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 75 percent of the observed cross-sectional variation in GDP in advanced economies during 2010-2014. Statistically, austerity is associated with lower GDP, lower inflation and higher net exports. A multi-country DSGE model calibrated to 29 advanced economies generates effects of austerity consistent with the data. Counterfactuals suggest that eliminating austerity would have substantially reduced output losses in Europe. Austerity was so contractionary that debt-to-GDP ratios in some countries increased as a result of endogenous reductions in GDP and tax revenue.

Keywords: Austerity, Fiscal Policy, Multi-Country DSGE Model
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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 United States, the European Union, Switzerland, and Norway. Taken as a whole, the recovery in Europe is similar to that of the United States. This similarity, however, masks a tremendous amount of variation across Europe. At one end of the spectrum is Greece, where per capita income at the end of 2014 is almost 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, statistically 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 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. The cross-sectional relationship between austerity and GDP is statistically robust to the inclusion of other variables such as TFP, household debt, sovereign risk premia and taxes. Austerity in government purchases is negatively associated with consumption, investment, GDP growth, and inflation. In addition, austerity is associated with an increase in net exports. This effect is larger for countries within the euro area and those with exchange rates fixed to the euro. Regressing GDP on austerity yields a slope coefficient of 1.75 – slightly higher than the "open-economy relative multiplier" for U.S. states reported by Nakamura and Steinsson (2014). Our estimate is in line with other studies that suggest that government spending multipliers 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 et al., 2018).

We develop a multi-country DSGE model that generates cross-sectional patterns in macroeconomic variables that are consistent with 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 elasticity of substitution between domestic and foreign goods 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 large effects of government spending *within* countries but has little influence on the magnitude of the *cross-sectional* impact of austerity for countries in a currency union.

One of the advantages of the model relative to the existing literature is that it adds realistic heterogeneity in terms of country size, trade openness and monetary policy regime. The model shows that the impact of austerity is weaker when the trade elasticity is high, and when the share of imports in government spending is high. For countries in a currency union, domestic spending has a smaller influence on production if the country is more open to trade. Quantitatively, spillover effects from austerity in other countries in Europe are large enough to reduce domestic production and increase debt-to-GDP. The magnitude of this effect varies substantially across countries.

Overall, our model corroborates the empirical finding that austerity may have 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 (Belgium, Germany, Estonia, France, Luxembourg, Netherlands, Austria, Slovenia, Slovak Republic, and Finland), the model generates a seven percent drop in production relative to the non-austerity counterfactual. 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 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 several 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 (either through revenue or outlays) 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.[1]

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 experienced 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 should presumably be associated with negative forecast errors in inflation and positive forecast errors in net exports. If one 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, one should expect that the additional explanatory power of government spending shocks would disappear once we include the other forcing variables. As shall be seen, 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 show that

[1] 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.

the measured shortfalls in government spending in 2010-2014 are sufficiently large, and are distributed across Europe in such a way, as to generate the changes in output, inflation and net exports as observed in the data. This conclusion is supported both by reduced-form empirical estimates as well as model simulations.

Alesina et al. (2015) and Alesina et al. (2016) follow the 'narrative' approach pioneered by Romer and Romer (2010) to examine the economic consequences of planned, multi-year, fiscal adjustments in OECD economies. 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 et al. (2015) base their conclusions on data since 1978, our paper focuses exclusively on the post-crisis period of 2010-2014, which was characterized by large contractions in government spending, a preexisting currency union, interest rates close to the ZLB, and financial market failures. We also 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.

The setup of our model is similar to Martin and Philippon (2017) who examine business cycle dynamics in eleven 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-to-GDP ratios.

Several papers have studied fiscal policy in a two-country framework: Blanchard et al. (2016) study how changes in spending by the core economies in Europe affect countries on the periphery. Consistent with our findings, their model produces sizeable spillover effects when monetary policy is constrained by the ZLB. Our model highlight that these spillover effects (and the effects of domestic fiscal policy) substantially vary in size and sign across countries in our multi-country model that is calibrated to match relative country size, trade linkages, heterogeneous fiscal policy and actual differences in monetary policy regimes. Kollmann et al. (2016) estimate a three-region model to tease out the factors that explain the different recovery paths observed in the United States and the euro area as a whole. As is clear from Figure 1, and in line with the findings in Kollmann et al. (2016), differences between the two aggregate regions are relatively small particularly compared to the much larger differences between European countries. Hence, it is perhaps not surprising that fiscal policy is found to play a limited role in their analysis. In contrast, Engler and Tervala (2018) show in a framework that allows for hysteresis effects of fiscal policy that austerity can account for about 80 percent of the overall euro area's output deviation from trend in 2013. Our study is complementary to these studies in that we focus on the cross-sectional heterogeneity in economic performance across Europe.

3. The Empirical Relationship between Austerity and Economic Performance

The data set includes the 28 largest economies in Europe and the United States (see the data appendix for details regarding primary sources and definition of variables). Twenty countries in the sample are formally in the euro area or are pegged to the euro (EU10, GIIPS, Bulgaria, Cyprus, Denmark, Latvia and Lithuania) and the remaining nine have floating exchange rates. Country size varies from less than one percent of the European aggregate (e.g. Cyprus and Luxembourg) to almost 100 percent (the United States is roughly the same size as the European aggregate). The import share varies from a low of 13 percent in the United States 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.

3.1. *Measuring Austerity*

We measure austerity as a shortfall in government purchases relative to forecast. Our empirical approach borrows from Blanchard and Leigh (2013), as discussed in the previous section. However, 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. Third, we see how the results change with different forecast specification.[2] And fourth, we can consider additional variables for which institutional forecasts are not available.

To illustrate our approach, the left column of Figure 2 shows real government purchases since 1996 for four countries: Germany, France, Greece and the United States. The years 2010-2014—our period of interest—is shaded. It is clear from the plots that government purchases declined significantly in Greece and, to a lesser extent, the United States. 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:

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

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). The forecast 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.

The forecasting equation (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 annual data for twelve advanced euro area economies over 1993-2005 using the specification

$$\ln Y_{EU,t} = \beta_{EU} + g_{EU} \cdot t + \varepsilon_{EU,t}. \tag{2}$$

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 (2).

The convergence parameter γ is estimated from the regression

$$g_{i,t} - \hat{g}_{EU} = \gamma\left(\ln \hat{Y}_{EU,t-1} - \ln Y_{i,t-1}\right) + \varepsilon^{\gamma}_{i,t} \tag{3}$$

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

The forecast errors for 2010 through 2014 are the difference between predicted values based on (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 (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

[2] Our results are essentially invariant to the forecast specification. The paper presents the 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.

in Figure 2. The cumulated forecast errors are consistent with the view that the fiscal stance was austere in Greece, somewhat austere in the United States and France, and neutral in Germany.

Forecasts for other fiscal policy measures are constructed as follows: Forecasts for social benefits and total revenue are based on a modified version of equation (1) that includes contemporaneous GDP to control for the mechanical link with income. These feedback parameters are estimated using data up to 2005. For statutory tax rates (the VAT, the top income tax rate, the top corporate tax rate) and for the ratio of primary balances to GDP, we adopt a random-walk specification. To reduce the sensitivity to the last observation, the forecast for each country takes the average value for 2008 and 2009 as the "last observation." That is, for dates t after 2009 the forecast for these variables is

$$\hat{x}_{i,t} = \frac{1}{2}\sum_{s=2008}^{2009} x_{i,s}, \tag{4}$$

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

Forecasts of economic performance follow the 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 United States 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), which again allows for a convergence factor to capture the medium-run growth dynamics of the Central and Eastern European economies:

$$\ln Y_{i,t} = \ln Y_{i,t-1} + \hat{g}_{EU} + \hat{\gamma}\left(\ln \widehat{Y}_{EU,t-1} - \ln Y_{i,t-1}\right) + \varepsilon^{Y}_{i,t}. \tag{5}$$

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 (2). As before, up to $t = 2010{:}1$, we use actual GDP data for $\ln Y_{i,t-1}$ in (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 for GDP growth, we use the estimated growth rate $\hat{g}_{i,t} \equiv \hat{g}_{EU} + \hat{\gamma}\left(\ln \widehat{Y}_{EU,t-1} - \ln Y_{i,t-1}\right)$.

Forecasts for the remaining performance indicators (inflation, net exports and the nominal effective exchange rate) are based on the random-walk specification as in (4). Plots for all series, actual and forecasts, are provided in Figures A2a to A8e 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, expressed as a share of GDP and averaged over 2010-2014. The y-axis is the shortfall in GDP relative to forecast, again averaged over 2010-2014. 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 greater 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 are most highly correlated with the decline in output. To establish this, we 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:

$$\tilde{Y}_{i,2010-2014} = \alpha_0 + \alpha \tilde{G}_{i,2010-2014} + \varepsilon_i \tag{6}$$

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 compared to estimates of the multiplier in the literature.[3] Note that the estimates are based on cross-sectional variation in the data rather than time-series variation.

The first column in Table 1a 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.[4] Based on these results, in what follows we use "austerity" to refer exclusively to reductions in government purchases.

One concern about these estimates is the possibility that the drop in government spending was a result of a contraction in economic activity caused by some third variable. Technically, our empirical analysis captures correlations in the data that may or may not reflect a causal relationship. To partially address these endogeneity concerns, Table 1b provides evidence on the significance of austerity after controlling for other variables in regression (6). 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. Controlling for TFP also weakens the coefficient to -1.79. Including credit measures (columns (4) through (7)) has very little impact on the estimates, including the specification controling for government debt. Columns (8) through (11) include total revenue and TFP together with each of the credit measures. Depending on the controls, the estimated coefficient on austerity 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 A4b). We take specification (11) and the coefficient 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 market stress.

An additional concern is that austerity policies during this period were 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 2 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. Again, while the results in Tables 1a, 1b and 2 suggest that it is spending austerity – not tax changes, productivity shocks, credit spreads or debt levels – that explains the observed changes in output, the number of statistical controls is necessarily limited. Thus, it is technically possible that some other omitted variable explains both the change in government spending and the change in output.

[3] Tax rates are expressed in percentage points.

[4] 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 A3).

Table 3 reports the impact of austerity on other macroeconomic variables. While these empirical results are interesting in and of themselves, they also provide additional information that we later use to evaluate the performance of our model. In each regression, we include all of the control variables from specification (11) of Table 1b, though the table reports only the coefficients on government purchases. 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}.

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, 2016). 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 et al. (2016), and Nakamura and Steinsson (2014). There 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. The last six columns of Table 3 will be discussed in Section 5.

In summary, we find a robust statistical relationship between austerity, measured as cuts in government spending relative to forecast, and a decline in GDP. The cross-sectional pattern in GDP cannot be explained by TFP, changes in taxes, interest rates or household debt. Austerity is also negatively correlated with declines in consumption and investment and with an increase in net exports.

4. Model

Next we develop a multi-country business cycle model that can explain the observed correlations between austerity and various macroeconomic variables found in Section 3 for fixed and floating exchange rate countries. The model is calibrated to match the economic size and bilateral trade flows of the 29 countries in our sample and incorporates many features from modern monetary business cycle models (e.g. Smets and Wouters, 2007; Christiano et al., 2005), international business cycles models (e.g. Chari et al., 2000), and financial accelerator models (e.g. Bernanke et al., 1999; Brave et al., 2012). 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 written 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 $\pi(s^t)$. Unless confusion arises, we write $X_{n,t}$ for $X_n(s^t)$.

At date 0, the expected discounted sum of future period utilities for a household in country n is given by

$$\sum_{t=0}^{\infty}\sum_{s^t}\pi\left(s^t\right)\beta^t U\left(c_{n,t}, L_{n,t}\right), \tag{7}$$

where $c_{n,t}$ and $L_{n,t}$ denote (state-contingent) consumption and labor allocations, respectively. We set the flow utility function $U(\cdot)$ to

$$U(c_n, L_n) = \frac{1}{1-\frac{1}{\sigma}}\left(c_n - \kappa_n \frac{L_n^{1+\frac{1}{\eta}}}{1+\frac{1}{\eta}}\right)^{1-\frac{1}{\sigma}}, \tag{8}$$

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. This specification follows Greenwood et al. (1988) (GHH hereafter) and assumes 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.

A key feature of the model is a hand-to-mouth restriction on a fraction χ of a household's members in the economy. 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 $c_{n,t}^{htm} \equiv \frac{\bar{C}_n}{\bar{Y}_n} Y_{n,t}$ where the bars indicate steady-state values.[5] The remaining $1-\chi$ members of the representative household choose consumption optimally and thus behave in accordance with the permanent income hypothesis. *Aggregate* consumption is then given by

$$C_{n,t} = (1-\chi)\, c_{n,t} + \chi c_{n,t}^{htm}. \tag{9}$$

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 $c_{n,t}$, labor $L_{n,t}$, next period's capital stock $K_{n,t}$ and current investment $X_{n,t}$ to maximize the expected discounted sum of future period utilities subject to a sequence of budget constraints.

The budget constraint for country n's representative household is

$$\begin{aligned} &P_{n,t}\left[(1+\tau_n^c)c_{n,t} + X_{n,t}\right] + (1-\delta)\,\mu_{n,t}K_{n,t-1} + \sum_{j=1}^{N}\frac{E_{j,t}S_{n,t}^j}{E_{n,t}} + \sum_{s^{t+1}}\frac{\varrho\left(s^t, s_{t+1}\right) b_n(s^t, s_{t+1})}{E_{n,t}} \\ &= \mu_{n,t}K_{n,t} + (1-\tau_n^L)W_{n,t}L_{n,t} + (1-\tau_n^{\Pi})\Pi_{n,t}^f + \sum_{j=1}^{N}\frac{E_{j,t}\left(1+i_{j,t-1}\right)S_{n,t-1}^j}{E_{n,t}} + \frac{b_n(s^{t-1}, s_t)}{E_{n,t}} + \mathbb{T}_{n,t}. \end{aligned} \tag{10}$$

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 $S_{n,t}^j$ be the number of bonds denominated in country j's currency and held by the representative agent in country n. The gross nominal interest rate for country n's bonds is $1+i_{n,t}$. The nominal exchange rate to convert country n's currency into the reserve currency is $E_{n,t}$.

The right side of the budget constraint reflects the household's income. The household earns nominal wages net of labor taxes $(1-\tau_n^L)W_{n,t}L_{n,t}$, nominal payments for sales of capital $\mu_{n,t}K_{n,t-1}$ and profits from intermediate good firms net of taxes on profits, $(1-\tau_n^{\Pi})\Pi_{n,t}^f$. Here $W_{n,t}$ is the nominal wage, τ_n^L is a constant

[5]Technically, our specification for the hand-to-mouth consumers assumes that they spend a fixed share of domestic absorption $Y_{n,t}$ rather than a fixed share of nominal national income $p_{n,t}Q_{n,t}$. Quantitatively there is only a small difference between these specifications.

labor tax rate, $\mu_{n,t}$ is the nominal price of capital, $\Pi^f_{n,t}$ are nominal profits of intermediate goods firms and τ^{Π}_n is the constant tax rate on profits. We assume that households sell capital to entrepreneurs and then subsequently repurchase the undepreciated capital. This assumption is convenient for introducing financial market imperfections later. The household also receives lump-sum transfers $\mathbb{T}_{n,t}$. This transfer includes nominal lump-sum taxes or transfers $T_{n,t}$, profits from the financial sector and entrepreneurs, $\Pi^{fin}_{n,t} + \Pi^e_{n,t}$, and the nominal amount consumed by hand-to-mouth consumers, $P_{n,t}c^{htm}_{n,t}$ where $P_{n,t}$ is the nominal price of the final good.[6] Thus,

$$\mathbb{T}_{n,t} \equiv -T_{n,t} + \Pi^e_{n,t} + \Pi^{fin}_{n,t} - P_{n,t}c^{htm}_{n,t}. \tag{11}$$

The household also faces the capital accumulation constraint:

$$K_{n,t} = K_{n,t-1}(1-\delta) + \left[1 - f\left(\frac{X_{n,t}}{X_{n,t-1}}\right)\right] X_{n,t}, \tag{12}$$

with $f(1) = f'(1) = 0$ and $f''(1) \geq 0$, as in Christiano et al. (2005).

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

$$\varrho\left(s^t, s_{t+1}\right)\frac{U_{1,n,t}}{E_{n,t}P_{n,t}} = \beta\pi(s^{t+1}|s^t)\frac{U_{1,n,t+1}}{E_{n,t+1}P_{n,t+1}} \tag{13}$$

and

$$\frac{U_{1,n,t}}{E_{n,t}P_{n,t}} = \frac{U_{1,m,t}}{E_{m,t}P_{m,t}}, \tag{14}$$

where $U_{j,n,t}$ denotes the derivative of $U(c_{n,t}, L_{n,t})$ with respect to its j^{th} argument.

The labor supply condition is

$$-\frac{U_{2,n,t}}{U_{1,n,t}} = \left(\frac{1-\tau^L_n}{1+\tau^c_n}\right)\frac{W_{n,t}}{P_{n,t}}. \tag{15}$$

Finally, the optimal choice for investment and capital requires

$$1 = \frac{\mu_{n,t}}{P_{n,t}}\left\{1 - f_{n,t} - \frac{X_{n,t}}{X_{n,t-1}}f'_{n,t}\right\} + \beta\frac{U_{1,n,t+1}}{U_{1,n,t}}\frac{\mu_{n,t+1}}{P_{n,t+1}}\left(\frac{X_{n,t+1}}{X_{n,t}}\right)^2 f'_{n,t+1}, \tag{16}$$

where we write $f_{n,t} = f\left(\frac{X_{n,t}}{X_{n,t-1}}\right)$.

4.2. Firms

There are three types of firms in the model. The first type, referred to as "final goods producers", are firms that combine tradable intermediate inputs to produce a final nontraded good for private consumption and investment and for government purchases. The two other types of firms produce tradable intermediate goods in a two-stage process. 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. In the second stage, competitive firms combine the input varieties into the tradable intermediate good. Neither capital nor labor can be moved across countries. Below, we describe the production chain of these three types of firms in detail, beginning with 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.

[6] 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 $(1+i_{n,t})F(\lambda_{n,t})$. 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.

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

$$\max_{q_{n,t}(\xi)} \left\{ p_{n,t} Q_{n,t} - \int_0^1 \varphi_{n,t}(\xi)\, q_{n,t}(\xi)\, d\xi \right\} \tag{17}$$

subject to the CES production function

$$Q_{n,t} = \left[\int_0^1 q_{n,t}(\xi)^{\frac{\psi_q - 1}{\psi_q}}\, d\xi \right]^{\frac{\psi_q}{\psi_q - 1}}. \tag{18}$$

Here $Q_{n,t}$ is the real quantity of country n's tradable intermediate good produced at time t. The variable ξ indexes the continuum of differentiated varieties and the parameter $\psi_q > 1$ governs the degree of substitutability across varieties. The nominal price of each variety is $\varphi_{n,t}(\xi)$ and its quantity is $q_{n,t}(\xi)$. Demand for each variety has an iso-elastic form

$$q_{n,t}(\xi) = Q_{n,t} \left(\frac{\varphi_{n,t}(\xi)}{p_{n,t}} \right)^{-\psi_q}. \tag{19}$$

The competitive price of the intermediate $p_{n,t}$ is a combination of the prices of the varieties,

$$p_{n,t} = \left[\int_0^1 \varphi_{n,t}^{1-\psi_q} d\xi \right]^{\frac{1}{1-\psi_q}}. \tag{20}$$

First-Stage Intermediate Producers. The varieties $q_{n,t}(\xi)$ are produced by first-stage intermediate producers that hire workers at the nominal wage $W_{n,t}$ and rent capital at the nominal rental price $R_{n,t}$. These firms have Cobb-Douglas production functions

$$q_{n,t}(\xi) = Z_n \left[k_{n,t}(\xi) \right]^{\alpha} \left[l_{n,t}(\xi) \right]^{1-\alpha}, \tag{21}$$

where Z_n measures (constant) total factor productivity. Because first-stage producers are monopolistically competitive, they typically charge a markup for their products. The desired price naturally depends on the demand curve (19). Each variety good producer ξ freely chooses capital and labor each period. Cost minimization implies that the nominal marginal cost is

$$MC_{n,t} = \frac{W_{n,t}^{1-\alpha} R_{n,t}^{\alpha}}{Z_n} \left(\frac{1}{1-\alpha} \right)^{1-\alpha} \left(\frac{1}{\alpha} \right)^{\alpha}. \tag{22}$$

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

$$\max_{\varphi_{n,t}^*} \sum_{j=0}^{\infty} (\theta\beta)^j \sum_{s^{t+j}} \pi(s^{t+j}|s^t) \frac{U_{1,t+j}}{(1+\tau_n^c) P_{n,t+j}} \left(\varphi_{n,t}^* - MC_{n,t+j} \right) Q_{n,t+j} \left(\frac{\varphi_{n,t}^*}{p_{n,t+j}} \right)^{-\psi_q}. \tag{23}$$

We denote the optimal reset price as $\varphi_{n,t}^*$. Because the first-stage intermediate producers adjust their prices infrequently, the nominal price of the tradable intermediate goods is sticky. In particular, using (20), the nominal price of the tradable intermediate good evolves according to

$$p_{n,t} = \left[\theta p_{n,t-1}^{1-\psi_q} + (1-\theta) \left(\varphi_{n,t}^* \right)^{1-\psi_q} \right]^{\frac{1}{1-\psi_q}}. \tag{24}$$

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) constant-returns-to-scale 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 and therefore make zero profits. The final goods producers solve

$$\max_{y^j_{n,t}} \left\{ P_{n,t} Y_{n,t} - \sum_{j=1}^{N} \frac{E_{j,t}}{E_{n,t}} p_{j,t} y^j_{n,t} \right\} \tag{25}$$

subject to the CES production function

$$Y_{n,t} = \left(\sum_{j=1}^{N} \left(\omega^j_n\right)^{\frac{1}{\psi_y}} \left(y^j_{n,t}\right)^{\frac{\psi_y - 1}{\psi_y}} \right)^{\frac{\psi_y}{\psi_y - 1}}. \tag{26}$$

Here, $y^j_{n,t}$ is the amount of country-j intermediate good used in production by country n. The parameter ψ_y governs the degree of substitutability across the tradable intermediate goods and the preference weights satisfy $\omega^j_n \geq 0$ with $\sum_{j=1}^{N} \omega^j_n = 1$ for each country n. The country-pair-specific ω^j_n parameters are later calibrated to match data on bilateral import shares.

Demand for country-specific intermediate goods is isoelastic:

$$y^j_{n,t} = Y_{n,t} \omega^j_n \left[\frac{E_{j,t}}{E_{n,t}} \frac{p_{j,t}}{P_{n,t}} \right]^{-\psi_y}. \tag{27}$$

The implied nominal price of the final good is

$$P_{n,t} = \left(\sum_{j=1}^{N} \omega^j_n \left(\frac{E_{j,t}}{E_{n,t}} p_{j,t} \right)^{1-\psi_y} \right)^{\frac{1}{1-\psi_y}}. \tag{28}$$

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.

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 et al. (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 (see also Brave et al., 2012, for the same approach).

Formally, at the end of period t, entrepreneurs purchase capital $K_{n,t}$ from the households at the nominal price $\mu_{n,t}$ per unit. Entrepreneurs finance these purchases with their own internal funds (net worth) and intermediated borrowing. Let end-of-period nominal net worth be $P_{n,t} NW_{n,t}$, denominated in country n's currency. Then, to purchase capital, the entrepreneur borrows $B_{n,t} = \mu_{n,t} K_{n,t} - P_{n,t} NW_{n,t}$ units from the households in their country. The nominal interest rate on business loans equals the nominal interest rate on government bonds times an external finance premium $F(\lambda_{n,t}) \equiv F_{n,t}$ with F' and $F'' > 0$ and $F(1) = 1$. Here, $\lambda_{n,t} = \frac{\mu_{n,t} K_{n,t}}{P_{n,t} NW_{n,t}}$ is the leverage ratio. The interest rate is then $(1 + i_{n,t}) F_{n,t}$. 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 $(1-\tau_n^K)u_{n,t+1}R_{n,t+1}$ and then sell the undepreciated capital back to the households at the capital price $\mu_{n,t+1}$. Depreciation costs are tax deductible. Varying the utilization of capital requires $K_{n,t}a\left(u_{n,t+1}\right)$ units of the final good. Each period, a fraction $(1-\gamma_n)$ of the entrepreneurs' net worth is transferred to the households. We set $\gamma_n = \frac{\beta}{F_n}$ so that net worth is constant in a stationary equilibrium.

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

$$\frac{NW_{n,t+1}}{\gamma_n} = K_{n,t}\left[(1-\tau_n^K)u_{n,t+1}\frac{R_{n,t+1}}{P_{n,t+1}} + \frac{\mu_{n,t+1}}{P_{n,t+1}}(1-\delta(1-\tau_n^K)) - a\left(u_{n,t+1}\right)\right] - \frac{(1+i_{n,t})F_{n,t}}{P_{n,t+1}}B_{n,t}. \tag{29}$$

The utilization choice requires the first-order condition

$$(1-\tau_n^K)\frac{R_{n,t}}{P_{n,t}} = a'\left(u_{n,t}\right). \tag{30}$$

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

The first-order condition for the choice of $K_{n,t}$ requires

$$\frac{\mu_{n,t}(1+i_{n,t})F_{n,t}}{P_{n,t+1}} = \sum_{s^{t+1}}\pi(s^{t+1}|s_t)\left[(1-\tau_n^K)u_{n,t+1}\frac{R_{n,t+1}}{P_{n,t+1}} + \frac{\mu_{n,t+1}}{P_{n,t+1}}\left(1-\delta(1-\tau_n^K)\right) - a\left(u_{n,t+1}\right)\right]. \tag{31}$$

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

4.4. Government Policy

Government purchases follow an auto-regressive process

$$G_{n,t} = \left(1-\rho_G\right)\bar{G}_n + \rho_G G_{n,t-1} + \varepsilon_{n,t}^G, \tag{32}$$

where $\bar{G}_n$ indicates the steady-state level of government purchases. The government raises revenue by imposing taxes on consumption, labor income, capital income and monopoly profits at constant rates. In periods where revenue falls short of expenditures, the government imposes a lump sum tax on households.[7]

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. Below, υ_n is calibrated to match the oberseved (country-specific) home bias of government purchases.

In countries with floating exchange rates, monetary policy is conducted through a Taylor Rule that targets the nominal interest rate. The Taylor Rule has the form

$$1+i_{n,t} = \phi_i\left(1+i_{n,t-1}\right) + \left(1-\phi_i\right)\left[\left(\frac{GDP_{n,t}}{\overline{GDP}_n}\right)^{\phi_{GDP}}\left(\pi_{n,t}\right)^{\phi_\pi} + \bar{\imath}_n\right] + \varepsilon_{n,t}^i, \tag{33}$$

where $GDP_{n,t}$ is country n's real GDP, $\overline{GDP}_n$ its steady-state value, $\pi_{n,t}$ is country n's inflation and $\bar{\imath}_n$ is the steady-state nominal interest rate. For simplicity the reaction parameters ϕ_{GDP}, ϕ_π and ϕ_i are assumed to be common across countries.

[7] 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 A2a 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.

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 (33) with the exception that monetary policy reacts to the GDP-weighted average of innovations in GDP and inflation for the countries in the union. 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) given by

$$Q_{n,t} = Z_n \left(u_{n,t} K_{n,t-1}\right)^{\alpha} L_{n,t}^{1-\alpha}. \tag{34}$$

Market clearing for the intermediate goods produced by country n is

$$Q_{n,t} = \left(\sum_{j=1}^{N} \frac{\mathbb{N}_j}{\mathbb{N}_n} y_{j,t}^{n} \right) + \upsilon_n G_{n,t}. \tag{35}$$

The market clearing condition for the final good is

$$Y_{n,t} = C_{n,t} + X_{n,t} + (1-\upsilon_n) G_{n,t} + a\left(u_{n,t}\right) K_{n,t-1}. \tag{36}$$

Finally, the bond market clearing conditions require

$$\sum_{n=1}^{N} \mathbb{N}_n S_{n,t}^{j} = \sum_{n=1}^{N} \mathbb{N}_n b_n(s^t, s_{t+1}) = 0 \qquad \forall j, s_{t+1}. \tag{37}$$

Since final goods are not traded, net exports are comprised entirely of intermediate goods. For each country n, nominal net exports are the value of production less the value of domestic absorption:

$$NX_{n,t} = p_{n,t}\left(Q_{n,t} - \upsilon_n G_{n,t}\right) - P_{n,t} Y_{n,t}, \tag{38}$$

where the second equality follows from the zero profit condition for the final goods producers. Then, nominal GDP can be written as

$$NGDP_{n,t} = p_{n,t} Q_{n,t} = NX_{n,t} + P_{n,t}\left[C_{n,t} + X_{n,t} + G_{n,t} + a\left(u_{n,t}\right) K_{n,t}\right]. \tag{39}$$

Real GDP is $GDP_{n,t} = \bar{p}_n Q_{n,t}$, i.e. it is calculated using a fixed price deflator in which the base year prices are chosen as corresponding to the steady state).

4.6. Steady state and Calibration

The model is solved with a first-order approximation of the equilibrium conditions around the model's non-stochastic steady state with zero inflation. Table 4 provides a summary of the benchmark parameters.

Preferences. The subjective time discount factor β is set 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 in the original study by Campbell and Mankiw (1989) and is consistent with the calibration in Martin and Philippon (2017).

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 form of the investment adjustment cost $f(\cdot)$ implies a relationship between investment growth and Tobin's Q. We adopt the value $f''(1) = 2.48$ from Christiano et al. (2005) which implies that a one percent increase in Q causes investment to increase by roughly 0.4 percent. For the utilization cost function 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.

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

$$\frac{1}{\beta}\bar{F}_n = \left(1-\tau_n^K\right)\frac{\bar{R}_n}{\bar{P}_n} + \left(1-\delta\left(1-\tau_n^K\right)\right), \tag{40}$$

where steady state interest rate spreads are $\bar{F}_n \equiv F_n\left(\bar{\lambda}_n\right)$. These external finance premia 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.Given values for $\bar{F}_n$, the equation above determines the real rental price of capital $\bar{R}_n/\bar{P}_n$ in each country.

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.[8] The calibration for the leverage ratio lev_n adopts the value from Brave et al. (2012) for the U.S ($lev = 2.11$).

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). TiVA has information on the value added content 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 using averages for 2005 and 2010.

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 the shares of net exports relative to domestic absorbtion $\overline{NX}_n/\bar{Y}_n$ are matched.

The elasticity of substitution between home and foreign goods, 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 (2017) and Proebsting (2015) find elasticities close to 1.5. We consider higher elasticities in the sensitivity analysis below.

Price Rigidity. The Calvo price setting hazard is set to roughly match observed frequencies of price adjustment in the micro data. In their sample of European countries, Alvarez et al. (2006) find that the average duration of prices is 13 months. This corresponds to $\theta = 0.80$ for a quarterly model.

[8] In Bernanke et al. (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.

Fiscal and Monetary Policy. Steady-state values of government purchases, $\bar{G}_n$, are set to match each country's average value from 2000-2010. 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. We take these shares from the World Input Output Database (it is not available in the TiVA database). On average, the value for υ_n is 0.86, indicating that government purchases exhibit a stronger home bias than private purchases.

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 et al., 2011).

We use implicit tax rates to calibrate the values for τ_n^C, τ_n^L and τ_n^K, and set the profit tax rate equal to the capital tax rate, $\tau_n^{\Pi} = \tau_n^K$. Calculation of tax rates for consumption, labor and capital builds on Mendoza et al. (1994) and Eurostat (2014) and are based on data from the National Tax Lists. 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. We use the average over 2005 through 2009. Table A9 in the Appendix includes a list of all countries, implicit tax rates, shares of government purchases in GDP, import shares of government purchases and financial market spreads.

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 et al. (2000).

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, the model features monetary policy shocks.

Austerity Shocks. Government purchase shocks are based on forecast errors from equation (1). Annual forecast errors are interpolated to quarterly series 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 et al. (2000):

$$i_{n,t} = \phi_i i_{t-1} + (1-\phi_i)\left[r_n + \phi_\pi\left(\pi_{n,t} - \pi_n^*\right) + \phi_{GDP}\left(\ln GDP_{n,t} - \ln \overline{GDP}_{n,t}\right)\right] + \varepsilon_{n,t}^i, \tag{41}$$

where $i_{n,t}$ is the nominal (annualized) interest rate, r_n is the long-run (annualized) interest rate, $\pi_{n,t}$ is (annualized) inflation, π_n^* is the inflation target, $\ln GDP_{n,t} - \ln \overline{GDP}_{n,t}$ is the log deviation of real GDP from its trend, and $\varepsilon_{n,t}^i$ is a structural shock. We impose the values $\phi_i = 0.75$, $\phi_\pi = 1.5$ and $\phi_{GDP} = 0.5$ from our calibration and then estimate the intercept for each of the central banks in our model that have an independent monetary policy. Given our estimates of the intercepts, the monetary policy shocks can then be recovered as $\hat{\varepsilon}_{n,t}^i = i_{n,t} - \hat{i}_{n,t}$.

5. Model and Data Comparison

In this section, we feed the estimated structural shocks for the 2005-2014 period into the model and compare simulated data with actual data.

5.1. Benchmark Model Performance

The benchmark model includes austerity shocks and monetary policy shocks for the baseline calibration given in Table 4. Table 3 shows a comparison of the cross-sectional OLS estimates on austerity for the period 2010-2014 generated by the model and the data. Overall, the 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 coefficient on GDP is 1.77; the corresponding coefficient in the model is 1.94. 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 purchase shortfalls is 0.44 in the data and 0.39 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.

Figure 4 compares scatterplots of actual data for GDP, net exports and inflation (the left panels) with scatterplots of the corresponding simulated data (the right panels).[9] 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 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 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 (reflected in the intercept in Figure 4). 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 at the zero lower bound (ZLB), 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 et al. (2011) and Blanchard et al. (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, but are not captured by our model (see e.g. Kollmann et al., 2016).

The last three columns of Table 3 report the results when monetary policy shocks are removed. This leaves the coefficients virtually unchanged for countries in the euro area. Removing monetary shocks for floating exchange rate countries, however, reduces the cross-sectional coefficient on output for 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 coefficient for floating exchange rate countries falls to 1.00, half the size of the coefficient for fixed exchange rate countries. This is in line with studies emphasizing the strong effects of fiscal policy in currency unions (see e.g. Farhi and Werning, 2016).

As emphasized in the discussion of the empirical results in Section 2, it is possible that the observed relationship between spending and output is driven by some third variable that is correlated with both. Here we consider the effects of several other potential shocks that could drive changes in economic activity. We examine shocks to monetary policy, financial markets, consumption taxes (VAT), labor taxes, capital taxes and TFP. For each shock, we simulate the model and compare the model-generated variables with the data. Table 5 reports pseudo-R^2 measures of fit, given by

$$\text{pseudo-}R^2 = 1 - \frac{\sum_{i=1}^{N}\left(\tilde{x}^{\text{data}}_{i,2010-2014} - \tilde{x}^{\text{model}}_{i,2010-2014}\right)^2}{\sum_{i=1}^{N}\left(\tilde{x}^{\text{data}}_{i,2010-2014}\right)^2} \tag{42}$$

for each variable x. If any one of the shocks in the table, such as TFP, were responsible for the economic performance in Europe, one would expect the fit of the model-generated data to actual data to be good. A perfect fit would result in a pseudo-R^2 measure of 1.00. Column (1) in the table reports the fit for the benchmark model which includes two shocks: austerity shocks and monetary shocks. For most variables the

[9] Note, the plot of the actual data conditions on total revenue, TFP and government debt to GDP (i.e., specification 11 in Table 1b). 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.

fit is quite good with the main exception being the fit for GDP growth and the exchange rate. Column (2) shows that the fit remains good if we confine our attention to austerity shocks alone. Columns (3)–(8) report the fit for other shocks. These measures are uniformly poor indicating that none of these other shocks would produce patterns like those observed in the data. Perhaps the most consequential of these shocks is the financial market shock which has an R^2 with GDP of 0.22. This is still not as informative as the austerity shocks which have an R^2 of 0.67. Surprisingly, the tax shocks and TFP shocks actually have negative pseudo-R^2's indicating that they produce results that are at odds with the observations. The high pseudo-R^2 measures for austerity shocks gives us confidence that, while we cannot claim to have econometrically identified exogenous shocks to government spending, austerity seems to be the most likely cause of the variation in recovery paths observed across Europe.

Summing up our results so 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 effects of austerity 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) - (9) 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, several mechanisms act to magnify the reaction of output to a change in government spending. These mechanisms include the share of hand-to-mouth consumers, the financial accelerator, the trade elasticity and the trade share of government purchases. In the table, we examine how each of these features changes the effects of austerity in the model.

Column (3) shows the results when we relax the assumption of GHH preferences, and instead assume preferences that are separable in consumption and leisure. Under separable preferences the cross-sectional coefficient falls from 1.94 to 1.60, with most of the difference due to a weaker response of consumption spending. GHH preferences play a somewhat less prominent role in our setting 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).[10] 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 (see also Galí et al., 2007). Eliminating the hand-to-mouth constraint (column (4)) lowers the coefficient for output to 1.38, again mainly due to a weak response in consumption.[11]

[10] 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.

[11] We assume the same share of hand-to-mouth consumers across countries. Martin and Philippon (2017) report country-specific hand-to-mouth ratios for eleven countries in the euro area. Using these country-specific shares increases the estimated coefficient for the fixed exchange rate countries somewhat, mostly because the estimates by Martin and Philippon (2017) suggest that austere countries had particularly high shares of hand-to-mouth consumers.

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 -0.09 instead of -0.93 in our benchmark specification.

Columns (6) and (7) illustrate the influence of monetary policy on the cross-sectional effects of austerity. Column (6) shows results for a case of more accomodative monetary policy in which Taylor rule parameters are reduced to $\phi_{GDP} = \phi_\pi - 1 = 0.1$. The effects of austerity for the fixed exchange rate countries change only slightly. As emphasized by Nakamura and Steinsson (2014), the stance of monetary policy has little effect on the cross-sectional coefficient *in a monetary union*. For countries outside the currency union, the change to the Taylor rule increases the output coefficient from 1.56 to 2.55. 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.

Column (7) 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.[12] The monetary policy rules for the countries outside the euro remain the same. The ZLB specification has essentially no effect on the cross-sectional output coefficients 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 about 10 percent. At the ZLB, the decline is roughly 16 percent. In contrast, the cross-sectional relationship is unchanged.

To summarize, several amplification mechanisms generate large effects of austerity in the cross-section. Labor-consumption complementarities, hand-to-mouth consumers, and the financial accelerator make aggregate consumption and investment demand more responsive to changes in current income. Because monetary policy is the same across the euro area, variations in monetary policy (including the ZLB) leave the implied cross-sectional effect of austerity unchanged.

5.3. The Effects of Austerity in Integrated Economies

The countries in our model are linked by trade, capital markets, and, for some countries, a shared monetary policy. 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 and exchange rate adjustments, both of which serve to reduce the impact of austerity. Because our model is calibrated to observed trade shares, there will be cross-country heterogeneity in the impact of austerity on economic activity and the magnitude of spillover effects.

Column (8) of Table 6 considers the consequences of a higher elasticity of substitution between home and foreign goods ($\psi_y = 2$ instead of $\psi_y = 0.5$). The higher elasticity makes it easier to export excess supply of the home good, reducing the effect on GDP and increasing the effect on net exports. Our benchmark specification assumes that government purchases are primarily comprised of domestic goods and services

[12] 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.

while private consumption and investment goods have higher import shares. In column (9), we reduce the home bias of government expenditures to that of consumption and investment ($\upsilon = 0$) keeping overall import shares unchanged. With this increase in openness, the output coefficient falls from 1.94 to 1.63.

The multi-country model reveals that there is a strong negative relationship between the effect of austerity on domestic production and import shares within the currency union. Figure 6 illustrates this relationship by plotting domestic multipliers against each country's import share. We calculate the multiplier as the change in a country's GDP in response to an increase of domestic government purchases by 1 percent of GDP during the 2010 - 2014 period, holding spending in other countries constant. This figure makes three points. First, the figure shows that there is substantial variation in domestic multipliers across Europe due to differences in trade openness. Second, for countries with fixed exchange rates, there is an inverse relationship between the impact of government spending and the import share. Larger import shares imply that part of the increased demand due to stimulus would be met by an increase in imports.[13] Third, holding import shares fixed, there remains a clear difference between the economies within the euro and economies with floating exchange rates. Countries with floating exchange rates experience offsetting adjustments to monetary policy, weakening the effect of austerity. There is an adjustment in monetary policy in the euro area but, since it is responding to euro-area wide GDP, the offsetting effects are much smaller and thus the impact of austerity remains large.

Openness to trade is also important for spillover effects from austerity. To illustrate the extent of spillovers we consider the impact of changes in government spending in the rest of Europe assuming that there is no change in domestic government spending. Figure 7 includes results both with (the dark heavy bar) and without the ZLB (the thin light bar). For example, assuming the euro is at the ZLB, if the rest of Europe increased spending by 1 percent of European GDP, Greek GDP would increase by 0.8 percent. This occurs because demand for Greek exports increases with European demand. On the other hand, if monetary policy in Europe adjusts to the increase in government spending, then Greek output falls by nearly 1.5 percent (the thick dark bar). This is because the contractionary effects of monetary policy outweigh the spillover effects operating through trade. (Recall that Greece has a relatively small import share.) For countries with higher trade shares, such as Luxembourg, the spillover effect through trade becomes stronger. This finding is consistent with estimated regional spillover effects of government spending, particularly during recessions (see e.g. Auerbach and Gorodnichenko, 2013). Finally, the economies with floating exchange rates all experience contractions. The increased demand in Europe causes input prices to rise across the region. For the floating exchange rate economies, monetary policy reacts to this imported inflation by raising interest rates, which reduces GDP.

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. The "No Austerity" experiment removes all negative government spending shocks from our benchmark model. 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 8 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 for the GIIPS economies quite well but less so for the EU10. Actual GDP falls by almost 17 percent in the GIIPS economies

[13] For floating exchange rate countries, the relationship is less clear and might even be positive, similar to the finding in Cacciatore and Traum (2018).

and by 18 percent in the benchmark model. In contrast, when austerity is eliminated, output in the GIIPS group would have increased by roughly one percent.[14] 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 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, calculate 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 A9 in the Appendix—are 21 percent, 33 percent and 26 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. A potential limitation of this approach is that we abstract from endogenous changes in sovereign risk premia. To the extent that some countries faced escalating interest rate premia in 2010-2014 our exclusion of interest payments on the debt may be understating the full impact of austerity on a nation's debt trajectory. Whether investors took austerity measures as a positive or a negative signal with regard to debt sustainability remains an open question (see e.g. Born et al., 2014).

The middle panels in Figure 8 show the actual and simulated time paths for the debt-to-GDP ratio relative to its end of 2009 value. 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 the direct effects of 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 2009 to 2014 for the GIIPS region. In contrast, our benchmark model with the ZLB predicts an *increase* of 17 percentage points, roughly as large as that observed in the data.

The strong discrepancy between the "static" debt-to-GDP ratio and the benchmark debt-to-GDP ratio is driven by three endogenous responses captured by our model: First, fiscal consolidations cause reductions in GDP. Second, at the ZLB, austerity abroad further reduces GDP. Third, these reductions in GDP lead to lower tax revenues. All these effects lead to an increase in the debt-to-GDP ratio.

Looking at the euro area as a whole, our model suggests that austerity during the 2010-2014 period was "self-defeating" in the sense that debt-to-GDP ratios rose in response to the observed cuts in government spending. This is reminiscent of DeLong and Summers (2012) and Denes et al. (2013) who argue that a cut in government spending can perversely boost debt levels during a liquidity trap. Indeed, the empirical analysis in Fatás and Summers (2018) suggests that austerity in Europe caused debt-to-gdp ratios to rise as they do in our quantitative framework.

Figure 8 shows that debt-to-GDP ratios would have been lower in the euro area had no country implemented austerity. A separate question is whether austerity implemented by *individual* countries was self-defeating. To get at this question, we simulate our benchmark model (with the ZLB) for each country

[14] 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.

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 all other countries. The dark bars in Figure 9 correspond to the change in the debt-to-GDP ratio for each country for the benchmark simulation with austerity across Europe. The light bars correspond to the change in the debt-to-GDP ratio for each country when all other countries pursue austerity.

The figure reveals that spillovers coming from other countries' austerity measures led to an increase of the debt-to-GDP ratio of about 8 percentage points for the typical country in the euro area. For some countries, these spillovers—as opposed to domestic austerity—were the main reason why debt ratios went up. For other countries, domestic austerity also played a role: For Greece, the model indicates that domestic austerity raised Greece's debt-to-GDP ratio by 35 percentage points, whereas domestic austerity in Ireland reduced Ireland's debt-to-GDP ratio by about 8 percentage points. Austerity was therefore self-defeating for only some countries (like Greece), but not all. This large variation across countries partially reflects the size of the austerity packages, but also initial debt-to-GDP positions and the size of the domestic multipliers depicted in Figure 6.

Europe Without the Euro. The third set of panels in Figure 8 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.[15] 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 3 and 8 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 rates would stimulate exports and output.[16]

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, clear patterns emerge. Taken as a whole, we conclude that differences in austerity played an important role in accounting for differences in economic performance across countries. Specifically, contractions in government purchases are strongly associated with reductions in output.

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 the large estimated impact of austerity 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 has two

[15] Although the euro area itself was close to 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.

[16] See Figure A12 in the Appendix for the path of implied effective exchange rates for this experiment.

effects on the impact of country-specific austerity on economic activity. On the one hand, trade integration helps to mitigate the impact of austerity through spillovers to its trading partners. On the other hand, because monetary policy in the euro area is common to all countries, country-specific austerity shocks have larger effects relative to a flexible exchange rate regime. Our analysis, which incorporates both effects, 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 in certain European countries.

This paper emphasizes countries' variation in response to austerity, both implemented at home and abroad, and links this variation to countries' trade exposure, size, and monetary regime, among other factors. While the focus of our paper has been on fiscal policy, we believe that this variation in countries' sensitivity to economic shocks is particularly pertinent for countries in a currency union, in which monetary policy is substantially harder to tailor to national needs. Further investigating this variation and how it constrains policy choices would be a fruitful avenue for future research.

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Table 1a: 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 (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 1b: 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					−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 (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 its 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 2: 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	0.07	0.03	0.17	−0.03	0.07
	(0.02)		(0.02)		(0.03)	
Social Benefits	0.00	0.00	0.00	0.01	−0.01	0.05
	(0.01)		(0.01)		(0.01)	
Total Revenue	0.02	0.27	0.02	0.34	0.01	0.10
	(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	0.04
	(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 along the lines of (6) without any controls, as well as its R^2. The independent variable is the government debt to GDP ratio at the end of 2009. The dependent variables are forecast errors of government purchases, social benefits, 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 3: COMPARISON OF MODEL AND DATA

	Data			Benchmark			Only aust. shocks		
	All	Fix	Float	All	Fix	Float	All	Fix	Float
GDP	-1.77	-1.79	-1.70	-1.93	-2.03	-1.55	-1.76	-2.03	-1.00
	(0.20)	(0.24)	(0.40)						
Inflation	-0.44	-0.57	-0.17	-0.39	-0.50	-0.11	-0.35	-0.50	0.06
	(0.10)	(0.12)	(0.20)						
Consumption	-1.18	-1.20	-1.04	-1.19	-1.22	-1.02	-1.08	-1.22	-0.71
	(0.18)	(0.21)	(0.36)						
Investment	-1.29	-1.43	-0.92	-0.93	-0.98	-0.72	-0.79	-0.99	-0.27
	(0.16)	(0.19)	(0.31)						
Net Exports over GDP	1.43	1.61	0.91	1.20	1.19	1.19	1.13	1.19	0.97
	(0.20)	(0.22)	(0.37)						
Exchange Rate	-0.77	0.44	-2.92	-0.21	-0.11	-0.56	-0.30	-0.10	-0.90
	(0.36)	(0.30)	(0.50)						
GDP Growth	-0.52	-0.50	-0.51	-0.41	-0.49	-0.18	-0.38	-0.50	-0.07
	(0.08)	(0.10)	(0.17)						

Notes: Table displays the regression coefficients on government purchases (α in regression (6) and for the coefficients 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 1b. 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, the nominal effective exchange rate and the real per capita GDP growth rate. 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. 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 4: Calibration

Description	Parameter	Value	Source / Target
Preferences			
Discount factor (quarterly)	β	0.99	Standard value
Intertemporal elasticity of substitution	σ	0.5	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 (2017)
Trade and Country Size			
Trade preference weights	ω_n^j	x	OECD Trade in Value Added Dataset
Elasticity of substitution for intermediates	ψ_y	0.5	e.g. Heathcote and Perri (2002), Cravino (2017), 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 et al. (2005)
Elasticity of substitution for 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 spending 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 et al. (2000)
Taylor rule GDP coefficient	ϕ_{GDP}	0.5	Clarida et al. (2000)
Taylor rule inflation coefficient	ϕ_π	1.5	Clarida et al. (2000)

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

Table 5: Goodness of Fit: Alternative Shocks

	(1) Bench-mark	(2) Aust. shocks	(3) Mon. pol. shocks	(4) Financ. shocks	(5) Cons. tax shocks	(6) Lab. tax shocks	(7) Cap. tax shocks	(8) TFP shocks
GDP	0.66	0.67	0.03	0.22	0.02	0.01	0.01	−0.19
Inflation	0.51	0.53	−0.12	0.02	−0.66	−0.19	0.07	−1.94
Consumption	0.58	0.57	0.05	0.16	0.02	0.01	0.01	−0.46
Investment	0.39	0.36	0.06	0.33	−0.05	−0.04	0.06	−0.84
Net Exports over GDP	0.72	0.72	0.06	0.20	−0.05	−0.07	0.06	−1.49
Exchange Rate	0.15	0.22	−0.12	0.01	−0.00	−0.01	0.01	−0.36
GDP Growth	0.13	0.08	0.05	−0.09	0.06	0.08	0.02	−0.10

Notes: Table presents the goodness of fit of the model for various shocks and outcome variables. The benchmark model (column 1) includes both austerity and monetary policy shocks. The remaining columns refer to model simulations with only one type of shock at a time. Financial shocks are shocks to the interest rate spreads for loans extended to entrepreneurs (i.e., interest rates paid by entrepreneurs are now given by $\left(1+i_n\left(s^t\right)\right)F(\lambda_n\left(s^t\right))e^{\epsilon_n^F\left(s^t\right)}$, where $\epsilon_n^F\left(s^t\right)$ is a shock to the interest rate spread). The tax shocks refer to consumption taxes (τ_C), labor taxes (τ_L) and capital taxes (τ_K). TFP shocks are shocks to total factor productivity (Z). The goodness of fit reported for each outcome variable and each simulation is calculated as pseudo-$R^2 = 1 - \frac{\sum_{i=1}^N\left(\tilde{x}_{i,2010-2014}^{\text{data}} - \tilde{x}_{i,2010-2014}^{\text{model}}\right)^2}{\sum_{i=1}^N\left(\tilde{x}_{i,2010-2014}^{\text{data}}\right)^2}$

Table 6: Alternative Model Specifications

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	International Dimension (8)	(9)
	Data	Bench-mark	Separable preferences	No rule of thumb	No financial accelerator	Passive mone-tary policy	ECB at ZLB	High trade elasticity	High trade share for G
All									
GDP	−1.77	−1.94	−1.60	−1.38	−1.15	−2.19	−2.04	−1.16	−1.63
Inflation	−0.44	−0.39	−0.11	−0.27	−0.39	−0.79	−0.43	−0.12	−0.43
Consumption	−1.18	−1.20	−0.54	−0.36	−0.70	−1.37	−1.30	−0.93	−1.04
Investment	−1.29	−0.93	−0.72	−0.67	−0.09	−1.11	−1.00	−0.65	−0.78
Net Exports over GDP	1.43	1.21	0.69	0.66	0.67	1.31	1.28	1.44	1.22
Fixed									
GDP	−1.79	−2.03	−1.58	−1.38	−1.17	−1.98	−1.99	−1.10	−1.71
Inflation	−0.57	−0.49	−0.25	−0.32	−0.43	−0.47	−0.47	−0.23	−0.50
Consumption	−1.20	−1.23	−0.52	−0.37	−0.70	−1.24	−1.27	−0.88	−1.07
Investment	−1.43	−0.98	−0.69	−0.65	−0.08	−0.94	−0.92	−0.57	−0.82
Net Exports over GDP	1.61	1.19	0.65	0.64	0.63	1.21	1.22	1.37	1.20
Floaters									
GDP	−1.70	−1.56	−1.50	−1.23	−1.04	−2.55	−1.58	−1.16	−1.27
Inflation	−0.17	−0.12	0.26	−0.15	−0.26	−1.59	−0.12	0.14	−0.27
Consumption	−1.04	−1.03	−0.54	−0.28	−0.70	−1.63	−1.03	−0.99	−0.90
Investment	−0.92	−0.71	−0.69	−0.63	−0.12	−1.41	−0.74	−0.73	−0.60
Net Exports over GDP	0.91	1.19	0.74	0.69	0.78	1.50	1.20	1.57	1.24

Notes: See Table 3. Specifications: (3) separable preferences: $U(c_n, L_n) = \frac{(c_n)^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} - \kappa_n \frac{(L_n)^{1+\frac{1}{\eta}}}{1+\frac{1}{\eta}}$. Notice that we maintain our assumption that hand-to-mouth consumers supply the same amount of labor as unrestricted consumers. For the remaining specifications: (4) $\chi = 0$, (5) $F_\varepsilon = 0$, (6) $\phi_{GDP} = 0.1, \phi_\pi = 1.1$, (7) ECB at zero lower bound (see text), (8) $\psi_y = 2$, (9) $\upsilon = 0$

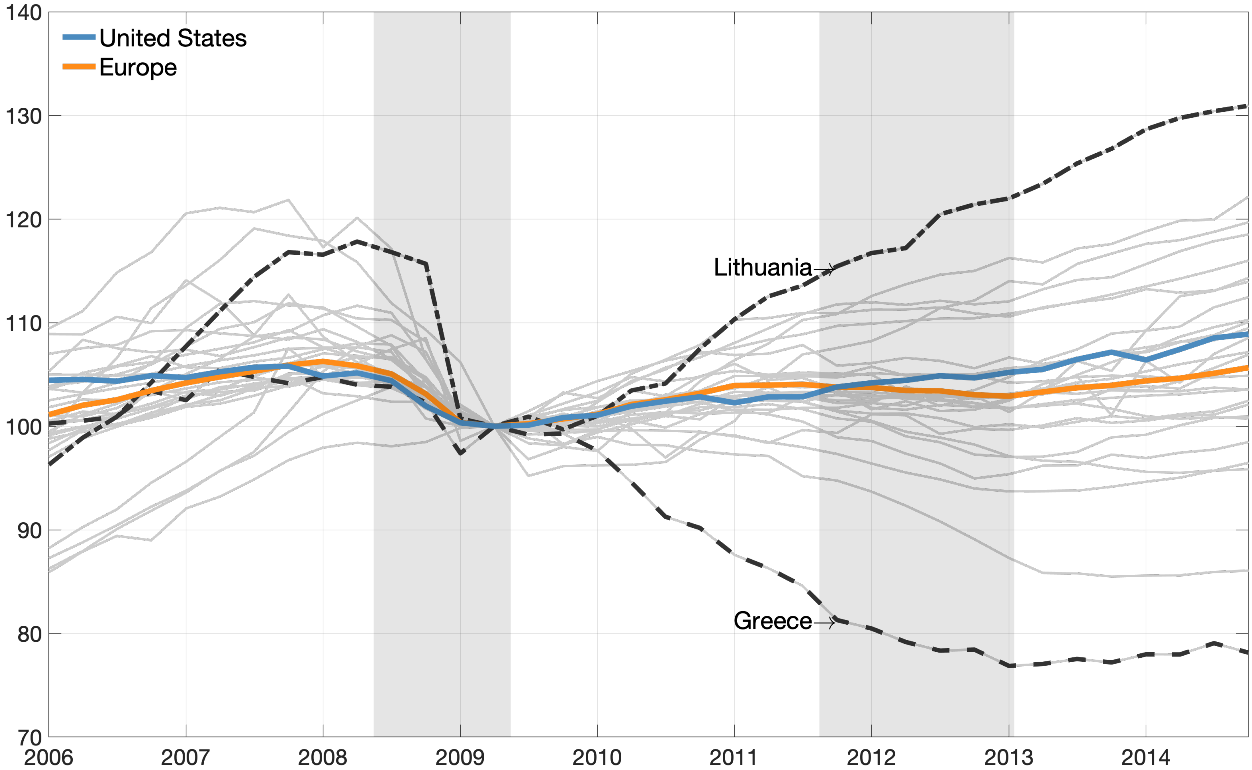

Figure 1: Real per Capita GDP Before, During and After the Crisis

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.

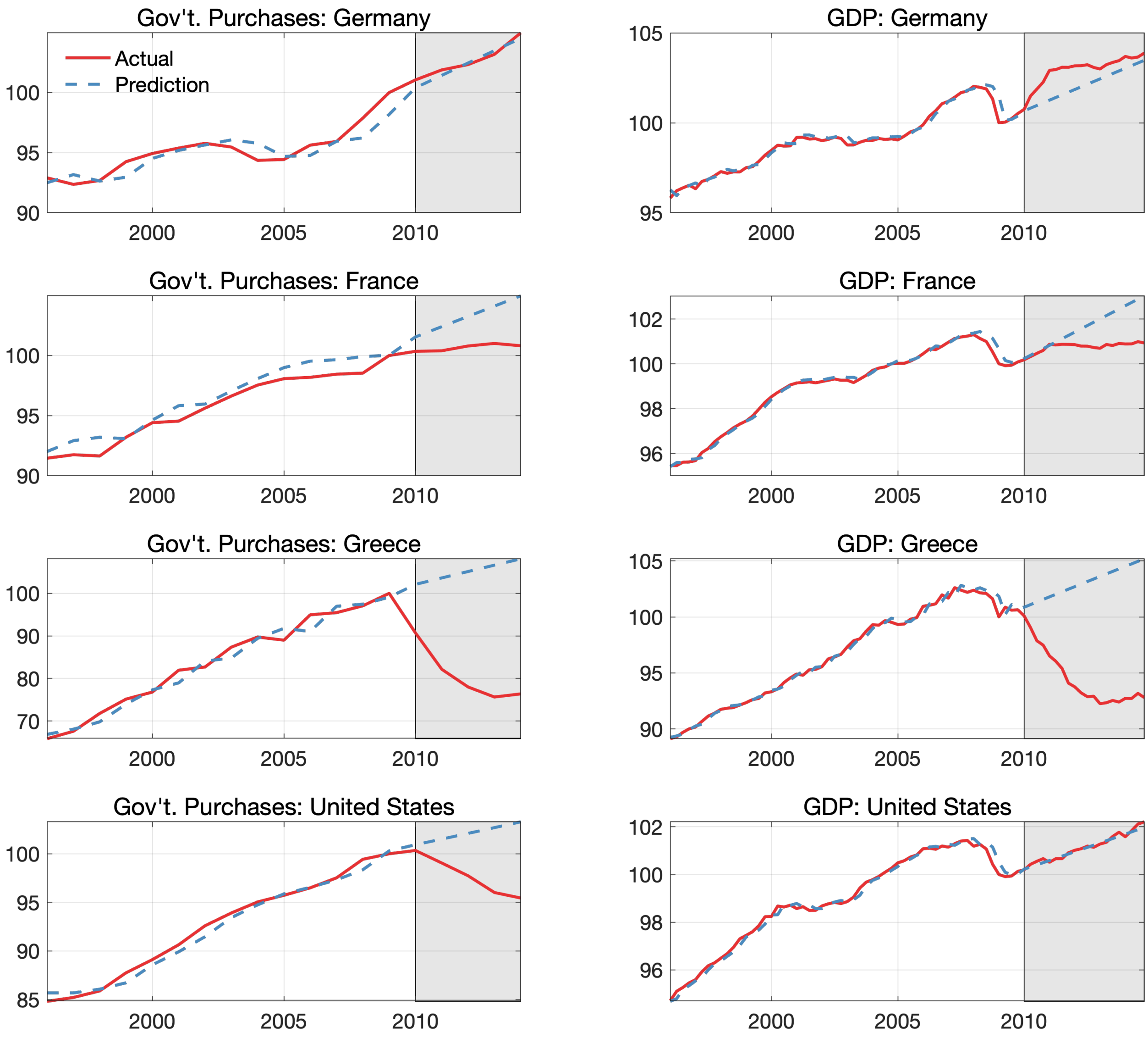

Figure 2: Government Purchases and GDP

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.

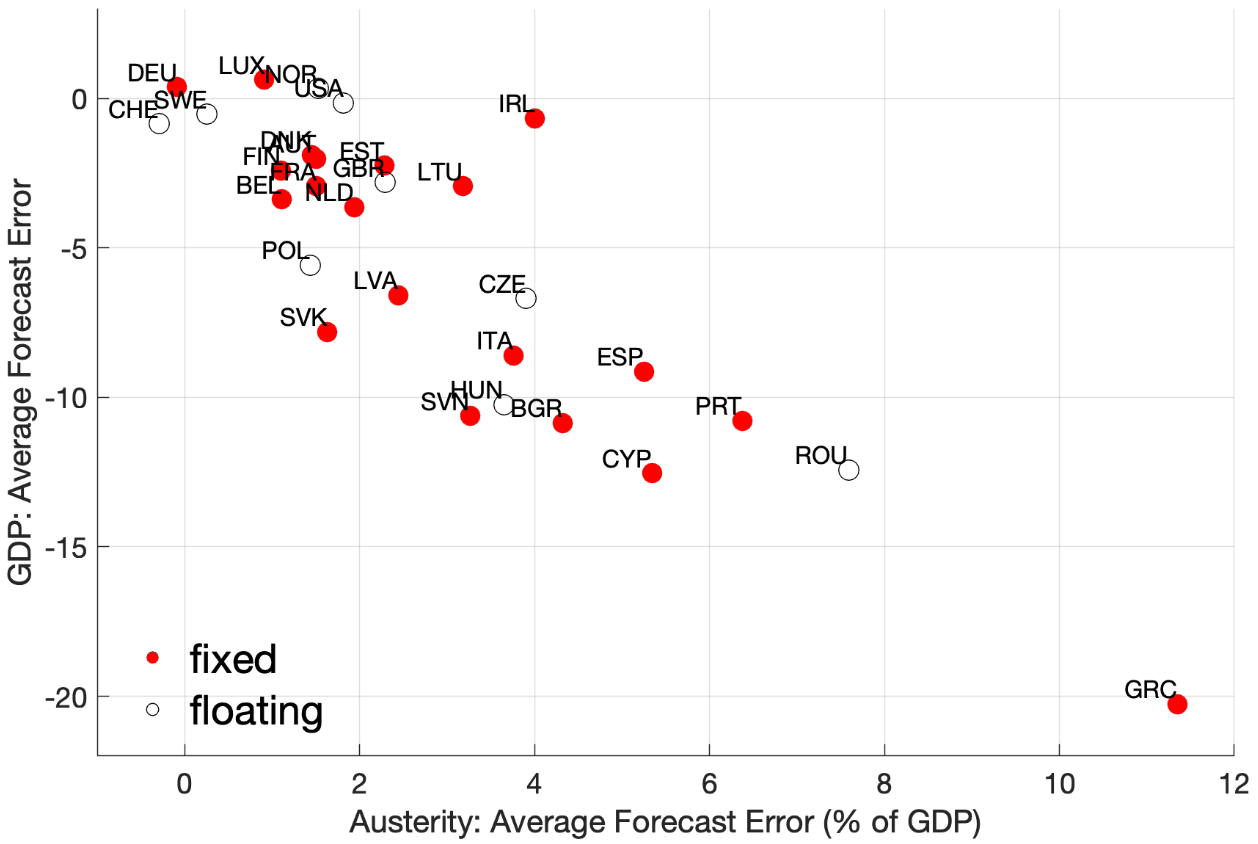

Figure 3: GDP and Austerity: Data

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.

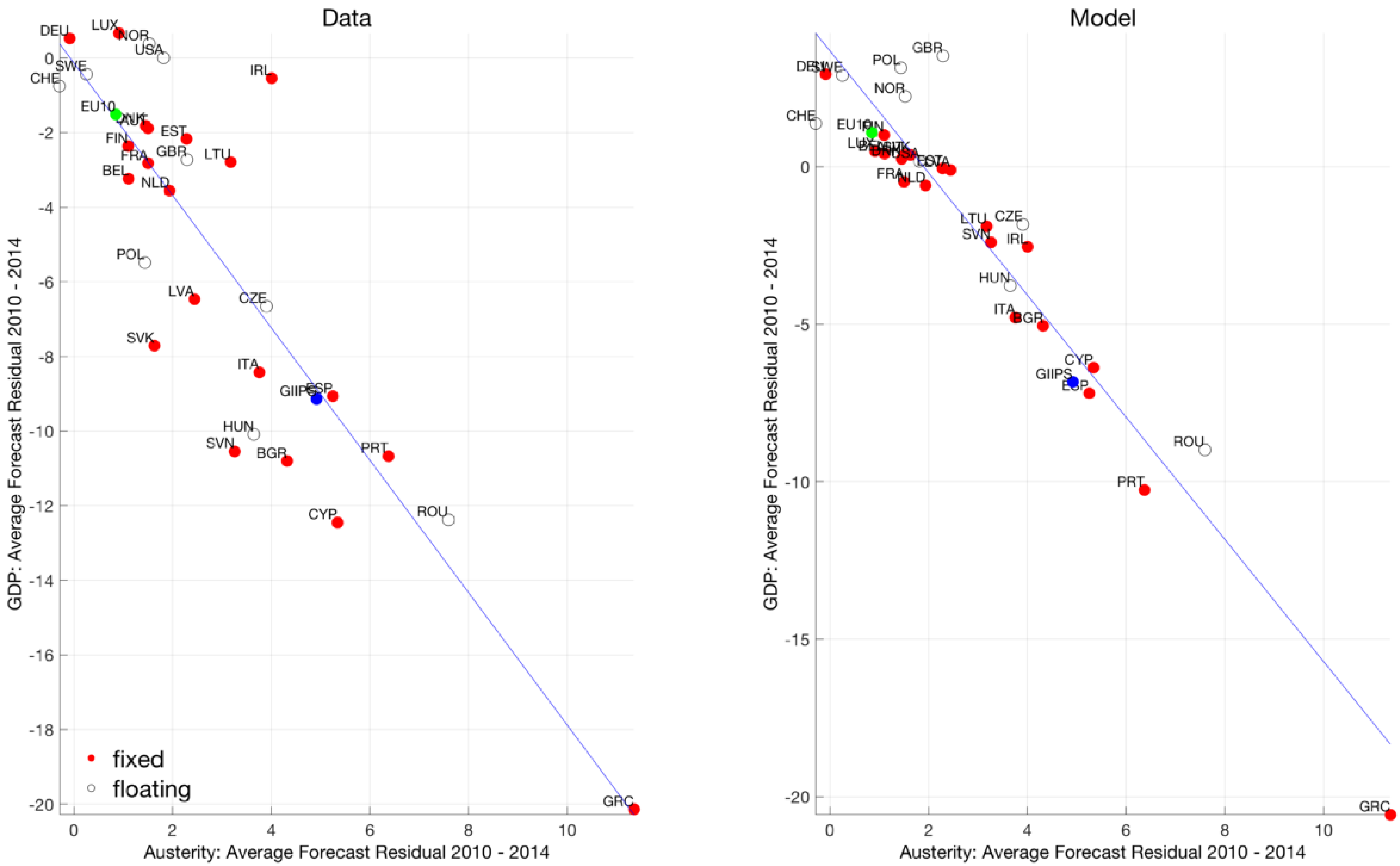

Figure 4: GDP and Austerity: Data vs. Model

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 1b; right panel refers to data from the simulated model. See text for details on the forecast specification.

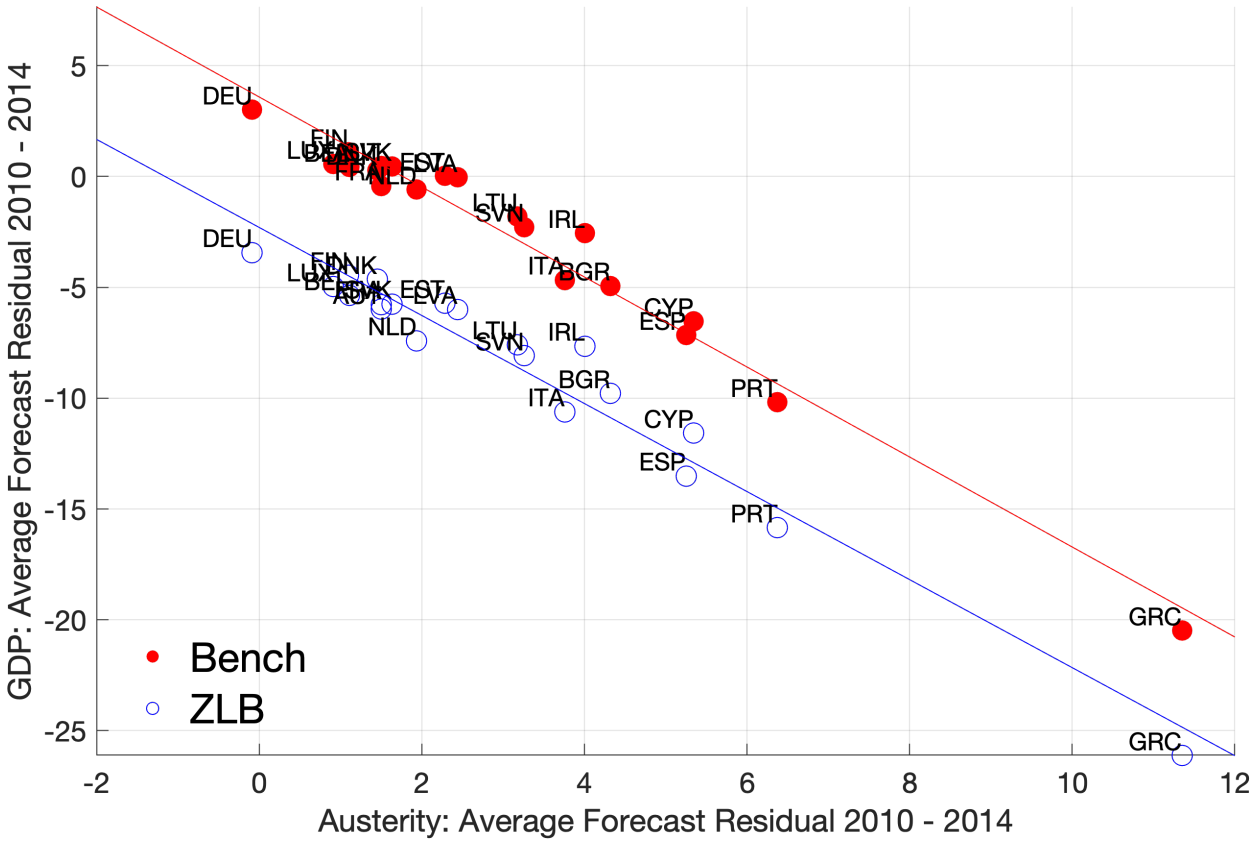

Figure 5: GDP and Austerity: Without and With ZLB

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.

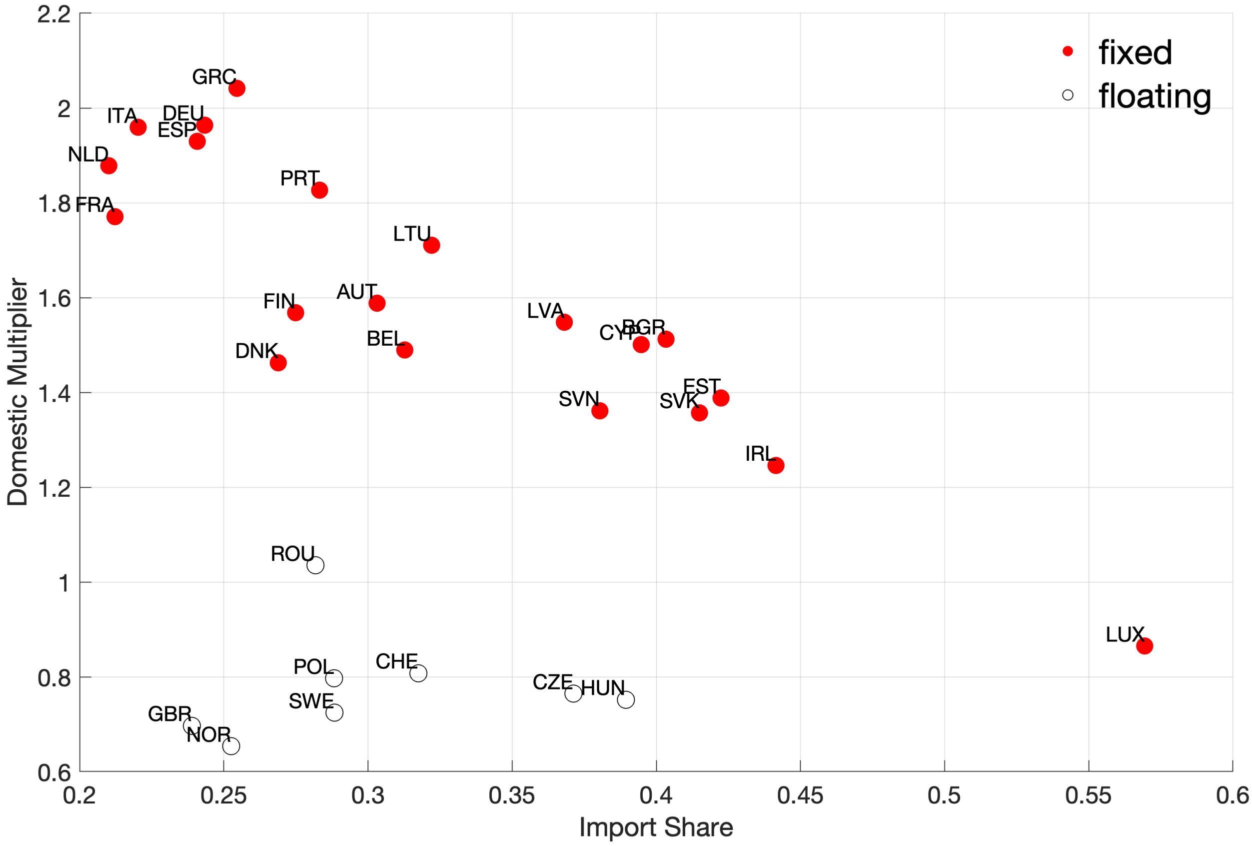

Figure 6: Domestic Multiplier and Import Share

Note: Figure plots domestic multipliers vs. a country's steady-state import share. The domestic multiplier is calculated as the average 2010 - 2014 GDP deviation (relative to the benchmark) in a counterfactual experiment, where the country that is plotted raises its government purchases by 1 percent of GDP. Hence, every dot corresponds to a different simulation. The model includes the ZLB specification for the ECB.

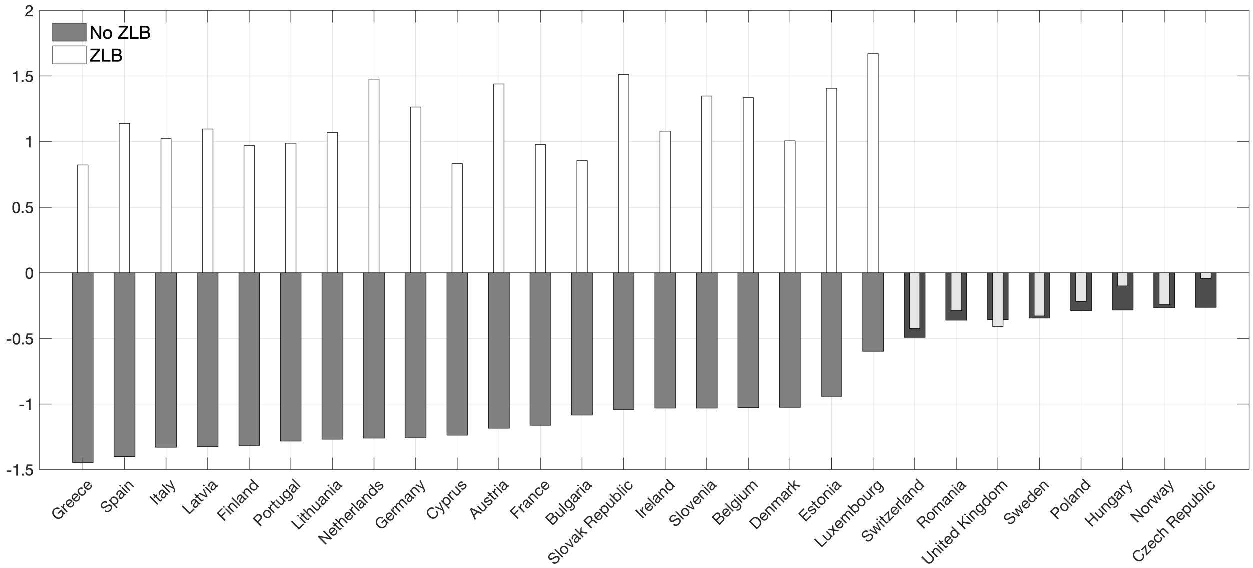

Figure 7: Spillover of Government Purchases

Note: Figure displays the average 2010 - 2014 GDP deviation predicted by the model in a counterfactual experiment relative to the benchmark model. In the counterfactual experiment, all countries in Europe raise their government purchases during the 2010 - 2014 period, except for the country whose GDP is plotted. Hence, every bar corresponds to a different simulation. The total increase in government purchases abroad is always set to 1 percent of European GDP for every year in 2010-2014, implying that countries have to raise their government purchases by more the larger the country that does not raise its government purchases. For a given experiment, the percent increase in government purchases is the same across all foreign countries. The thin light bars correspond to the scenario where a ZLB is imposed for the euro area.

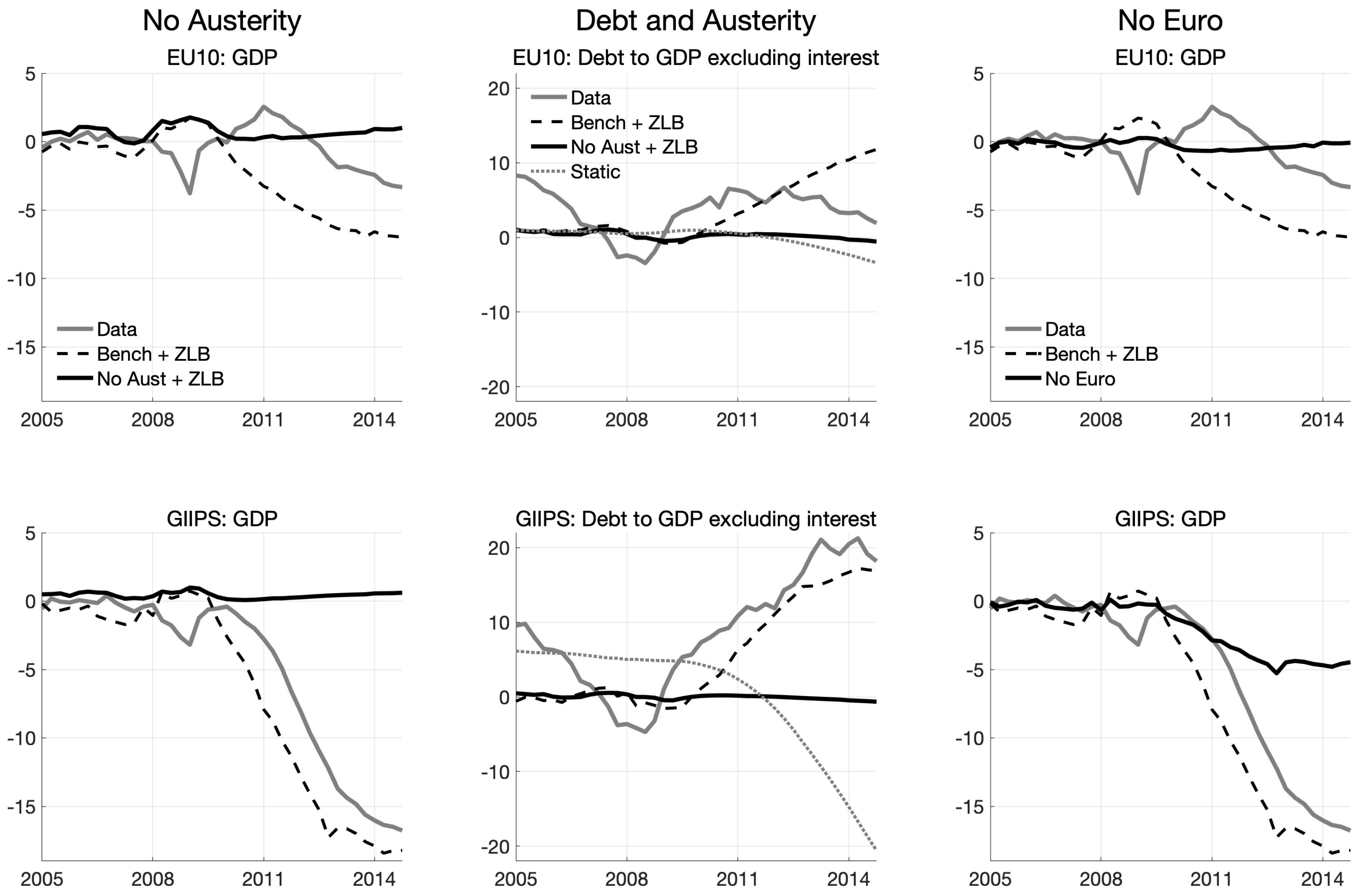

Figure 8: Counterfactual Policy Simulations

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 (5) for GDP and regression (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 end of 2009 value for the debt-to-GDP ratio.

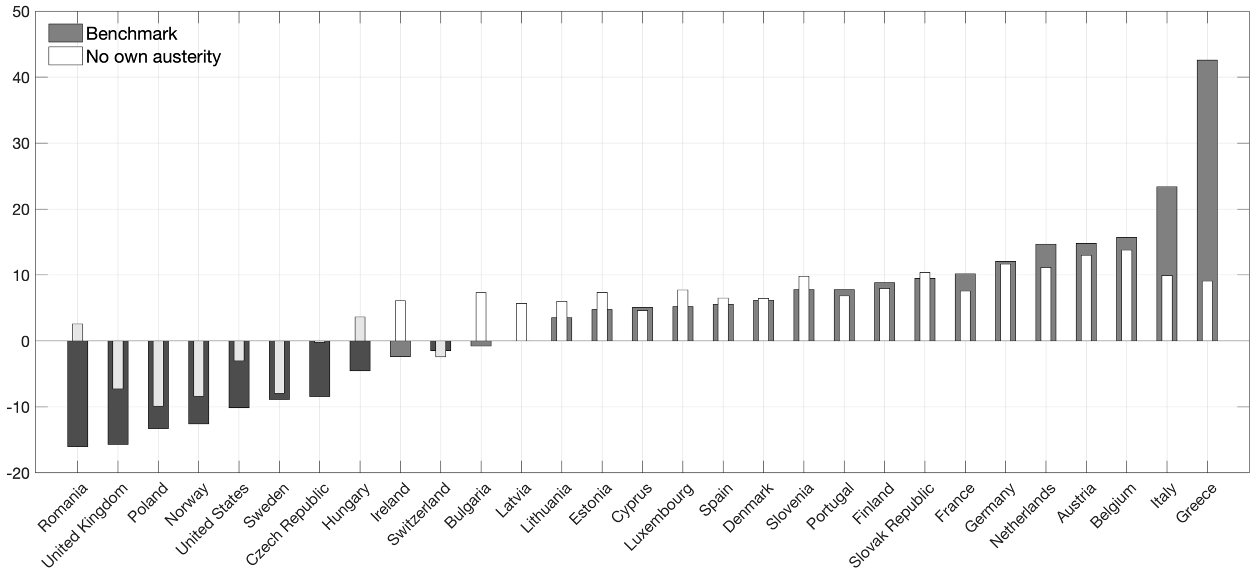

Figure 9: Debt-to-GDP Ratios in Counterfactuals

Note: Figure displays the percentage point change of the debt-to-GDP ratio (excluding interest payments) between the end of 2009 and the end of 2014 based on model simulations. The model includes the ZLB specification for the ECB. The dark heavy bars correspond to the benchmark model. The light thin bars are derived from a model simulation, where all countries receive the same shocks as in our benchmark model, except for the country whose debt-to-GDP ratio is plotted. That country is not hit by any government spending shocks.