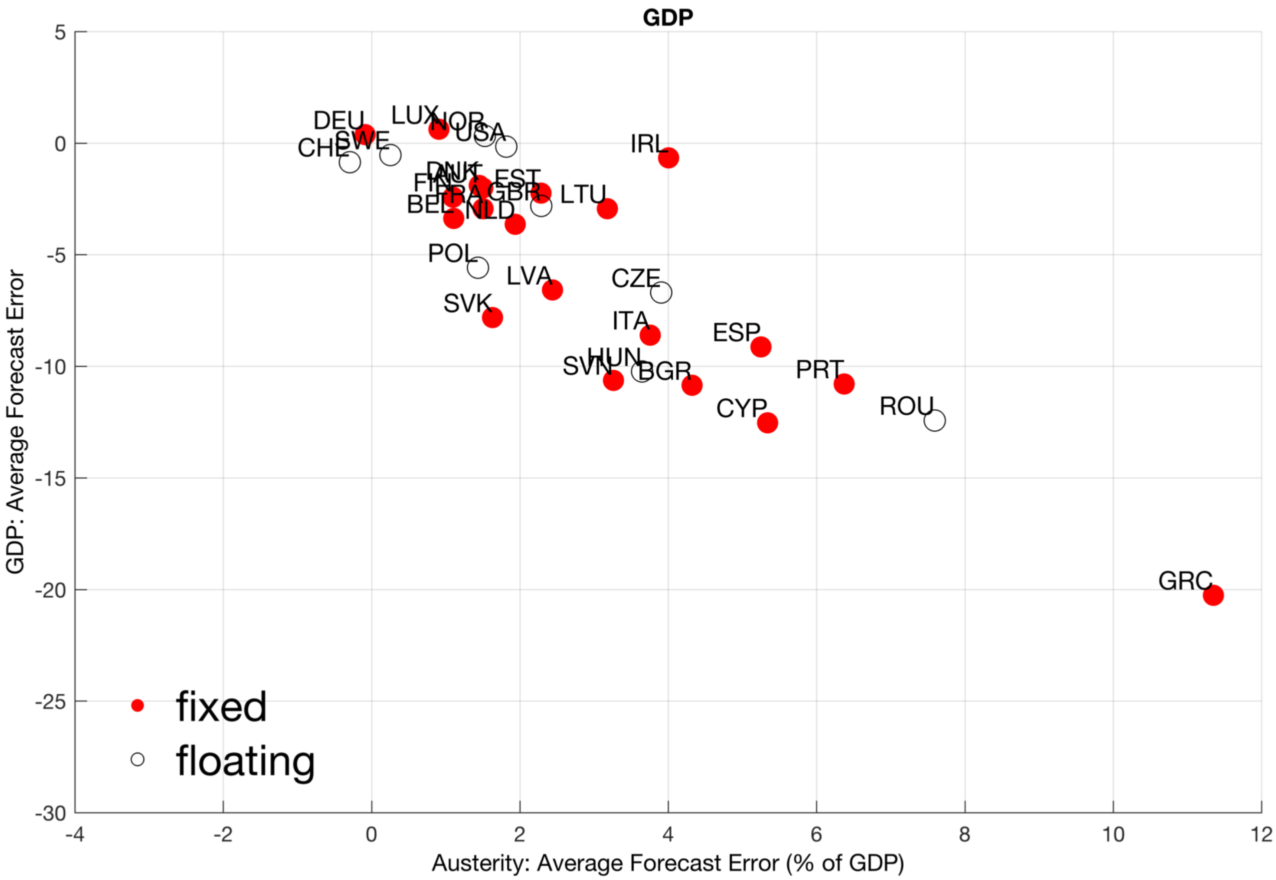

Figure 3: GDP and Austerity: Data

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 austerity, defined as 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). See text for details on the forecast specification.

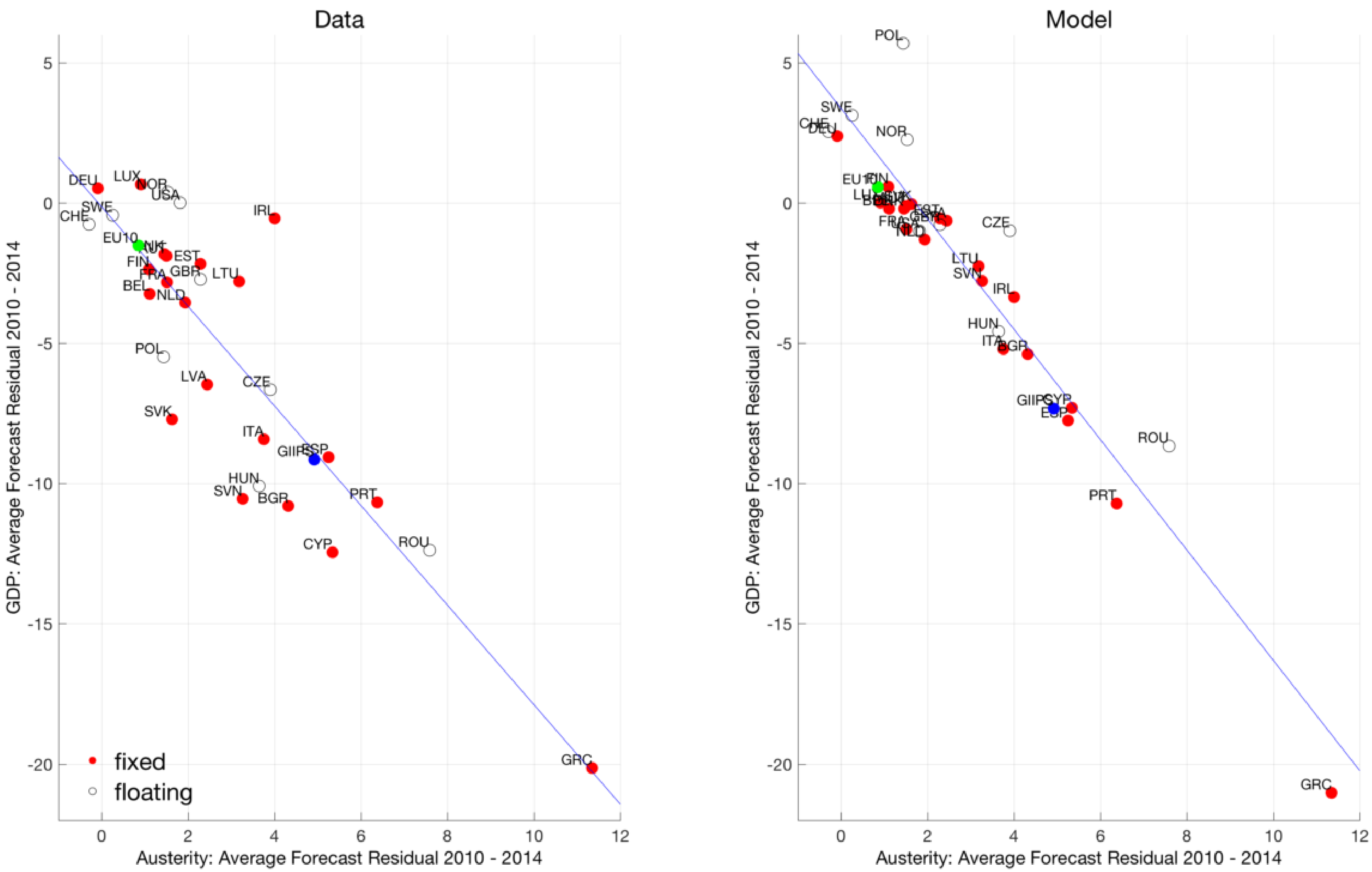

Figure 4a: GDP and Austerity: Data vs. Model

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 austerity, defined as 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 the overall sample of countries. Left panel is based on actually observed data and displays the GDP residual after controlling for forecast errors of government revenue, initial government debt and changes in TFP as is done in specification (11) of Table 2b; right panel refers to data from the simulated model. See text for details on the forecast specification.

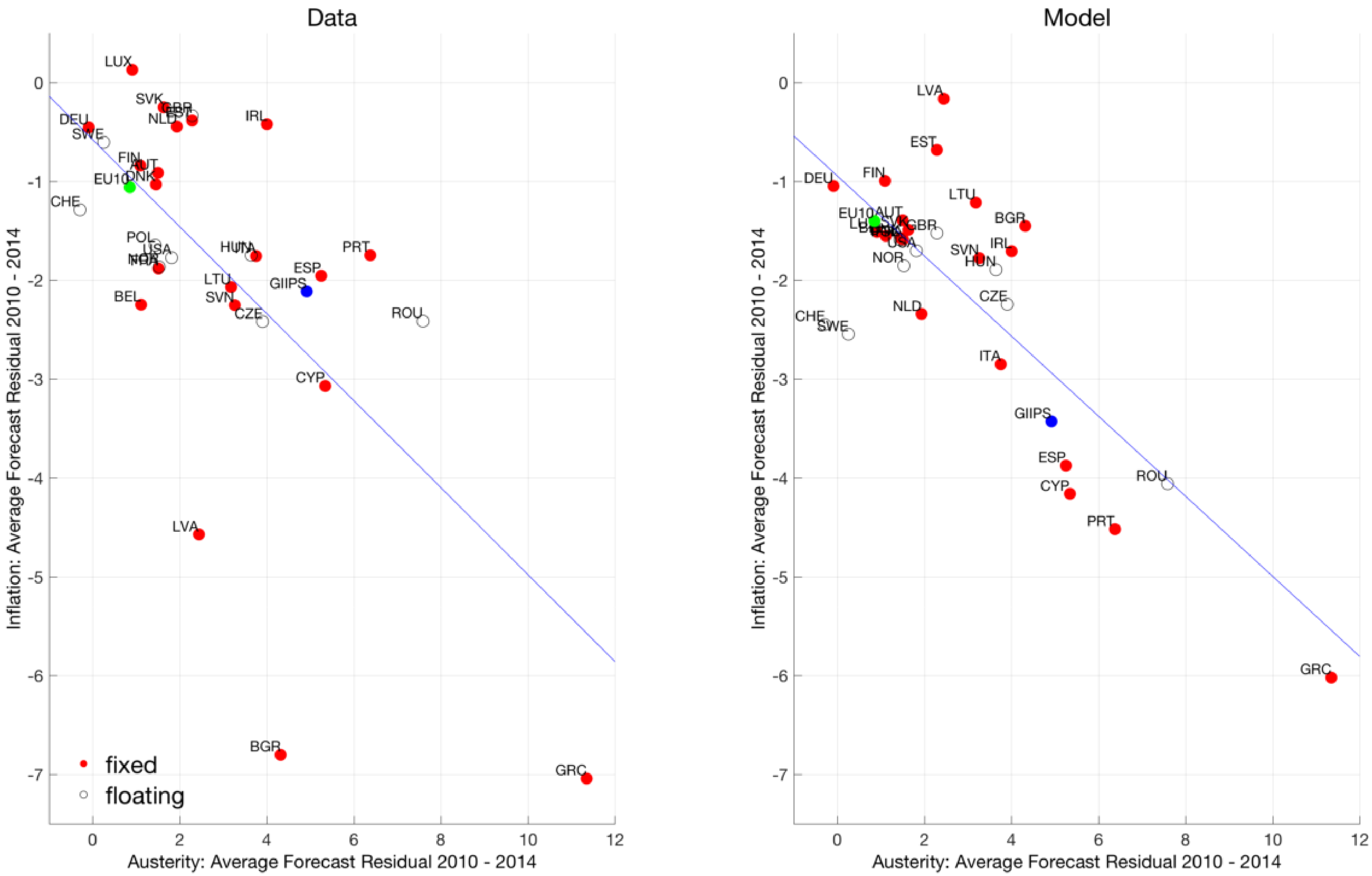

Figure 4b: Inflation and Austerity: Data vs. Model

Note: See Figure 4a.

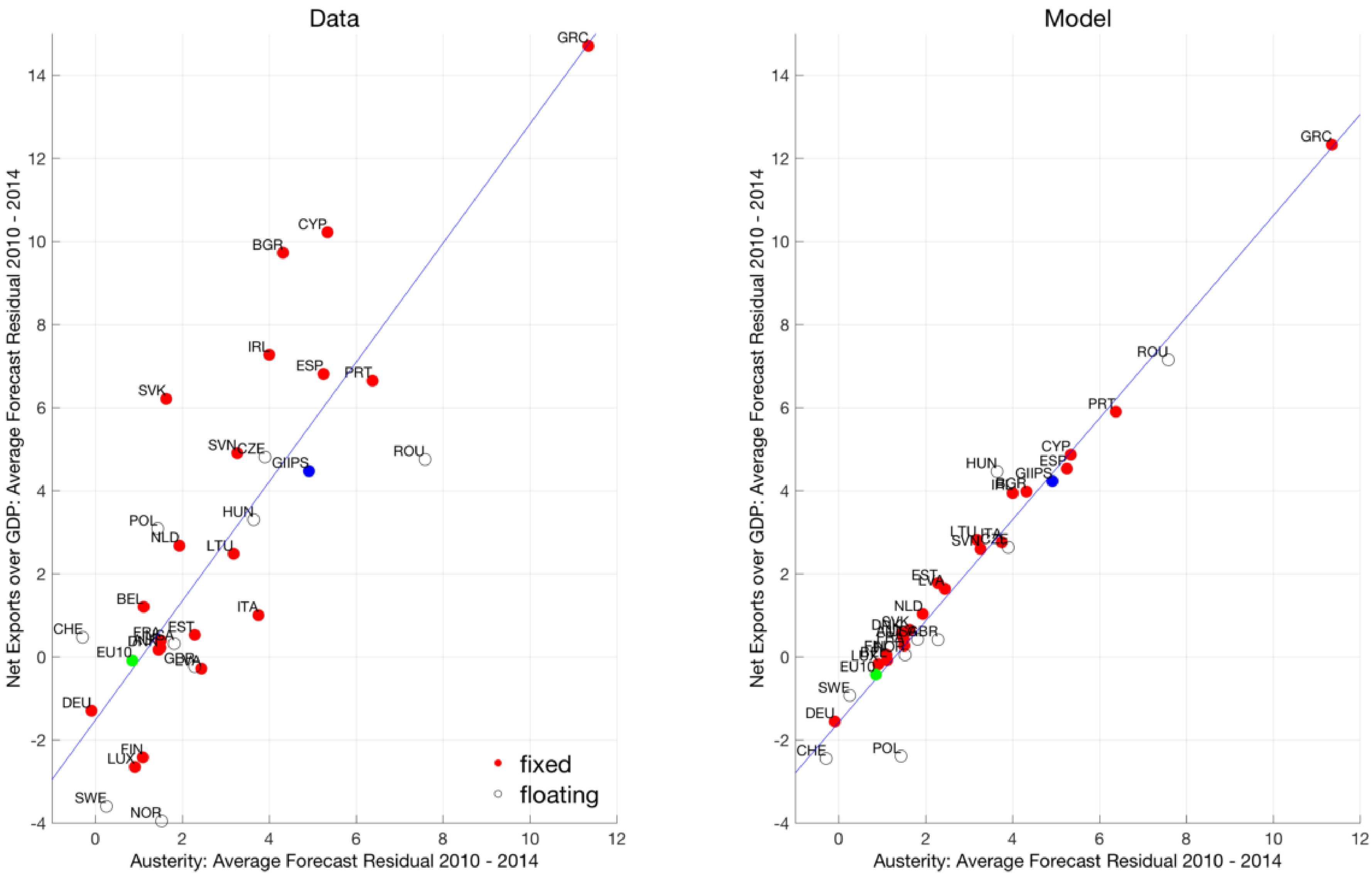

Figure 4c: Net Exports and Austerity: Data vs. Model

Note: See Figure 4a.

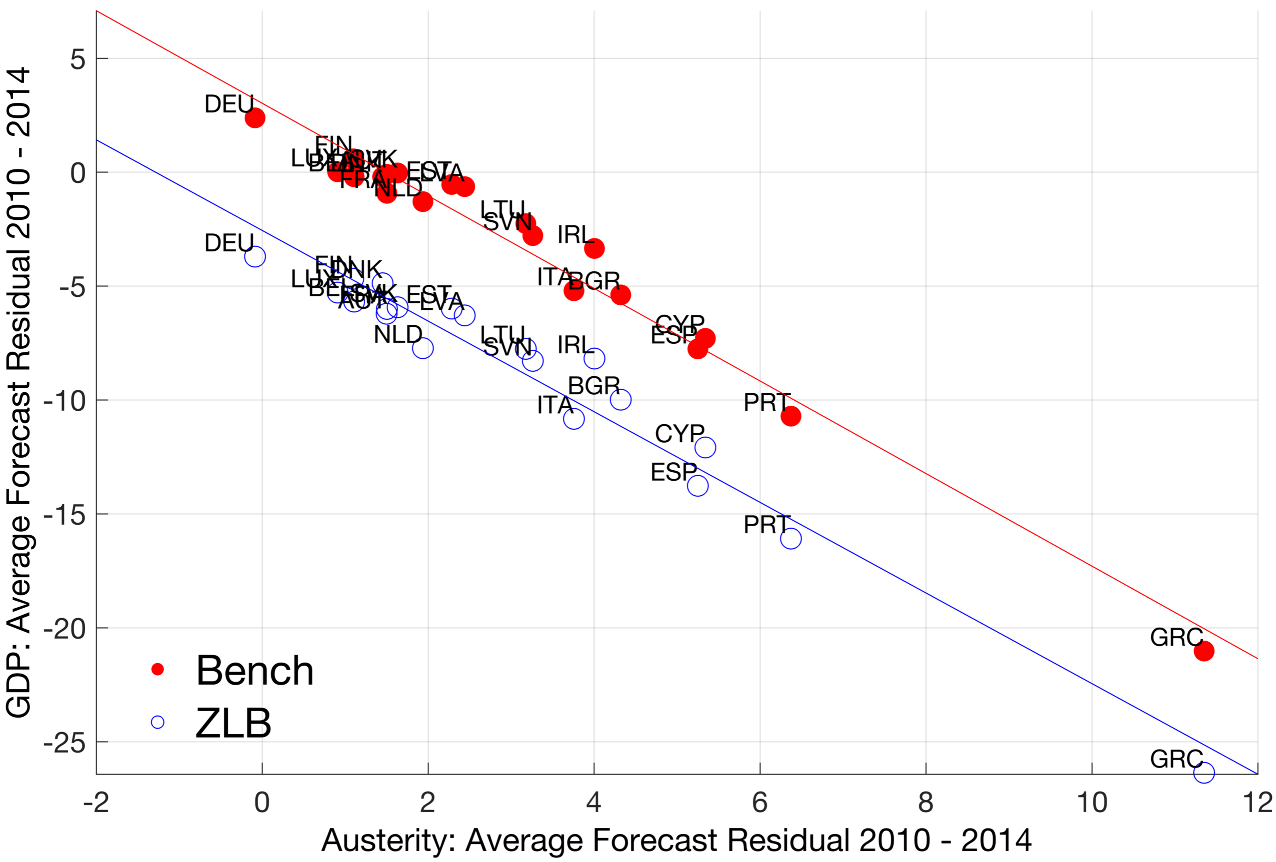

Figure 5: GDP and Government Purchases: Without and With a ZLB

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 austerity, defined as the shortfall in government purchases, also in log points. Sample only includes countries with fixed exchange rates. Red dots refer to simulated data under the benchmark calibration; blue dots refer to simulated data under the benchmark calibration with a ZLB for the ECB.

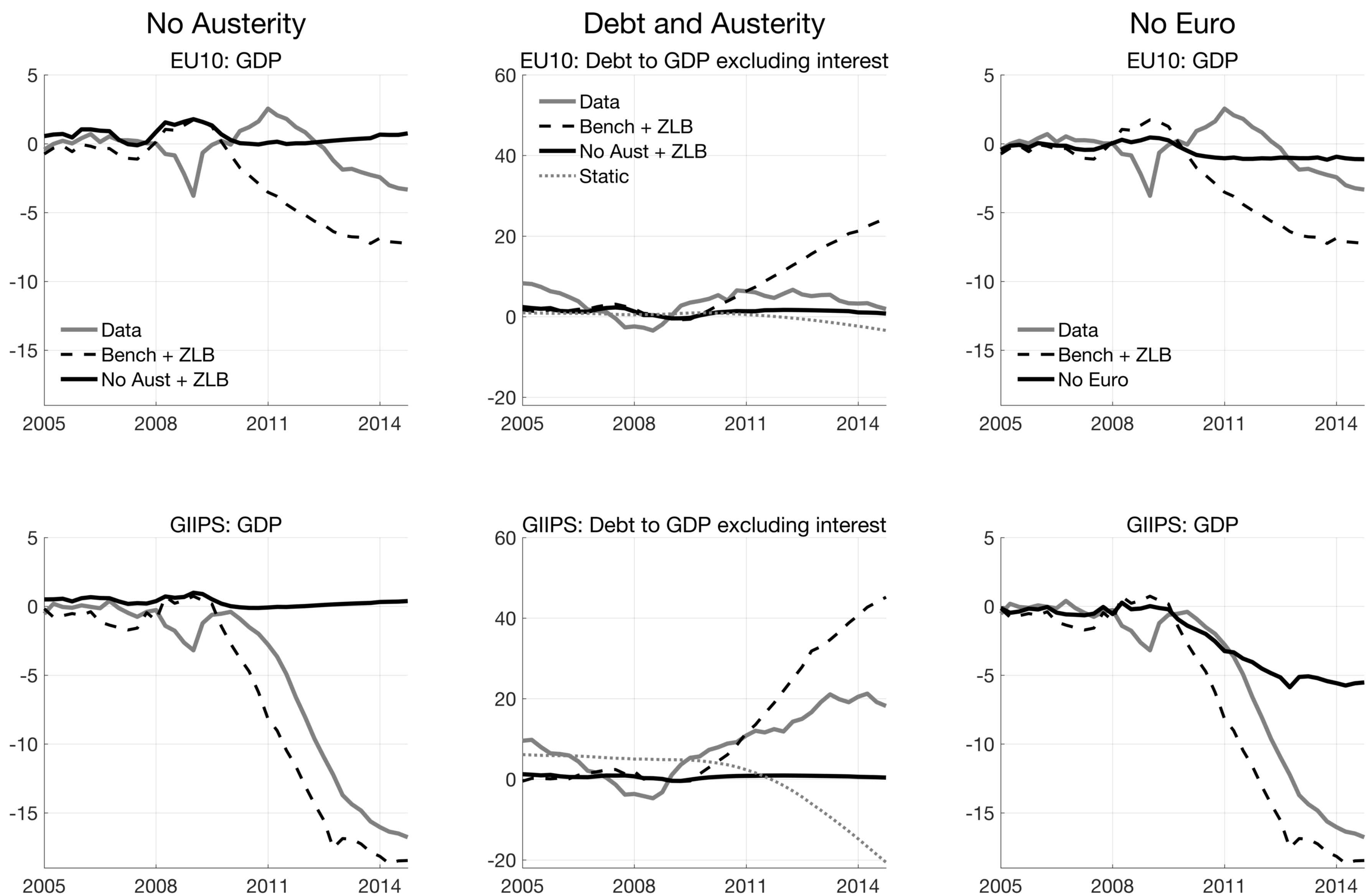

Figure 6: Counterfactual Policy Simulations

Note: Figures display actual and simulated data for GDP (columns 1 and 3) and the debt-to-GDP ratio (column 2) for the EU10 (row 1) and the GIIPS countries (row 2). The debt-to-GDP ratio is calculated as the cumulative primary balance, i.e. excluding interest payments. 'Data' refers to forecast errors from regression (3.5) for GDP and regression (3.4) for the debt-to-GDP ratio. Simulated data is expressed in percent deviations from the stationary equilibrium for GDP and in percentage point deviations from the average value 2008-2009 for the debt-to-GDP ratio.

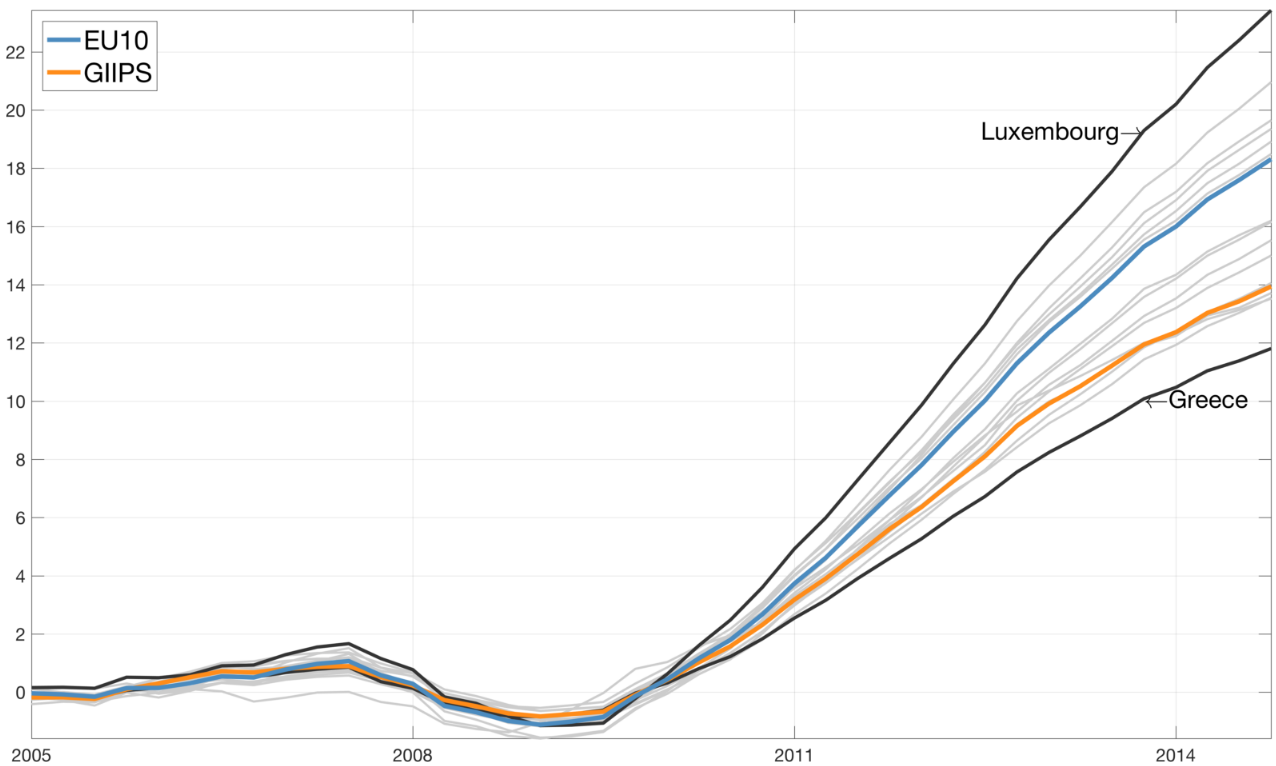

Figure 7: Debt-to-GDP Ratios in Counterfactuals

Note: Figure displays simulated data for the debt-to-GDP ratio from our benchmark model including the ZLB. The data is normalized to the average value of 2008-2009. Every grey line depicts the debt-to-GDP ratio of one of fifteen economies (EU10 + GIIPS) and corresponds to a separate simulation. In that simulation, all countries receive the same shocks as in our benchmark model, except for the country whose debt-to-GDP ratio is plotted. That country does not receive any government spending shocks.