Austerity in the Aftermath of the Great Recession.*

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Abstract

[**PRELIMINARY AND INCOMPLETE**]. This paper examines the effects of austerity on economic performance since the Great Recession. The analysis proceeds in two steps. The first step is to construct measures of "austerity" shocks in the 2010-2013 period in a sample of 29 countries including the U.S., the UK, Switzerland, countries in the Euro area and central and Eastern Europe. In our data set, austerity - a reduction in government spending that is larger than that implied by reduced-form forecasting regressions - is statistically associated with lower real per capita GDP, lower GDP growth, lower inflation and higher net exports. The second stage develops a multi-country DSGE model to make direct comparisons between the observed empirical relationships and the model predictions. The model is calibrated to reflect relative country size, trade and financial linkages, and the country's exchange rate regime. The model incorporates austerity shocks, shocks to the cost of credit and monetary policy shocks. Preliminary findings suggest that the benchmark model generates predictions that are qualitatively in line with those seen in the data.

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1 Introduction

The economies in Europe contracted sharply and almost synchronously during the global financial crisis. In the aftermath of the crisis, however, economic performance has varied. An open question is whether the difference in outcomes is due to variations in the severity of external shocks, the policy reactions to the shocks or the economic conditions at the time of the crisis. A number of prominent economists, including Ben Bernanke, Paul Krugman and Amartya Sen, have attributed at least some of the slow rate of recovery to austerity policies that cut government expenditures and increased tax rates at precisely the time when faltering economies required stimulus. This paper constructs measures of austerity and asks whether austerity can in fact account for the divergence in national economic performance since the Great Recession.

Figure 1 plots real per capita GDP for 29 countries, including the U.S., the UK, Norway, Sweden, Switzerland, countries in the euro area, and Central and Eastern Europe. The data is normalized so that per capita GDP is 100 in 2008:1 for every country. The figure also plots per capita GDP for the European aggregate. Overall, the aggregate European experience is similar to that of the United States. This similarity, however, masks a tremendous amount of variation across Europe. At one end of the spectrum is Greece for which the "recovery" never began. Greek per capita income at the end of 2013 is more than 25 percent below its 2008 level. While Greece's GDP performance is exceptionally negative, a contraction in GDP over this period is not unique. About a third of the countries in Figure 1 have end of 2013 levels of real per capita GDP below their 2008 levels. At the other end of the spectrum is Poland. Unlike Greece, Poland experienced only a very modest contraction during the Great Recession and returned to a rapid rate of growth quickly thereafter.

Our goal is to document the cross-country differences in economic performance since 2010 and to study the extent to which the differences can be explained by macroeconomic policy. We do not attempt to explain the Great Recession and its transmission - rather, we focus on the divergence in the paths of economic recovery after the crisis. Our analysis proceeds in two steps. The first step is to construct measures of austerity shocks that occurred during the 2010 to 2013 period. We consider both spending-based measures of austerity and tax-based measures of austerity. Both measures are constructed as (log) differences between observed spending (or tax revenues) and their predicted values. Using our methodology, we find that austerity in government expenditures - a reduction in government spending that is larger than that implied by reduced-form forecasting regressions - is statistically associated with below forecast GDP. Tax revenues and the primary balance generally have a weak or no statistically significant relationship with our measures of economic performance. Therefore, we focus our empirical analysis and our theoretical model on the impact of changes in government expenditures. The negative relationship between austerity in government expenditures and GDP is robust to the method used to forecast both GDP and government expenditures in the 2010 to 2013 period, and holds for countries with fixed exchange rates and flexible exchange rates. Austerity in government expenditures is positively associated with net exports and the exchange rate (that is, a real appreciation), and negatively associated with GDP growth and inflation.

The second stage of our analysis develops a multi-country DSGE model to make direct comparisons between the observed empirical relationships and the model predictions. The model features trade in intermediate goods, sticky prices, sticky wages, and financial frictions that drive a wedge between the marginal product of capital and the frictionless user cost of capital. The model is calibrated to reflect relative country size, observed trade flows and financial linkages, and the country's exchange rate regime. The model incorporates austerity shocks, shocks to the cost of credit and monetary policy shocks. We focus on these three shocks because there is broad agreement that these factors played an important role in shaping the reaction to the Great Recession. We then compare the model predictions for GDP, inflation, net exports and the exchange rate with actual data in the 2010-2013 period.

Our benchmark model enerates predictions that are consistent with those seen in the data. In the cross-section, a regression of austerity in government expenditures on GDP yields a coefficient of -0.34. That is, a one percent reduction in government spending is associated with a 0.34 percent reduction in GDP. In the analogous regression based on model-generated data, the coefficient is -0.20. The model is also successful in generating a positive relationship between austerity and net exports and the negative relationship between austerity and inflation and GDP growth. Austerity shocks are responsible for most of the observed variation in measures of economic activity in the model though monetary shocks are critical for generating realistic variation in nominal variables.

2 Empirical Findings

We begin by characterizing the economic performance of European nations and the United States following the crisis. Our primary data sources are Eurostat and the OECD. The dataset includes all nations in the European Union with the exception of Croatia and Malta (excluded due to data limitations) and with the addition of Norway and Switzerland (outside of the European Union but members of the European Free Trade Association, EFTA). We also include U.S. data for purposes of comparison. Our data sample covers the period 1970 to 2013; it is an unbalanced panel due to limitations in data availability for some countries.

Table 1 lists the countries in our data set together with each country's relative size, the share of imports in GDP (both averaged over 2003 to 2011) and the country's exchange rate regime as of 2010. Size is measured as the country's real absorption relative to the sum of all European countries' real absorption, where absorption is GDP less net exports. The size of the Rest of the World is real World GDP as reported by the World Bank less real absorption for the U.S. and the European aggregate. Country size varies from less than one percent of the European aggregate (e.g. Cyprus and Luxembourg) to over 100 percent (the U.S.). The import share is the ratio of imports to absorption (here absorption is gross output less net exports).[1] The import share varies from a low of 8 percent in the U.S. to very high shares in Belgium and Luxembourg (30 percent and 51 percent, respectively). The model in Section 4 will capture the extent of bilateral trade linkages between country pairs, as well as the overall openness to trade. Most countries in the sample have a fixed exchange rate because they are part of the euro area, or they have pegged their exchange rate to the euro. Nine have floating exchange rates.

2.1 Measuring Austerity

There are two conceptual issues in studying the impact of fiscal austerity on economic outcomes. One is that a policy can only be said to be austere relative to some benchmark. The second issue is the endogeneity of fiscal policy to the state of the economy – did a cut in government expenditures adversely affect output, or did government expenditures contract along with the decline in output? A commonly adopted approach is to identify periods of austerity as episodes when, for example, the primary balance (the general government balance net of

[1] We have two different measures of absorption because trade is measured on a gross basis, whereas GDP is measured on a value added basis.

interest payments) decreases by a certain amount. Such data is available from the IMF and the OECD, often reported as a share of "cyclically-adjusted GDP" as a way of correcting for the current stage of the business cycle. This approach partially addresses the issue of defining austerity by picking an arbitrary cut off, but does not address endogeneity. An alternative is the narrative approach pioneered by Romer and Romer (2004). This method relies on a subjective assessment of the historical policy record to identify policy shifts that are motivated by long-run fiscal consolidation rather than the need for short-run temporary fiscal stimulus. The narrative approach addresses the endogeneity problem, though it requires a great deal of judgment in interpreting policy statements by government officials. The identified policy shifts may also reflect the intent of policymakers and not capture the policies that are ultimately enacted.

A third approach, and the one we adopt here, is to examine forecast errors in fiscal policy variables (expenditures, tax revenue and primary balance) and their relationship with forecast errors in economic outcomes. We borrow heavily from Blanchard and Leigh (2013) who take a similar approach. However, rather than relying on forecasts generated by the IMF or national governments, we produce our own forecast measures. This gives us the flexibility to consider different methods of detrending and additional explanatory variables. In addition to focusing on the reaction of GDP, we also include the reactions of net exports, inflation, and the exchange rate in our analysis. We examine three potential measures of government austerity across countries: government expenditures, total tax receipts and the primary balance. Our measure of government spending is the sum of final government consumption expenditure and government gross fixed capital formation. Our measure of tax revenues is the sum of tax receipts from production (including VATs), imports, income, capital and wealth. Note that total tax receipts is not the same as total government revenue because tax receipts do not include e.g. social contributions to government health care or retirement programs.

Our preferred forecast specification includes a country-specific time trend, contemporaneous GDP and its own lag. The forecast errors can be interpreted as departures from "normal" fiscal policy reactions to economic fluctuations. That is, if a country typically does not increase spending in the face of economic contractions and it continues that policy in the aftermath of the crisis, our procedure will dictate that that country is not austere. On the other hand, a country that typically responds to recessions by spending more but does not do so in the aftermath of the crisis will be interpreted as austere. Austerity "shocks" generated in this way are not econometrically exogenous. We do not have a valid instrument for government spending and taxation and thus, the empirical patterns we report must be interpreted cautiously. We focus on the observed, quantitative changes in policy variables and asks whether there is any evidence that such changes are associated with changes in economic variables and whether the quantitative changes are large enough to explain observed variations in economic performance. While the shocks suffer from standard endogeneity problems, our preferred forecast specification does reduce one direct source of endogeneity by including contemporaneous GDP. Namely, we eliminate the direct connection between current economic activity and either spending or taxation. By including contemporaneous GDP in the forecast specification, the forecast errors report changes in spending or tax revenue that are not systematically related to the current state of the economy.

2.2 Constructing forecasts of austerity

For all variables, we construct reduced-form forecasts of what we would anticipate the variable to be given a set of information. The forecast equations are estimated on data prior to the crisis (1980, or the earliest available year, to 2005). We then construct out-of-sample residuals or forecast errors as the difference between predicted values and the actual values for the crisis period. The out-of-sample residuals can be interpreted as unusually high or low realizations of that variable relative to its predicted values. Though they are not identified structural shocks from an econometric point of view, we can still ask whether there is any observed correlation between the forecast errors of government policy and various measures of economic performance. In our analysis below, we will focus on the forecasts for the post-recession period 2010-2013. We treat the crisis as an anomalous period in that the forecasting regression does not use data during the crisis and we do not attempt to account for patterns in the data during the crisis.

Fiscal variables Let G_t^i be one of the three measures of fiscal austerity (government spending, primary balance or tax receipts) for country i at date t.[2] The basic form of the forecast specification is given by equation (2.1) and includes country-specific time trends, lagged values of the log of G_t^i and the log of real per capita GDP.

$$\ln G_t^i = \beta_0^i + \beta_1^i t + \beta_2^i \ln G_{t-1}^i + \beta_3^i \ln GDP_t^i + \varepsilon_t^i. \tag{2.1}$$

[2] We normalize the primary balance by dividing by a country's GDP in 2005. Also, we do not use the log for the primary balance, but the percent value of GDP.

Some countries report data for only a relatively short time span and therefore some of the estimated coefficients in the forecasting regression will be imprecise. To deal with this lack of precision, we use a two-stage "shrinkage" proceedure. In the first stage, we estimate two different versions of (2.1). We begin by seperately estimating (2.1) by OLS for each country in our data. This produces a set of estimates $\hat{\beta}_j^{i,1}$ with standard errors $SE\left(\hat{\beta}_j^{i,1}\right)$. We then estimate (2.1) imposing the restriction that $\beta_2^i = \beta_2$ and $\beta_3^i = \beta_3$. That is, we assume that all nations have the same reaction to changes in log real per capita GDP and to lagged values of G_t^i. This produces estimates $\hat{\beta}_j^{i,\text{pool}}$ where the superscript indicates that the data are pooled to produce a common estimate. In the second stage we compute the convex combinations

$$\hat{\beta}_j^{i,2} = \frac{1}{\gamma + SE\left(\hat{\beta}_j^{i,1}\right)}\hat{\beta}_j^{i,1} + \frac{SE\left(\hat{\beta}_j^{i,1}\right)}{\gamma + SE\left(\hat{\beta}_j^{i,1}\right)}\hat{\beta}_j^{i,\text{pool}}, \text{ for } j = 2, 3$$

where $\gamma > 0$ is a tuning parameter.[3] We then re-estimate (2.1) by OLS but imposing $\beta_j^i = \hat{\beta}_j^{i,2}$ for $j = 2, 3$. This approach allows countries to have distinct autoregressive coefficients and distinct reactions to $\ln GDP_t^i$ if the estimates in the first stage are precise (in the sense that the standard errors of the first stage coefficients are low). In contrast, if the initial country specific estimates are imprecise, our procedure stipulates that the reactions are governed relatively more by the pooled estimates. Note that we do not convexify the country specific intercept (β_0^i) or time trend (β_1^i). Given the estimated coefficients, we use (2.1) to forecast G_t^i for periods after 2005. The out-of-sample forecasts use actual values of $\ln GDP_t^i$ but quasi-predicted values of $\hat{G}_t^i$.[4]

The first six columns of Table 2 report the statistical properties of the log difference between the actual time series and the forecast for three fiscal variables (G): Govt (government expenditures), Tax (tax revenue) and PB (primary balance). The subscript 1 indicates the

[3] The results presented below have

$$\gamma_j = \frac{\text{mean}_i\left(SE\left(\hat{\beta}_j^i\right)\right)}{3}.$$

This setting implies that a nation i with the average precision (given by its standard error) has a coefficient which places a weight of 0.75 on the pooled estimate. Note that for any fixed γ, the estimate $\hat{\beta}_j^{i,2}$ is a consistent estimator.

[4] Specifically, we form an iterative sequence of forecasts as follows. At the start of the forecast period (2006) we initialize G_{t-1}^i according to its actual value in 2005. For the next value however, we use the esitmated version of (2.1) to predict $\widehat{\ln G_t^i}$ given current X_t^i and $\widehat{\ln G_{t-1}^i}$. We repeat this procedure for the entire out-of-sample period using predicted values for $\ln G_t^i$ rather than actual values. Thus, $\widehat{\ln G_t^i}$ changes over time due only to realized changes in $\ln X_t^i$ and the time trend. See the appendix for additional details.

specification of the forecasting regression that includes a time trend and GDP; subscript 2 is the specification with a time trend, GDP and lagged G. The sample is 2010-2013. Both specifications use the shrinkage estimation method described above. The first row of the table, the mean of the deviation from forecast, indicates that the average of the three fiscal variables is small in the cross section. The standard deviations are large, reflecting the dispersion in policy responses across countries. The correlations in the bottom section of the table show that the forecasts are highly correlated across the two specifications (e.g. the correlation between Govt_1 and Govt_2 is 0.94).

Figures 2 and 3 show actual and forecast values of log government expenditures and tax revenues for two countries: France and Germany, respectively. During the 2010-13 period, France pursued a relatively austere path with actual government expenditures falling well short of the forecast. Tax revenues are also below forecast but over the 2010-13 period the gap between the forecast and actual revenues is narrowing. In Germany, on the other hand, both government expenditures and tax revenues are above forecast. We next turn to an analysis of the impact of the deviations in government expenditures and tax revenues from forecast on economic performance.

2.3 Austerity and economic performance

We focus on several different measures of economic activity including deviations in GDP per capita, the inflation rate, the exchange rate and the ratio of net exports to GDP. The primary source for the data on GDP and Net Exports is the OECD. The primary source for the data on inflation, population and nominal exchange rates is Eurostat. We describe our procedure for forecasting these variables below. As with the measures of government austerity, we leave many of the details of these calculations to the data appendix.

For real GDP per capita we use simple forecasting specifications of the following form

$$\ln GDP_t^i = \beta_0^i + \beta_1^i t + \beta_2^i \ln GDP_{t-1}^i + \varepsilon_t^i. \tag{2.2}$$

One of the difficulties in forecasting the future path of GDP is that it is unclear how to detrend the series. Many countries in our sample had rapid rates of growth leading up to the crisis, a sharp fall during the crisis, and then a slower growth rate after the crisis. Applying the pre-crisis growth rate to the series produces massive output gaps in the post-crisis period. We adopt three alternative methods of detrending to address this problem.

First, following the method described for the austerity forecasts, we convexify the autoregressive parameter β_2^i with the pooled estimate across countries. Second, we impose a "trend hugging" condition using the pooled estimate β_2^{pool}. See the appendix for a detailed discussion of this point. The third approach is to assume that all countries are ultimately converging to a common growth rate ('convergence' estimator). We estimate time-varying growth rates composed of two parts: a constant growth rate that reflects the average growth rate of Western European countries between 1993 and 2005, and a country-specific time-varying growth rate component that is a linear function of the log gap in real GDP per capita between the country and Western Europe.

The statistical properties of the deviations from the forecast for real GDP per capita are in the last three columns of Table 2. Not surprisingly, real GDP is below forecast for all three forecasting methods, ranging from -11.5 percent per year for specification 1 to -18.8 percent for specification 3. There is considerable heterogeneity across countries, reflected in the standard deviations in the second row. The correlations between the forecasting specifications is fairly high, especially between the hugging estimator and the shrinkage estimator.

Implicitly, our forecast for real per capita GDP is based on a trend stationary view of GDP. Following the crisis, few countries experienced above average economic growth while many experienced below average growth during their recoveries. As a result, the trend stationary perspective embodied specification (2.2) produces surprisingly large measures of the shortfall in GDP. Many researchers suggest that GDP is best modelled as a unit root process in which shocks are essentially permanent.[5] To accommodate this view, we also produce forecasts for GDP growth. The growth rate forecasts take the view that the growth rates are stationary but the levels are integrated processes. But instead of assuming a pure random-walk specification for the growth rates, we use our growth rate estimates from our 'convergence' estimator (see the third approach above, and also the appendix). This convergence estimator takes into account that growth rates in Central and Eastern European countries are expected to slow down as their per capita GDP approaches Western European levels.

For the nominal inflation rate, the nominal effective exchange rate and the net export to GDP ratio, we impose a pure random-walk specification. To reduce the sensitivity to the last observation, for each country we take an average of the variable x_t^i for all quarters in the two

[5] See among others, Nelson and Plosser (1982), Rudebusch (1993), Kilian and Ohanian (2002), Campbell and Perron (1991) and Campbell and Mankiw (1987).

years 2004 and 2005 as the last "observation."[6] That is, our forecast for these variables is simply

$$x_t^i = \frac{1}{8} \sum_{s \in 2004,2005} x_s^i + \varepsilon_t^i$$

for dates t after 2005:4. For our measure of the inflation rate, we use "core inflation" (all items less energy and food) as reported by Eurostat. For each country we use the nominal effective exchange rate which is an average of nominal exchange rates weighted according to the trade shares of each of country i's trading partners.

Figures 4 - 8 show scatterplots of the relationship between shortfalls in government spending with a different measure of economic performance. The figures report results for both the actual data (the left-hand-side panels) and simulated data from the model (the right-hand-side panels). We will return to a discussion of the simulated data after discussing the model. For now we will focus on the empirical scatterplots.

Figure 4 shows how GDP is related to the government spending shortfall. In the figure, each point corresponds to a country in our dataset. The solid/filled circles are countries with fixed exchange rates (i.e., the countries in the Eurozone plus Denmark, Bulgaria and the Baltic countries). Empty circles are countries with floating exchange rates. Country abbreviations are included in the plot. The horizontal axis reflects our measure of the shortfall in government spending estimated by our preferred specification (2.1) while the vertical axis represents the forecast error for GDP based on the convergence estimator. The figure displays an overall negative relationship between austerity and the measured GDP shortfall. The OLS regression coefficient of our measure of the GDP gap and austerity is -0.34 with a standard error of 0.07. Based on the regression coefficient, a country with a 10 percent government spending shortfall relative to forecast, has a corresponding output shortfall that is roughly 3.4 percent lower than otherwise.

Table 3 provides the results from regressions of the different austerity measures (Govt, Tax and PB) on GDP, inflation, net exports, the nominal effective exchange rate and GDP growth. The austerity measures are deviations from forecasts based on specification 2 and the economic performance variables are deviations from the forecast based on the convergence

[6] We have also experimented with specifications that build in persistence to these variables as

$$\ln x_t^i = \beta_0^i + \beta_1^i \ln x_{t-1}^i + \varepsilon_t^i.$$

However, for countries with adequate data, the estiamtes imply very low values for β_1^i. Because our focus is on performance several years into the future, the effects of this persistence are virtually zero.

estimator or the unit root forecast. We also report the results for the subsamples of fixed and floating exchange rates. As already noted, we see that shortfalls in government spending are associated with lower real per capita GDP. This negative association between austerity in government spending and real GDP is robust to the exchange rate regime, and, as shown in Table A2 in the appendix, to the forecast specification for government expenditures and to the detrending method for GDP. There are some differences between the results for fixed exchange rate countries and floating exchange rate countries, though the differences are not statistically significant (this is not surprising, given the small number of floaters in our sample).

Figures 5 and 6 show results for inflation and the ratio of net exports to GDP. The inflation results are estimated with the most precision. Countries with unusually low levels of government spending, as measured by the residuals from our preferred forecast method, have relatively lower inflation rates for the period 2010-2013 compared to inflation prior to the crisis. Net exports are positively correlated with the spending measure of austerity (Lithuania is a curious outlier).

Figure 8 presents results for GDP growth in the post crisis period. The vertical axis plots the difference between the average annual growth rate in GDP over the years 2010-2013 and the estimated growth rate based on our convergence estimator. (The horizontal axis is again the measured shortfall in government spending.) Here, the negative relationship again emerges. The OLS coefficient is -0.07 with a standard error of 0.02. In this case, a country with a 10 percent spending shortfall experiences an average growth rate in the post-crisis period that is about three-quarters of a percent lower than otherwise for the four years 2010-2013.

Unlike the results for government spending, the tax-based austerity measure and the primary balance measures are not as strongly associated with systematic changes in economic performance. Most of the estimates for GDP, net exports, inflation and the exchange rate are simply too inaccurate to draw sharp conclusions. We will therefore focus the remainder of our analysis on the impact of shortfalls in government spending.

3 Model

Here we present a multicountry business cycle model of the 29 countries in our data set. The model includes every country in the Eurozone and is calibrated to roughly match both contemporaneous trade flows as well as recent long-run growth trajectories of certain nations particularly the former Eastern Bloc countries. The model incorporates many features from modern monetary business cycle models (e.g., Smets and Wouters (2007), Christiano *et al.* (2005)), international business cycles models (e.g., Backus *et al.* (1992, 1994), Chari *et al.* (2002), Heathcote and Perri (2002)), and financial accelerator models (e.g., Bernanke, *et al.* (1999), Brave *et al.* (2012), Christiano *et al.* (2014)). The main ingredients of the model are (i) price and wage rigidity (ii) international trade in productive intermediate goods, (iii) a net worth chanel for business investment and (iv) government spending shocks, monetary policy shocks and spread shocks.

3.1 Households

The world economy is populated by $n = 1...N$ countries denoted by subscript i. The number of households in any country n is $\mathbb{N}_n$. The model is written in per capita terms. To convert any variable to a national total, we simply scale by the population. Thus if $X_{n,t}$ is per capita investment in country n at time t, total investment is simply $\mathbb{N}_n X_{n,t}$. In each period t the economy experienes one event s_t from a potentially infinite set of states. We denote by s^t the history of events up to and including date t. The probability at date 0 of any particular history s^t is given by $\pi(s^t)$.[7]

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

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

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

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

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

competitive labor supply unions (see below). The utility function for real balances $\Lambda(.)$ is assumed to be increasing and concave.

Households in each country own the capital stock $K_{n,t}$ of that country. They supply labor and capital to the intermediate goods producing firms. In return, they earn nominal wages $W_{n,t}L_{n,t}$ and nominal payments for capital $\mu_{n,t}K_{n,t}$. Here $W_{n,t}$ is the nominal wage and $\mu_{n,t}$ is the nominal price of capital that prevail in country n at time t. Let $T_{n,t}$ denote nominal lump-sum taxes at time t. Finally, the household may also receive profits from domestic firms. Let $\Pi_{n,t}$ be nominal profits paid to the household at time t.

Our specification of the payments associated with capital deserves some additional discussion. Rather than assuming that the households rent capital directly to firms, we assume that the households sell capital to the firms and then subsequently repurchase the undepreciated capital the following period. This assumption is convenient when we introduce financial market imperfections later.

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

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

$$P_{n,t}\left[C_{n,t} + X_{n,t}\right] + (1-\delta)\,\mu_{n,t}K_{n,t} + \sum_{j=1}^{n}\frac{E_{j,t}S^j_{n,t}}{E_{n,t}} + M_{n,t} + \mathbb{I}_{\text{comp}}\left[\sum_{s^{t+1}}\frac{a\left(s^t, s_{t+1}\right)b_n(s^t, s_{t+1})}{E_{n,t}} - \frac{b_n(s^{t-1}, s_t)}{E_{n,t}}\right]$$

$$= \mu_{n,t}K_{n,t+1} + W_{n,t}L_{n,t} + \Pi_{n,t} + \sum_{j=1}^{n}\frac{E_{j,t}\left(1 + i_{j,t-1}\right)S^j_{n,t-1}}{E_{n,t}} + M_{n,t-1} - T_{n,t}$$

and

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

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

The indicator variable $\mathbb{I}_{\text{comp}}$ takes the value 1 if markets are complete and 0 otherwise.[8] The first order conditions for an optimum are as follows.[9] The household's Euler equation for purchases of state contingent bonds $b_n(s^t, s_{t+1})$ requires

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

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

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

The optimal choice for investment and capital requires

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

where the notation $f_{n,t}$ denotes the value of f evaluated at $X_{n,t}/X_{n,t-1}$. Finally, the optimal choice of date t money holdings implies a standard money demand equation

$$C_{n,t}^{-\frac{1}{\sigma}} \left(\frac{i_{n,t}}{1 + i_{n,t}}\right) = \Lambda' \left(\frac{M_{n,t}}{P_{n,t}}\right).$$

3.1.1 Wage Setting

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3.2 Firms

There are three groups of productive firms in the model. First there are firms that produce the "final good." The final good is used for consumption, investment and government purchases within a country and cannot be traded across countries. The final good producers take intermediate goods as inputs. Second, intermediate goods firms produce country-specific goods which are used in production by the final goods firms. Unlike the final good, the intermediate goods are freely tradeable across countries. The intermediate goods firms themselves take sub-intermediate goods or varieties as inputs (the domestic producers of the tradeable intermediate in country n use only sub-intermediates produced in country n as inputs). The sub-intermediate goods are produced using capital and labor as inputs. Like the final good, neither capital nor labor can be moved across countries. Below we describe the production chain of these three groups of firms. We begin by describing the production of the intermediate goods which are traded across countries.

3.2.1 Tradeable Intermediate Goods

Each country produces a single (country-specific) type of tradeable intermediate good. The intermediate goods are used in the production of the final good which is ultimately the source of consumption and investment for each country. The intermediate goods are the only goods that can be traded between countries. Production of the intermediate good occurs in two stages. As we did with the supply of labor above, we employ a two-stage production process to allow us to use a Calvo price setting mechanism. In the first stage, monopolistically competitive domestic firms produce differentiated "sub-intermediate" goods which are used as inputs into the assembly of the tradeable intermediate good for country n. In the second stage, competitive intermediate goods firms produce the tradeable intermediate good from a CES combination of the sub-intermediates. These firms then sell the intermediate good on international markets at the nominal price $p_{n,t}$. We describe the two-stage process of production of the intermediate goods in reverse, starting with the second stage.

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

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

subject to the CES production function

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

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

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

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

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

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

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

Because the first-stage producers are monopolistically competitive, they typically charge a markup for their products. The desired price naturally depends on the demand curve (3.3). Each type of sub-intermediate good producer ξ freely chooses capital and labor each period but there is a chance that their nominal price $\varphi_{n,t}(\xi)$ is fixed to some exogenous level. In this case, the first-stage producers choose an input mix to minimize costs taking the date-t price $\varphi_{n,t}(\xi)$ as given. Cost minimization implies that

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

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

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

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

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

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

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

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

The solution to this optimization problem requires

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

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

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

Our specification of price setting entails firms setting prices in their own currency. As a result, when exchange rates move, the implied import price moves automatically (there is complete pass-through). This is somewhat at odds with the data which suggests that many exporting firms fix prices in the currency of the country to which they are exporting. See Betts and Devereux (1996, 2000) and Devereux and Engel (2003) for a discussion of the differences between local currency pricing and domestic currency pricing. See Gopinath and Itskhoki (2010) and Burstein et al. (2005) for empirical evidence on the relationship between pass-through, price rigidity and exchange rate movements.

3.2.2 Non-Tradeable Final Goods

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

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

subject to the CES production function

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

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

Demand for country-specific intermediate goods is isoelastic

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

The implied nominal price of the final good is

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

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

3.3 The Supply of Capital and Financial Market Imperfections

The model incorporates a financial accelerator mechanism similar to Carlstrom and Fuerst (1995), Bernanke, *et al.* (1999) and Christiano *et al.* (2014). Entrepreneurs buy capital goods from households using a mix of internal and external funds (borrowing). The entrepreneurs rent out the purchased capital to the first-stage sub-intermediate goods producers in their own country and then sell it back to the household the following period. The interest rate that entrepreneurs face for borrowed funds is a function of their financial leverage ratio. As a consequence, fluctuations in net worth cause changes in the effective rate of return on capital and thus directly affect real economic activity.[10]

Formally, at the end of period t, entrepreneurs purchase capital $K_{n,t+1}$ from the households at the nominal price $\mu_{n,t}$ per unit. Entrepreneurs finance the capital purchases with their own internal funds (net worth) and intermediated borrowing. Let end-of-period nominal net worth be $NW_{n,t}$. Then to purchase capital, the entrepreneur will have to borrow $B_{n,t} = \mu_{n,t}K_{n,t+1} - NW_{n,t}$ units of their own currency (entrepreneurs borrow money from the households in their country). Both $B_{n,t}$ and $NW_{n,t}$ are denominated in country n's currency. The nominal interest rate on business loans equals the nominal interest rate on safe bonds times an external finance premium $F(\lambda_{n,t})$, with $F(1) = 1, F'$ and $F'' > 0$. Here $\lambda_{n,t} = \frac{\mu_{n,t}K_{n,t+1}}{NW_{n,t}}$ is the leverage ratio.[11] The interest rate for securing next period capital is then $(1 + i_{n,t})\, F(\lambda_{n,t})e^{\epsilon^F_{n,t}}$, where $\epsilon^F_{n,t}$ is a shock to the interest rate spread. The function $F(\cdot)$ implies that entrepreneurs who are more highly levered pay a higher interest rate.

At the beginning of period $t + 1$, entrepreneurs earn a utilization-adjusted rental price of capital $u_{n,t+1}R_{n,t+1}$ and then sell the undepreciated capital back to the households at the capital price $\mu_{n,t+1}$. Varying the utilization of capital requires $K_{n,t+1}a\,(u_{n,t+1})$ units of the final good. Each period, a fraction $(1 - \gamma_n)$ of the entrepreneurs' net worth is transferred to the households.[12]

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

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

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

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

Following Christiano *et al.* [2014] we assume that the utilization cost function is $a\,(u) = \frac{\bar{R}}{P}\left[\exp\{h\,(u-1)\} - 1\right]\frac{1}{h}$ where the curvature parameter h governs how costly it is to increase

[10] See Brave *et al.* (2012) for the same approach. Christiano *et al.* (2014)) microfound the dependence of the interest rate on the leverage ratio by introducing agency problems associated with financial intermediation.

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

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

or decrease utilization from its steady state value of $u = 1$. Note that in steady state $a(u) = 0$.

The first order condition for the choice of $K_{n,t+1}$ requires

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

As is standard in financial accelerator models, the external finance premium $F(\lambda_{n,t})$ drives a wedge between the nominal interest rate on bonds and the expected nominal return on capital.[13] Notice that if $F(\lambda_{n,t}) = 1$ then we obtain the standard efficient outcome in which the market price of capital is the discounted stream of rental prices.

3.4 Government Policy

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

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

We choose the parameter G_n to match observe ratio's of government spending to GDP for each country.

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

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

For simplicity we assume that the reaction parameters ϕ_{GDP}, ϕ_π and ϕ_i are common across countries. In all of our numerical exercises, we require that $\frac{\phi_\pi}{1-\phi_i} > 1$ for local determinacy of the equilibrium (see e.g., Woodford 2003).

Countries in a currency union have a fixed nominal exchange rate for every country in the union. Because *currency* is freely mobile across countries, nominal interest rates for countries in a currency union must also be equal. As a consequence, individual nations in a

[13]Our specification technically requires that the banks do not directly observe individual leverage ratios but instead observe only country-wide leverage when they set interest rates.

currency union cannot have independent monetary policies. Instead, we assume that monetary policy for the countries within the union are set by a single monetary authority (the ECB in our case) that has a Taylor Rule similar to (3.7) with the exception that it reacts to the weighted average of innovations in GDP and inflation for the countries in the union. For our purposes, the currency union consists only of the countries in the Eurozone and the weights are proportional to GDP relative to the total GDP in the Eurozone.

3.5 Aggregation and Market Clearing

For each country n, aggregate production of the tradeable intermediate goods is (up to a first-order approximation[14]) given by

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

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

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

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

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

Finally, the bond market clearing conditions require

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

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

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

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

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

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

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

3.6 Steady state

In our empirical application, we capture country size differences by calibrating each country's steady-state absorption, Y_n, to its empirical counterpart, the sum of consumption, investment and government purchases. The corresponding population levels in the model, $\mathbb{N}_n$, reflect differences in GDP, net exports and government purchases and do not have a direct counterpart in the data.

We set κ_n such that $L_n = 1$ in steady state.[15] Steady-state inflation is zero, so that nominal prices are constant. We normalize the price level P_n to 1.

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

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

The rental price of capital is the marginal product of capital, augmented by a markup $\frac{\psi_q - 1}{\psi_q}$.

$$\frac{F(\lambda_n)}{\beta} - (1 - \delta) = \frac{\psi_q - 1}{\psi_q} p_n \alpha Z_n K_n^{\alpha - 1}. \tag{3.8}$$

We adjust the technology level Z_n so that all intermediate goods prices, expressed in the reserve currency, are 1 in steady state: $p_n E_n = 1$. Inserting this into the demand equation for intermediate goods and using the production function of the final good implies that trade shares are determined by the preference weights $\omega_{n,j}$

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

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

It follows that all exchange rates E_n and all prices p_n equal 1 in steady state. The value of intermediate goods produced in country n equals domestic absorption Y_n plus net exports:

$$Q_n = \sum_{j=1}^{N} \frac{\mathbb{N}_j}{\mathbb{N}_n} y_j^n = \sum_{j=1}^{N} y_n^j + NX_n = Y_n \sum_{j=1}^{N} \omega_{n,j} + NX_n = Y_n + NX_n,$$

where net exports are

$$NX_n = \sum_{j=1}^{N} \frac{\mathbb{N}_j}{\mathbb{N}_n} y_j^n - y_n^j$$

Inserting the production function for Q_n and the market clearing condition for Y_n gives

$$Z_n K_n^{\alpha} = C_n + X_n + G_n + NX_n$$
$$\frac{R_n}{\alpha} \frac{\psi_q}{\psi_q - 1} K_n^{1-\alpha} K_n^{\alpha} = 1 + \delta K_n + G_n + NX_n,$$

where we replace Z_n by equation (3.8) and investment by its steady-state value δK_n. Note that the marginal utility of consumption equals the real exchange rate when financial markets are complete, so that consumption is $C_n = 1$ for all countries. Solving for K_n gives

$$K_n = \frac{1 + G_n + NX_n}{\frac{R_n}{\alpha} \frac{\psi_q}{\psi_q - 1} - \delta}.$$

Next, we derive an expression for countries' population. We use the expression for K_n to solve for GPD_n in the model:

$$GDP_n = Z_n K_n^{\alpha} = \frac{R_n}{\alpha} \frac{\psi_q}{\psi_q - 1} K_n = \frac{1 + G_n + NX_n}{1 - \frac{\alpha\delta}{R_n} \frac{\psi_q - 1}{\psi_q}}$$
$$= \frac{1}{1 - \frac{\alpha\delta}{R_n} \frac{\psi_q - 1}{\psi_q} - \frac{G_n + NX_n}{GDP_n}} \tag{3.9}$$

Given empirical data on the net exports to GDP ratio, government purchases to GDP ratio and GDP we calculate population as the ratio of empirical GDP and the value in equation (3.9).

3.7 Calibration

Trade Parameters The preference parameters $\omega_{n,j}$ are calibrated to match imports y_n^j over domestic absorption Y_n in the data. To do so, we proceed in two steps:[16] First, we calibrate a country's overall import share using data from the World Input-Output Database (WOID) on total imports to domestic absorption. Domestic absorption in the WOID is measured as gross output less net exports. We use gross output instead of GDP because trade is measured in gross terms. Second, we calibrate the share of a country's imports coming from a specific trading partner using bilateral trade data. Our main data source for bilateral trade is the BACI dataset from CEPII that provides harmonized trade data for all countries in our sample. The BACI trade dataset is harmonized in the sense that it only reports one value for any given trade flow instead of reporting different values reported by importing and exporting countries. A shortcoming of the BACI dataset is that it only includes trade in goods, but excludes services. We therefore use the WOID to measure a country's total imports, and only rely on the BACI dataset to measure the relative distribution of those imports among its trading partners. We implicitly assume that trade flows in services across countries are proportional to trade flows in goods.

The trade elasticity ψ_y is set to 1.5. This is comparable to calibrations used in international business cycle models with trade. In their original paper, Heathcote and Perri (2002) estimated $\psi_y = 0.90$. Backus *et al.* (1994) set the trade elasticity to 1.5. Using firm-level data, Cravino (2014) and Proebsting (2015) find elasticities close to 1.5.[17].

Price and Wage Rigidity We calibrate the Calvo price and wage setting hazards to roughly match observed frequencies of price adjustment in the micro data. For price rigidity, Nakamura and Steinnsen (2008) report that prices change roughly once every 8 to 11 months; Klenow and Krivstov (2008) report that prices change roughly once every 4 to 7 months. Evidence on price adjustment in Europe suggests somewhat slower adjustment. Alvarez et al. (2005) find that the average duration of prices is 13 months (for a quarterly model this corresponds to $\theta_p = 0.77$). The evidence on wage rigidity is somewhat more sparse. Perhaps the best study is Barattieri, Basu and Gottschalk (2014) who use a careful analysis of SIPP data to conclude that wages change on average once every 12 months (which corresponds to

[16] See the appendix for more details.

[17] The literature on international trade outside of business cycle analysis typically adopts higher elasticities. For instance Broda, Greenfield and Weinstein (2010) find a long-run trade elasticity of 6.8.

$\theta_w = 0.75$).[18] Our baseline calibration takes $\theta_p = 0.80$ and $\theta_w = 0.80$. These are somewhat higher than the empirical findings for U.S. price and wage adjustment. Our main reason for adopting this calibration is to match the data indicating slightly more sluggish price adjustment in European countries compared to the U.S.[19]

Other Parameters. We set the subjective time discount factor β to imply a long run real annual interest rate of four percent. The capital share parameter α is set to 0.36 and the quarterly depreciation rate is set to 0.03. 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), Hall (1985)). We adopt the calibration for the financial market imperfections from Brave *et al.* (2012). They set a quarterly external finance premium of .0074 which implies an annual premium of roughly three percent. The steady state leverage ratio is 1.11, the elasticity of the external finance premium with respect to leverage F_ϵ is 0.20 and the quarterly persistence of the shocks to the external finance premium is set to 0.99. We set our Taylor rule parameters as $\phi_\pi = 1.5$, $\phi_{GDP} = 0.5$ and $\rho_i = 0.75$. Finally, we set the population measures $\mathbb{N}_n$ to ensure that the model matches the relative aggregate GDP across the countries in our dataset and we set the steady state ratio of government purchases to GDP to match data from the OECD and Eurostat. Our benchmark calibration is summarized in Table 4.

4 Model and Data Comparison

We can now simulate the calibrated model's reaction to austerity shocks to compare the model's reaction to the observed patterns in the data. Our approach is to treat the austerity forecast deviations calculated in Section 2 as structural shocks. To incorporate these shocks, we first modify the forecast deviations to quarterly data (the data in Table 3 was annual because we only have quarterly data for a short time period). To construct quarterly forecasts we use forecasting equation (2.1) which includes a time trend, as well as lagged government spending and contemporaneous GDP. We impose the same estimated coefficients from the annual forecasting equation used to create Table 3 but we adjust the parameters for quarterly

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

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

frequencies (e.g., the time variable proceeds in quarters of a year rather than integers). The shock is then the log difference between actual quarterly government spending and forecast government spending. We ignore tax shocks and shocks to the primary balance since these shocks appear to exert only a minor influence on the system.

In addition to the austerity shocks, we also include shocks to monetary policy and shocks to financial markets. Including other shocks is important because it is likely that some of the observed differences in economic performance can be traced to shocks other than austerity. We describe these additional shocks below.

4.1 Forcing Variables

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

Monetary Policy Shocks To estimate monetary policy shocks we proceed as follows. We begin by estimating a generalized Taylor rule of the form suggested by Clarida, Gali and Gertler (1999).[20]

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

where i_t is the nominal interest rate, r is the long-run interest rate, π_t is inflation, π^* is the inflation target, $\%GDP_t$ are percent deviations of real GDP from its trend (i.e., the output gap), and ε_t^i is a structural shock. Inflation is measured using the GDP deflator. The interest rate and the inflation rate are measured in annual percent. We estimate this rule by first imposing the original estimate of $\rho = 0.79$ by Clarida, Gali and Gerlter (1999) and then estimating ϕ_π and ϕ_{GDP} for the U.S. over the period 1980.1 - 2005.4. This estimation implicitly assumes that the U.S. has been adhering to a fairly stable monetary rule since the early 1980's.

We then impose the estimated coefficients ϕ_π, ϕ_{GDP} and the constrained coefficient ρ for each of the countries in Europe that have an independent monetary policy. We do not estimate separate Taylor rules for each central bank primarily because of data limitations. For the Eurozone, we assume that the ECB reacts to the weighted average of inflation and

[20]The original rule analyzed by Clarida, Gali and Gertler (1999) depends on expected inflation and the expected output gap instead of contemporaneous inflation and output gap.

output over all countries in the Euro. With these coefficients we then estimate country-specific intercepts (corresponding to the parameters $r - \pi$ in the Taylor rule). We can then recover the monetary policy shocks for each country n as $\hat{\varepsilon}^{i}_{n,t} = i_{n,t} - \hat{\imath}_{n,t}$.

Financial Shocks We take our measure of financial shocks from data on spreads between lending rates and interest rates on safe government bonds. For the U.S., we match the TED spread which is the difference between the 3 month LIBOR and the interest rate on 3 month U.S. government debt. For European countries we take the difference between interest rates on business loans and the interest rate on German government debt for 10-year maturity bonds.

4.2 Benchmark Model Performance

We can now compare the benchmark model with the earlier empirical results. The left panel of Table 5 shows the empirical relationship between the austerity shocks (negative shocks to government spending) and our five measures of economic performance. These results are essentially identical to the estimates in Table 3; the coefficients differ slightly because here we are using quarterly data rather than annual data. The right panel of Table 5 shows the same regression results but run on the simulated data. Several points are worth emphasizing. First, the estimated effects of the austerity shocks are substantially smaller than the estimates from the data. Empirically, every one percent reduction in government spending is associated with a reduction in GDP of roughly 0.32 percent. In contrast, the model estimates suggest a reduction in GDP of only 0.20 percent. Similarly, the inflation reactions are also not of the same magnitude. In the data, a one percent reduction in government spending is associated with an small reduction in inflation of roughly 0.05 percent while in the model the reduction is even smaller – only 0.03 percent. As one would anticipate, net exports are positively associated with reductions in government spending though again somewhat less than in the data.

Figures 4 - 8 show comparisons of scatterplots of the actual data (left panels) and the scatterplots of simulated data (right panels). For each panel, the log austerity shocks (i.e., forecast errors) are on the horizontal axis. The units of both axes are log points times 100. For example, 50 on the horizontal axis is 0.50 log points and corresponds to a *reduction* in government spending (i.e., an increase in austerity). The panels also show the OLS regression lines for the fixed exchange rate countries (the solid dots) and the floating exchange rate countries (the open dots).

The figures reveal several differences between the actual data and the model. First and most importantly the actual data has substantially more noise than the model simulations. This is not surprising since the model includes only a limited number of shocks. Second, the inflation data exhibits substantially more variation across countries within the Eurozone than the model permits. In the model, even though there are sharp differences in government spending across countries, there is a strong tendency for countries in the currency union to have inflation rates that are nearly the same. On the other hand, the model displays substantial swings in inflation for countries that are not in the Eurozone while in the data, inflation does not differ radically from that of the Eurozone. This may be due to the fact that even though these countries technically have floating exchange rates and independent monetary policy, the monetary authorities in these countries do not depart from the policies enacted by the ECB. Third, the exchange rate data display only a very weak relationship to austerity shocks. In the model, exchange rates in the Eurozone display virtually no variation across countries (recall, these are trade-weighted exchange rates and thus countries in the Eurozone can have changes in their exchange rate).[21]

To understand the mechanisms operating in the model, we examine the model's reaction to variation in each of the three forcing variables—austerity, monetary shocks, financial shocks—separately. Table 6 reports the results of such a decomposition. It displays the regression coefficients for the five measures of economic performance. The regressions use the model-implied performance and the empirically observed austerity shocks. The two left most panels report the data and the results for the benchmark model; the three other panels report the results for each shock separately. The decomposition reveals two things: First, the negative relationship between austerity and performance in the model is only partially driven by austerity. Countries that are empirically identified as austere were also hit by contractionary monetary policy and spread shocks. For countries with a floating exchange rate, the negative austerity-performance relationship even mainly derives from austere countries implementing contractionary monetary policy.

Second, while the benchmark model produces regression coefficients that are qualitatively consistent with those observed in the data, this is not true for the individual shocks. Both austerity and monetary policy shocks are needed to generate patterns as those observed in

[21] Slovakia is a clear outlier in the scatter plot in Figure 7. This is because Slovakia was actively bringing its exchange rate into alignment with the Euro after 2005 (when our unit root forecast starts) and before it adopted the euro in 2009.

the data. Austerity shocks lead to declines in GDP and rising net exports as in the data, but also produce counterfactual inflation in floating exchange rate countries and a depreciation of their exchange rates. Monetary policy shocks can explain the pattern of inflation and exchange rates in floating exchange rate countries, but—not surprisingly—cannot explain the variation observed across fixed exchange rate countries. We now explain the effects of these two shocks in the model.

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

The effect on inflation is ambiguous. Inflation is forward looking and depends on the future path of real marginal costs, including wages. Wages will be low if the reduction in labor demand outweighs the fall in labor supply. This is typically the case under fairly standard parameterizations of a closed economy New Keynesian model (including a closed economy version of our model), so that reductions in government spending cause deflation. In our open economy setting, however, reductions in government spending can cause inflation for countries with floating exchange rate (see the coefficient for inflation, 0.03, in Table 6 in the 'Only Govt' panel). This is because of the exchange rate: In response to a fall in government spending, the nominal exchange rate depreciates (see the coefficient -0.04). This raises the price of imports and stimulates demand for exports, which counterbalances the fall in labor demand and prevents wages from falling (too much). Both effects cause inflation.

Although our model features only limited risk sharing, increases in consumption translate into a depreciation of the real exchange rate in both fixed and floating exchange rate countries. For fixed exchange rate countries, the depreciation of the real exchange rate is achieved through deflation. For floating exchange rate countries, the depreciation of the real exchange rate comes from a depreciation of the nominal exchange rate (despite inflation).[22]

As mentioned above, the implied response of inflation and exchange rate for floating exchange rate countries is counterfactual in the experiment with government spending shocks only. Adding monetary policy shocks improves the model's performance along these dimen-

[22]This is at least partially caused by our choice that prices are sticky in the producer's currency (as opposed to the buyer's currency).

sions. In particular, in our dataset empirically austere countries tend to have interest rates above the level suggested by the Taylor rule. These high interest rates reduce consumption and output, push down inflation and lead to an appreciation of the nominal (and real) exchange rates.

4.3 Variations on the Benchmark Model

The simulations displayed in Figures 4 - 8 and the results in Tables 5 and 6 all correspond to the benchmark parameterization described in Table 4 with government spending shocks (i.e., austerity shocks), monetary policy shocks and financial shocks included as forcing variables. Here we briefly consider some variations of our preferred specification to show whether the model results depend crucially on particular assumptions.

Alternative Parameter Configurations [To be added]

5 Conclusion

Since the end of the Great Recession in 2009, European countries have experienced radically different recoveries. Some enjoyed a return to normal economic growth shortly following the financial crisis while others have suffered through prolonged periods of low employment and low growth. We have attempted to make sense of this diversity of experiences by examining empirical comovements for various measures of economic activity for the nations of Europe. Despite substantial noise in the data, there are clear patterns that suggest that a surprising amount of the differences in economic performance are due to austerity policies. In particular, the evidence suggests that contractions in government spending have played a surprisingly large role in reducing output for some countries. Evidence for tax policies and the primary balance is more mixed. Countries that increase taxes fare worse than otherwise but the effects of raising taxes are modest and not strongly statistically significant. In contrast, countries that reduce government spending experience sharp reductions in output and inflation.

We use a multi-country DSGE model to see whether standard macroeconomic theory can make sense of the observed changes in economic activity. The model features government spending shocks, monetary policy shocks, and shocks to financial markets and allows us to make direct comparisons between the observed empirical relationships in the data and the model's predictions. The model is calibrated to match the main features of the European countries in our dataset including country size, observed trade flows and exchange rate regimes. The model output broadly matches the empirical patterns observed in the data. While our preliminary findings suggest that standard Keynesian mechanisms are playing a strong role in shaping the behavior of countries across Europe, the quantitative predictions of the model for GDP are too small to fully match the empirical findings. This likely means that the magnitude of the demand multipliers in the model are simply too weak to match the data. Future work is needed to refine the model's performance along this dimension.

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

Country	Size	Import share	XRT regime	Country	Size	Import share	XRT regime
Belgium	2.4 %	30.3 %	Euro	Bulgaria	0.2 %	25.9 %	Peg
Germany	18.3 %	18.9 %	Euro	Denmark	1.2 %	23.1 %	Peg
Ireland	1.0 %	34.7 %	Euro	Estonia	0.2 %	27.8 %	Peg
Greece	2.2 %	18.0 %	Euro	Latvia	0.3 %	22.6 %	Peg
Spain	9.1 %	14.1 %	Euro	Lithuania	0.2 %	29.3 %	Peg
France	13.9 %	13.7 %	Euro	Czech Republic	1.6 %	26.6 %	Floating
Italy	12.1 %	13.3 %	Euro	Hungary	1.2 %	32.4 %	Floating
Cyprus	0.1 %	23.4 %	Euro	Poland	4.2 %	19.6 %	Floating
Luxembourg	0.2 %	50.5 %	Euro	Romania	0.8 %	15.3 %	Floating
Netherlands	4.1 %	25.8 %	Euro	Sweden	2.1 %	21.1 %	Floating
Austria	2.0 %	24.2 %	Euro	United Kingdom	15.2 %	14.6 %	Floating
Portugal	1.8 %	18.5 %	Euro	Norway	1.4 %	18.8 %	Floating
Slovenia	0.4 %	28.0 %	Euro	Switzerland	2.0 %	26.0 %	Floating
Slovak Republic	0.7 %	31.4 %	Euro	United States	104.3 %	7.9 %	Floating
Finland	1.2 %	18.6 %	Euro	RoW	141.8 %	9.1 %	Floating

Notes: Table displays the 29 countries plus the Rest of the World in our sample. Size is measured as the country's real absorption relative to the sum of all European countries' real absorption. Real absorption is measured in value added terms, i.e. GDP less net exports. Shares are averaged over 2003 - 2011. The import share is measured as the share of imports in absorption, where absorption is measured in gross terms, i.e. gross output less net exports. The exchange rate regime is as of 2010. Countries with a peg have their currencies pegged to the Euro. Countries with a floating currency are either free or managed floaters or countries with a wide crawling peg. The classification follows Ilzetzki et al. (2004), *http://www.carmenreinhart.com/data/browse-by-topic/topics/11/*..

Table 2: SUMMARY STATISTICS OF DEVIATIONS FROM FORECAST

	$Govt_1$	$Govt_2$	Tax_1	Tax_2	PB_1	PB_2	GDP_1	GDP_2	GDP_3
Average	−0.002	0.012	−0.030	−0.056	−0.003	0.004	−0.115	−0.176	−0.188
Std. dev.	0.042	0.055	0.152	0.187	0.105	0.119	0.092	0.118	0.130
Correlation matrix									
$Govt_1$	1.000								
$Govt_2$	0.936	1.000							
Tax_1	−0.177	−0.193	1.000						
Tax_2	−0.185	−0.239	0.924	1.000					
PB_1	0.255	0.226	0.174	0.052	1.000				
PB_2	0.189	0.137	0.266	0.186	0.819	1.000			
GDP_1	0.028	0.002	0.696	0.692	0.186	0.122	1.000		
GDP_2	−0.099	−0.130	0.317	0.262	−0.032	−0.217	0.451	1.000	
GDP_3	−0.082	−0.139	0.372	0.355	−0.009	−0.126	0.470	0.975	1.000

Notes: Table displays statistics of the log-difference between the actual time series and the forecast, averaged over 2000 - 2013, for GDP, government purchases, primary balance and tax revenue. The first row displays the average of this difference across countries; the second row displays the standard deviation across countries. The remaining rows display the correlation across the various measures.

Table 3: AUSTERITY AND ECONOMIC PERFORMANCE

	Government Spending Shortfall					
	All countries		Fixed		Floating	
	β_1	R^2	β_1	R^2	β_1	R^2
GDP	−0.34	0.48	−0.34	0.48	−0.35	0.58
	(0.07)		(0.08)		(0.11)	
Inflation	−0.05	0.36	−0.04	0.28	−0.08	0.57
	(0.01)		(0.02)		(0.03)	
Net Exports	0.14	0.18	0.13	0.13	0.16	0.62
	(0.06)		(0.08)		(0.05)	
Exchange Rate	−0.02	0.00	−0.04	0.01	0.03	0.00
	(0.10)		(0.07)		(0.30)	
GDP Growth	−0.07	0.36	−0.08	0.36	−0.06	0.56
	(0.02)		(0.03)		(0.02)	
	Government Tax Revenue					
	All countries		Fixed		Floating	
	β_1	R^2	β_1	R^2	β_1	R^2
GDP	0.09	0.01	0.08	0.01	0.25	0.09
	(0.15)		(0.17)		(0.30)	
Inflation	−0.01	0.01	−0.03	0.05	0.03	0.03
	(0.03)		(0.03)		(0.07)	
Net Exports	0.06	0.01	0.08	0.02	−0.06	0.03
	(0.10)		(0.13)		(0.14)	
Exchange Rate	−0.03	0.00	0.05	0.01	−0.36	0.06
	(0.15)		(0.11)		(0.52)	
GDP Growth	0.04	0.04	0.05	0.06	0.02	0.03
	(0.04)		(0.05)		(0.05)	
	Government Primary Balance					
	All countries		Fixed		Floating	
	β_1	R^2	β_1	R^2	β_1	R^2
GDP	0.00	0.00	0.14	0.01	−0.37	0.06
	(0.32)		(0.42)		(0.53)	
Inflation	0.02	0.01	0.01	0.00	0.05	0.02
	(0.06)		(0.07)		(0.12)	
Net Exports	−0.04	0.00	−0.16	0.02	0.24	0.14
	(0.21)		(0.30)		(0.23)	
Exchange Rate	−0.52	0.09	−0.52	0.22	−0.44	0.03
	(0.32)		(0.23)		(0.93)	
GDP Growth	0.05	0.01	0.06	0.02	0.01	0.00
	(0.08)		(0.11)		(0.09)	

Notes: All government variables are forecasted using time trend, GDP and own lag (forecast 2). GDP and GDP growth are forecasted using the 'convergence' estimator. Inflation, net exports and exchange rates are forecasted using unit root. Exchange rate is the nominal effective exchange rate. Reported standard errors in parentheses are (untreated) OLS errors.

Table 4: CALIBRATION

Description	Parameter	Value	Source
Preferences			
Discount factor (quarterly)	β	0.99	Standard value
Coefficient of relative risk aversion	$\frac{1}{\sigma}$	2	Standard value
Frisch elasticity of labor supply	η	1	Barsky et al. (1997)
Trade preference weights	ω_n^j		World Input-Output Table and BACI dataset
Technology			
Population	$\mathbb{N}_n$		matching relative GDP size, OECD and Eurostat
Capital share	α	0.36	Christiano et al. (2005)
Depreciation (quarterly)	δ	0.03	Brave et al. (2012)
Utilization cost	a''	0.286	Del Negro et al. (2013)
Elasticity of substitution between varieties	ψ_q	10	Standard value
Sticky price probability	θ_p	0.80	Different sources (see text)
Sticky wage probability	θ_w	0.80	Different sources (see text)
Investment adjustment cost	f''	2.48	Christiano et al. (2005)
Trade demand elasticity	ψ_y	1.5	e.g. Backus et al. (1994), Cravino (2014), Proebsting (2015)
Elasitcity external finance premium	F_ϵ	0.20	Brave et al. (2012)
SS External finance premium	$F(\lambda_{ss})$	1.0074	Brave et al. (2012)
SS Leverage ratio	$\lambda - 1$	1.11	Brave et al. (2012)
Persistence spread shock	ρ_F	0.99	Brave et al. (2012)
Fiscal and monetary policy			
Gov't purchases over GDP	$\frac{G_n}{GDP_n}$		OECD and Eurostat
Persistence government spending shock	ρ_G	0.93	Del Negro et al. (2013)
Persistence monetary policy shock	ρ_i	0	Standard value
Taylor rule persistence	ϕ_i	0.75	
Taylor rule GDP coefficient	ϕ_{GDP}	0.5	
Taylor rule inflation coefficient	ϕ_π	1.5	

Table 5: COMPARISON OF MODEL AND DATA: BENCHMARK CALIBRATION

	Data			Benchmark		
	All	Fix	Float	All	Fix	Float
GDP	-0.32	-0.33	-0.32	-0.20	-0.19	-0.26
	(0.07)	(0.08)	(0.11)			
Inflation	-0.05	-0.04	-0.07	-0.03	-0.01	-0.06
	(0.01)	(0.02)	(0.02)			
Net Exports	0.14	0.13	0.15	0.10	0.12	0.04
	(0.05)	(0.08)	(0.04)			
Exchange Rate	-0.01	-0.03	0.04	0.02	-0.00	0.07
	(0.09)	(0.07)	(0.28)			
GDP Growth	-0.07	-0.08	-0.05	-0.02	-0.02	-0.02
	(0.02)	(0.03)	(0.02)			

Notes: Table displays data and model results for austerity regressions. The benchmark calibration includes shocks to government spending, the Taylor rule and interest rate spreads. The following columns display results if only one of those shocks is fed into the model.

Table 6: COMPARISON OF MODEL AND DATA: INDIVIDUAL SHOCKS

	Data			Benchmark			Only Govt			Only Money			Only Spread		
	All	Fix	Float	All	Fix	Float	All	Fix	Float	All	Fix	Float	All	Fix	Float
GDP	-0.32	-0.33	-0.32	-0.20	-0.19	-0.26	-0.13	-0.16	-0.09	-0.04	0.00	-0.16	-0.03	-0.04	-0.01
	(0.07)	(0.08)	(0.11)												
Inflation	-0.05	-0.04	-0.07	-0.03	-0.01	-0.06	0.00	-0.02	0.03	-0.03	-0.00	-0.10	0.00	0.00	0.00
	(0.01)	(0.02)	(0.02)												
Net Exports	0.14	0.13	0.15	0.10	0.12	0.04	0.10	0.11	0.09	-0.01	0.00	-0.05	0.01	0.01	0.00
	(0.05)	(0.08)	(0.04)												
Exchange Rate	-0.01	-0.03	0.04	0.02	-0.00	0.07	-0.01	0.00	-0.04	0.03	-0.01	0.11	0.00	0.00	0.00
	(0.09)	(0.07)	(0.28)												
GDP Growth	-0.07	-0.08	-0.05	-0.02	-0.02	-0.02	-0.02	-0.02	-0.01	-0.01	0.00	-0.02	-0.00	-0.01	0.00
	(0.02)	(0.03)	(0.02)												

Notes: Table displays data and model results for austerity regressions. The benchmark calibration includes shocks to government spending, the Taylor rule and interest rate spreads. The following columns display results if only one of those shocks is fed into the model.

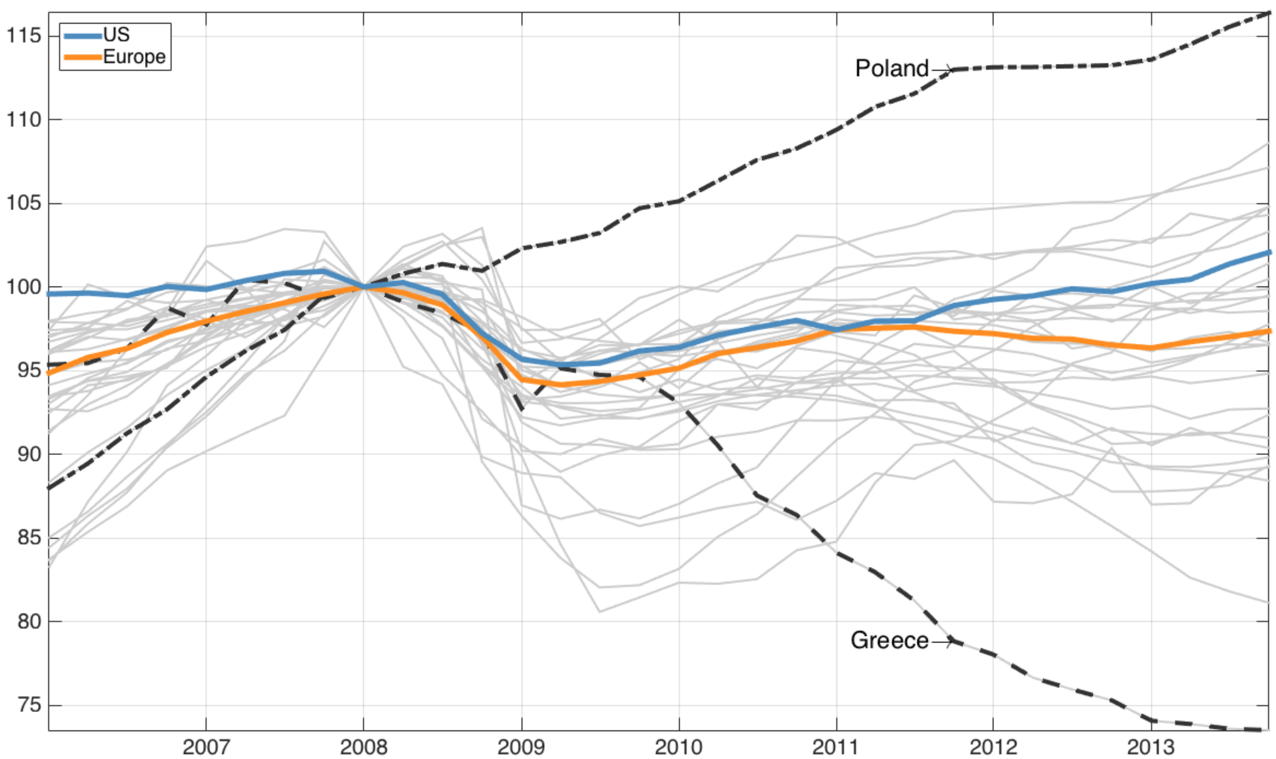

Figure 1: REAL PER CAPITA GDP BEFORE, DURING AND AFTER THE CRISIS

Notes: The figure plots the time paths of real per capita GDP for the period 2006-2014 for the countries in our data set. The paths are indexed to 100 in 2008:1. The two shaded regions indicate recession dates according to the NBER and CEPR.

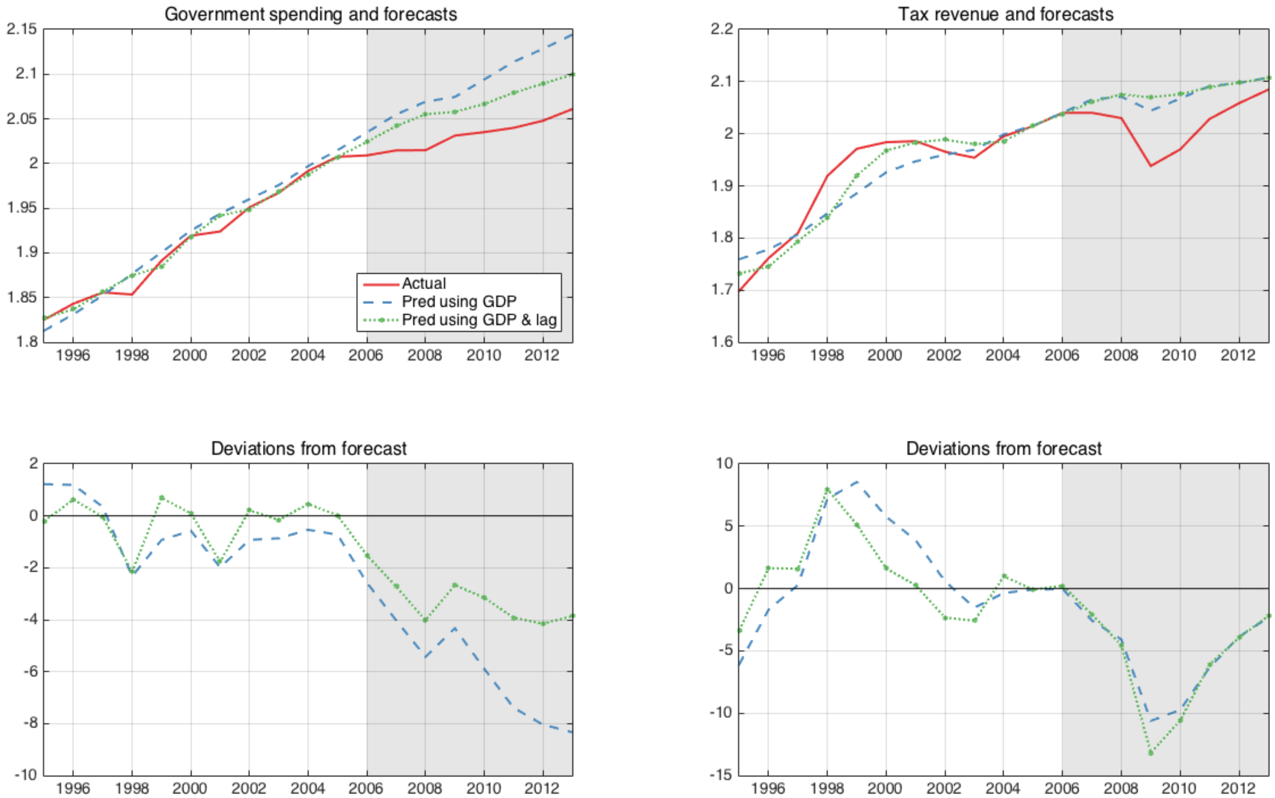

Figure 2: MEASURES OF AUSTERITY FOR FRANCE

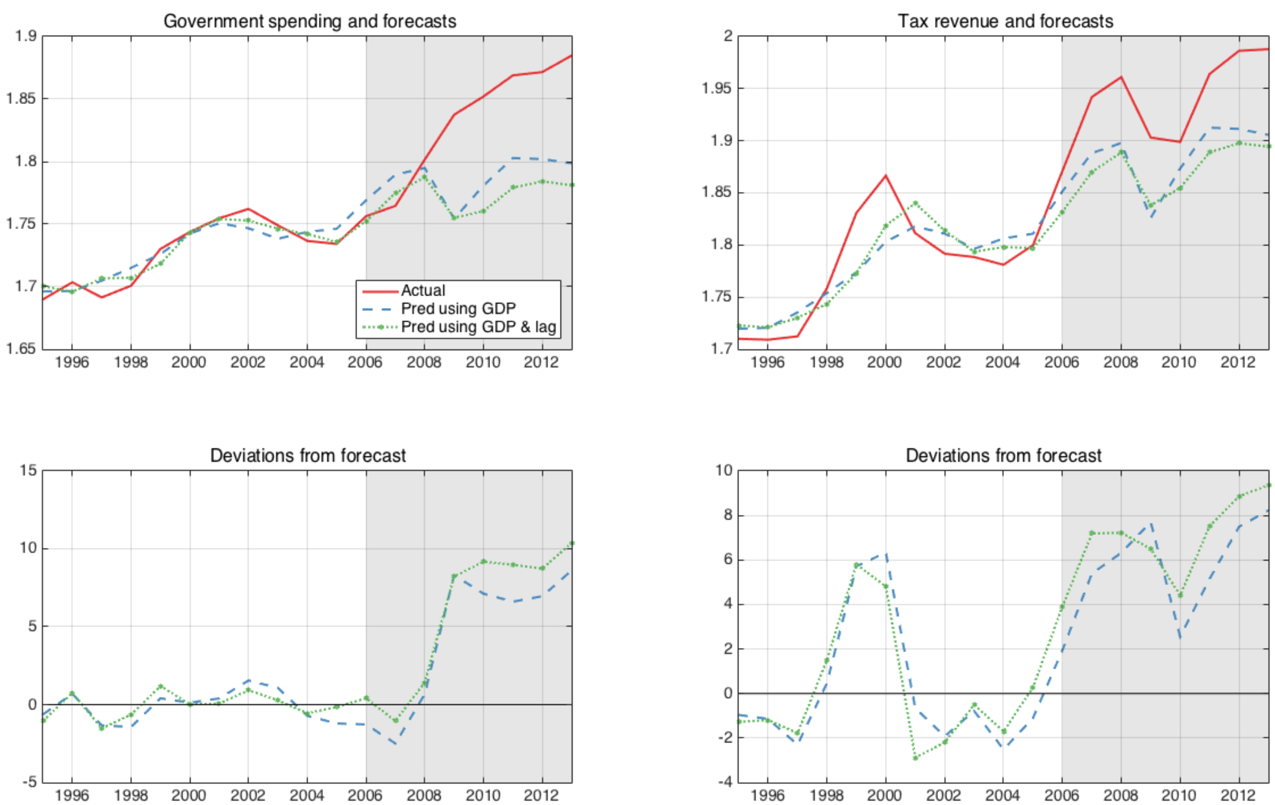

Figure 3: MEASURES OF AUSTERITY FOR GERMANY

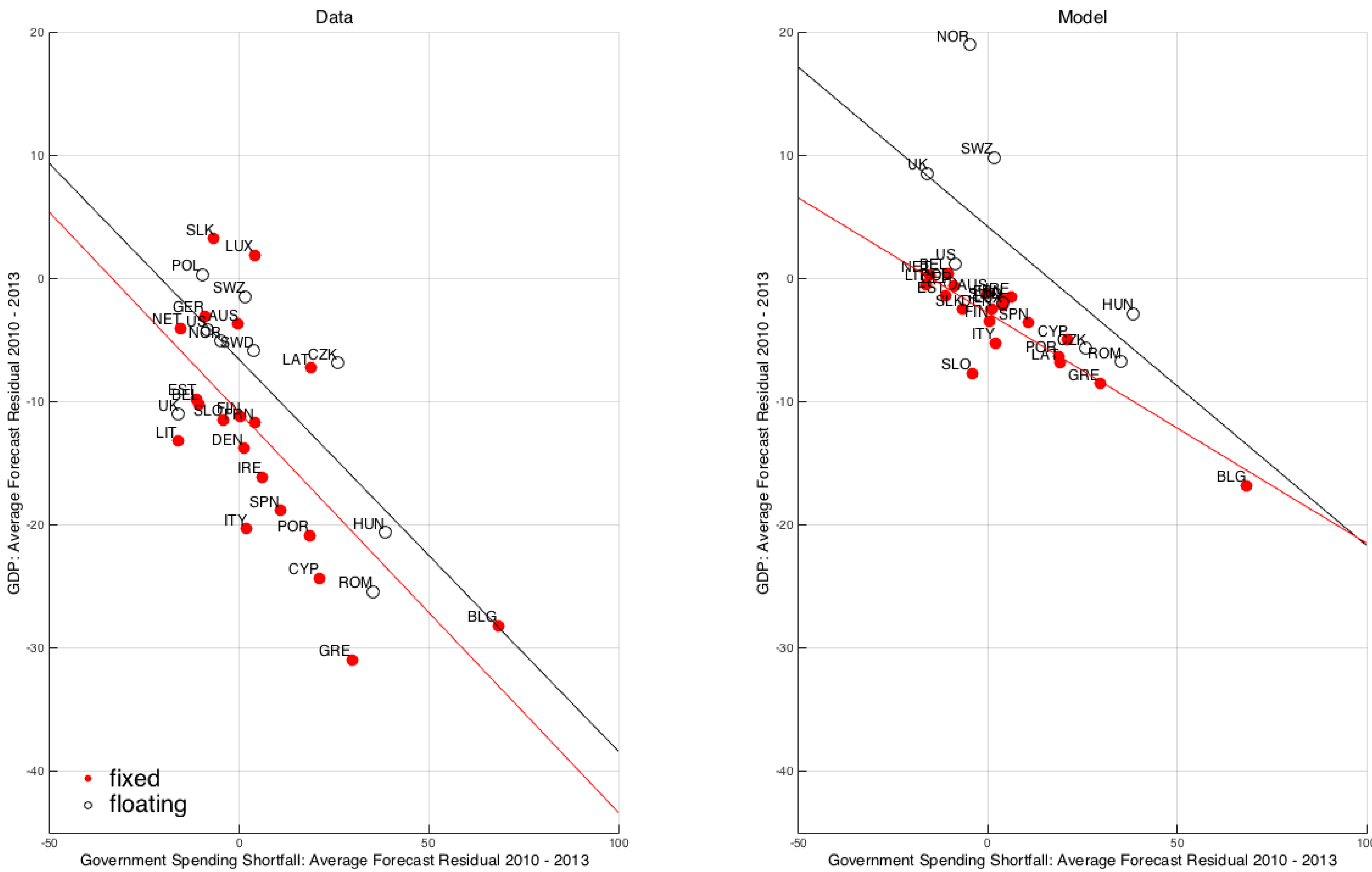

Figure 4: GDP AND AUSTERITY: DATA VS. MODEL

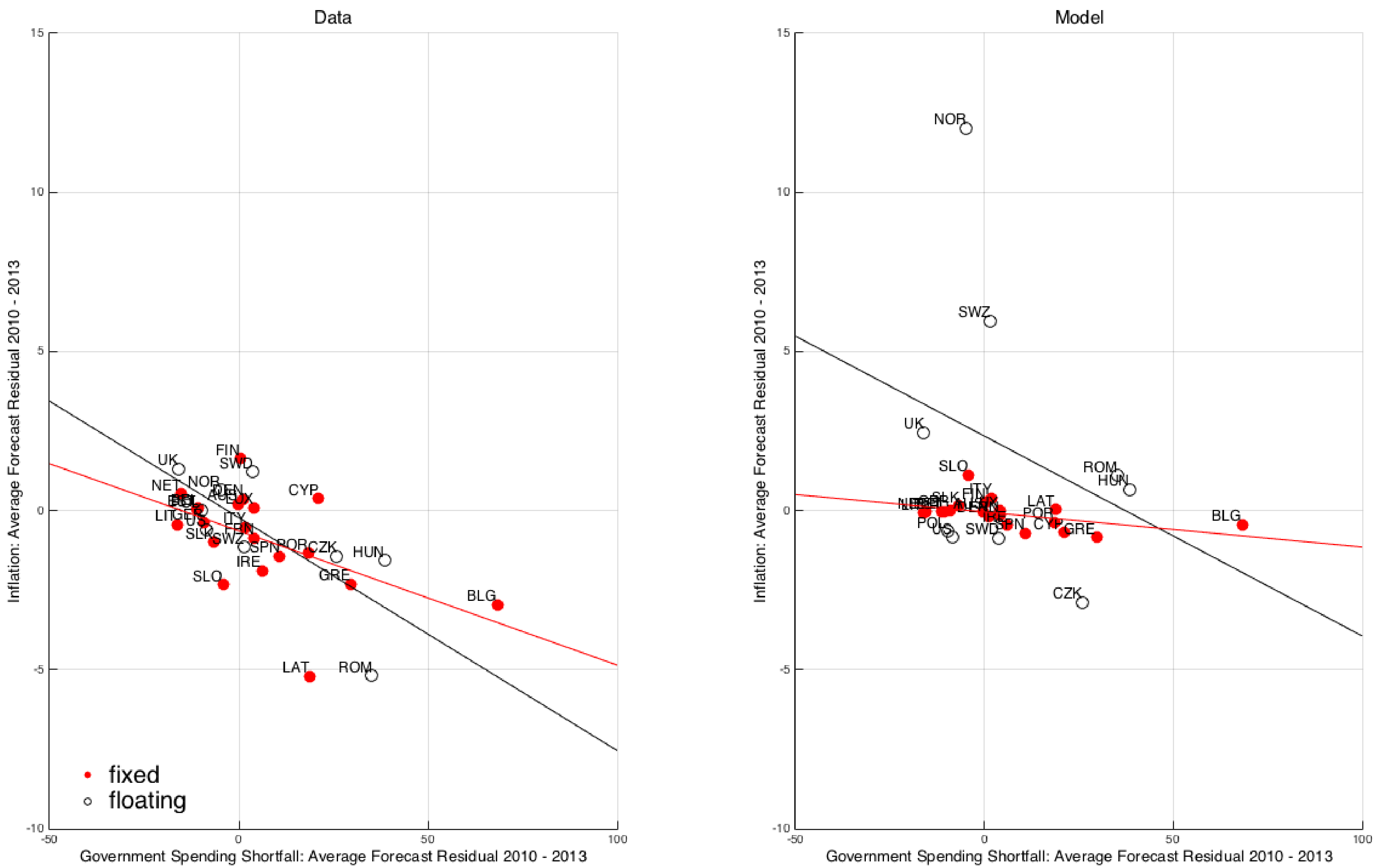

Figure 5: INFLATION AND AUSTERITY: DATA VS. MODEL

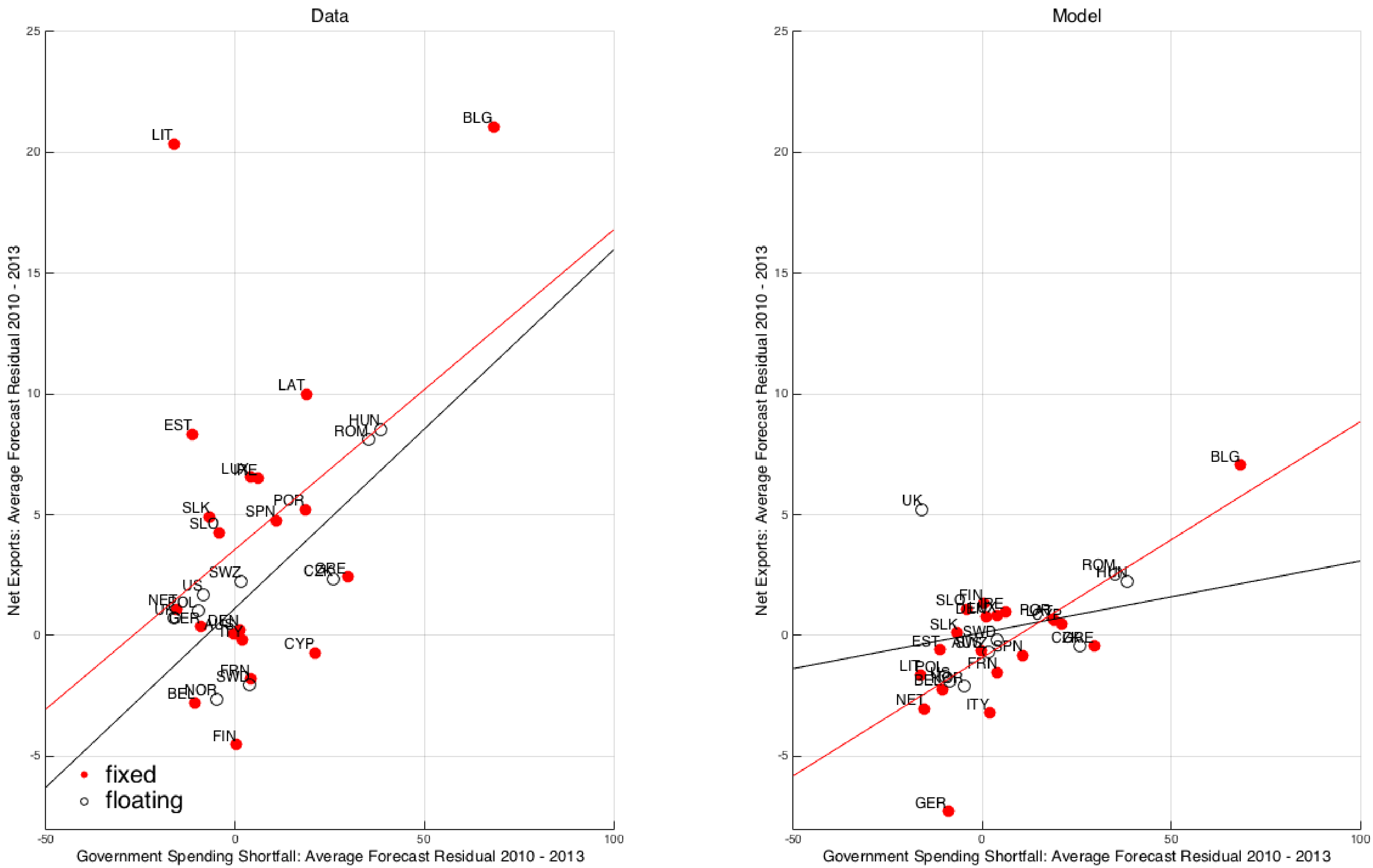

Figure 6: NET EXPORTS AND AUSTERITY: DATA VS. MODEL

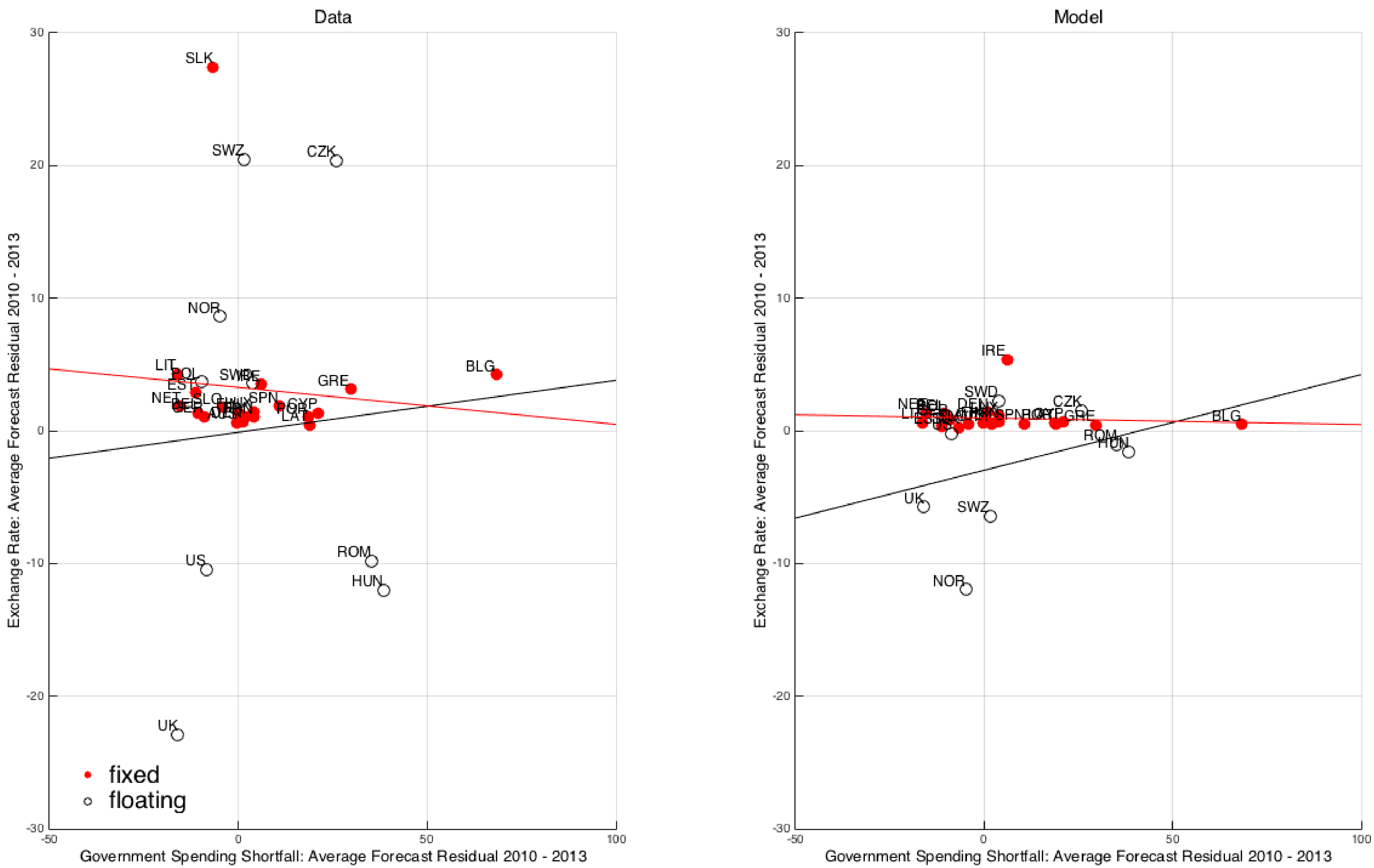

Figure 7: NOMINAL EFFECTIVE EXCHANGE RATE AND AUSTERITY: DATA VS. MODEL

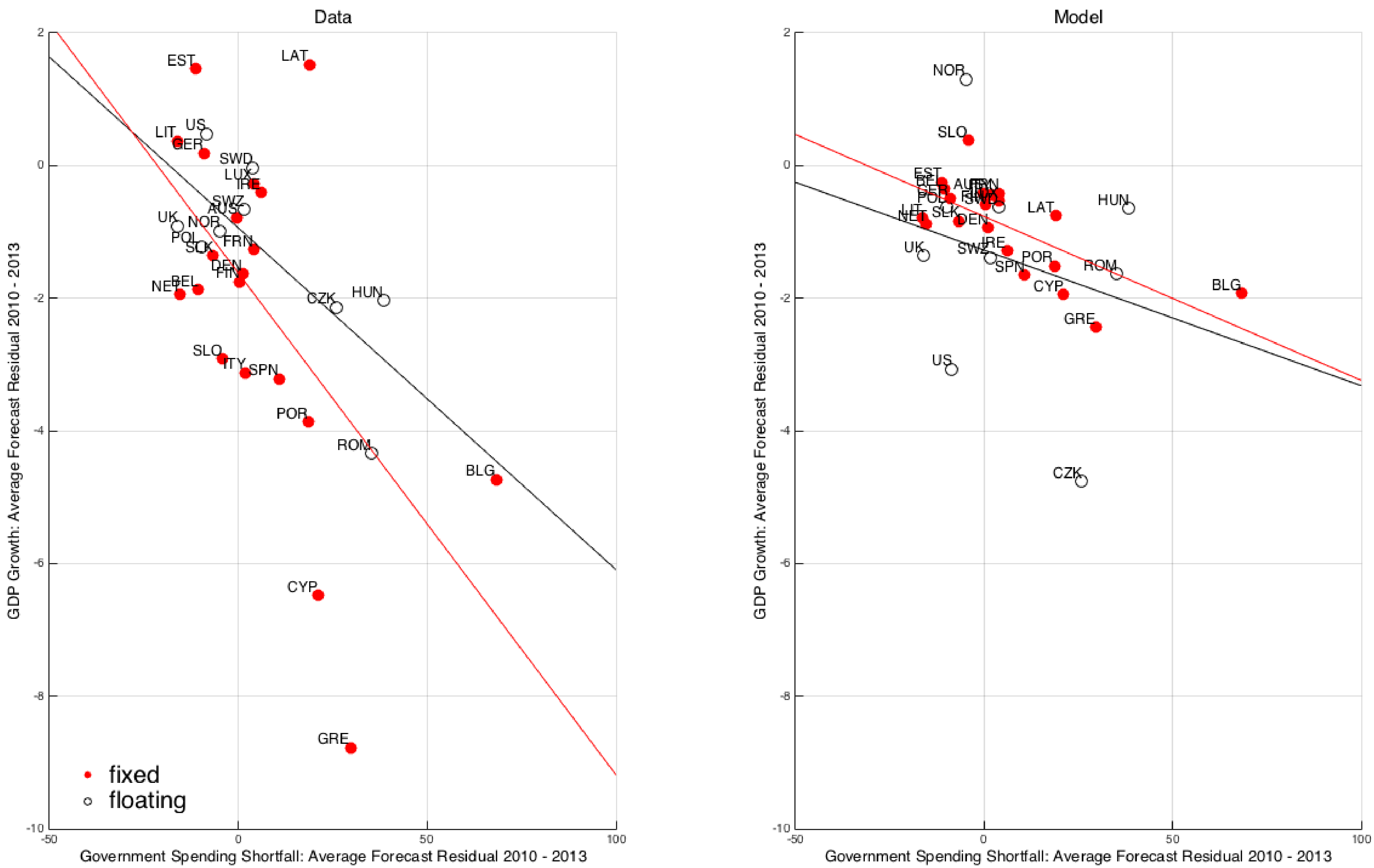

Figure 8: GDP GROWTH AND AUSTERITY: DATA VS. MODEL

Appendix

A Details on convergence estimator.

The third approach to forecast the level of GDP, and our approach to forecast the growth rate of GDP are based on the conditional convergence hypothesis. We assume that countries in Europe converge to a common path for GDP per capita. This can be justified on basis of the Single European Act (Article 158), which foresees economic cohesion across all member states as a central goal of the EU. Economic cohesion is typically interpreted as reducing disparities in GDP per capita. This convergence process especially affects our forecasts for Central and Eastern European countries, which, after strong economic growth in the 90s and 2000s, have reduced the gap to Western European countries. For instance, between 1995 and 2014, Estonia increased its GDP per capita from 30% to more than 60% of the EU-12 average.

We estimate a time-varying growth rate for all countries in our sample in a two-step procedure. The two steps break the growth rate into a constant part and a time-varying part. In a first step, we estimate a constant growth rate for twelve advanced European countries, called EU-12 (Belgium, Denmark, Germany, Ireland, Spain, France, Italy, Luxembourg, Austria, Netherlands, Portugal and Finland). This growth rate $\bar{g}$ is estimated on data from 1993:1 to 2005:4:

$$\ln GDP_t^{EU} = \beta_0 + \bar{g}t + \epsilon_t^{EU}.$$

The estimate of $\bar{g}$ is 0.49 percent with a standard deviation of 0.01 percent. In a second step, we estimate the time-varying part of the growth rate. We assume that the time-varying part is a linear function of the log difference between the predicted EU-12 GDP per capita and a country's GDP per capita:

$$g_t^i = \bar{g} + \gamma \left(\ln \widehat{GDP}_{t-1}^{EU} - \ln GDP_{t-1}^i \right),$$

where $\ln \widehat{GDP}_{t-1}^{EU} = \hat{\beta}_0 + \hat{\bar{g}}(t-1)$. We estimate γ using

$$\ln GDP_t^i - \ln GDP_{t-1}^i - \hat{\bar{g}} = \gamma \left(\ln \widehat{GDP}_{t-1}^{EU} - \ln GDP_{t-1}^i \right) + \epsilon_t^i.$$

We estimate a common γ for all countries in Central and Eastern Europe (Bulgaria, Czech Republic, Estonia, Greece, Cyprus, Latvia, Lithuania, Hungary, Poland, Romania and Slovenia, Slovak Republic) using 1993:1 (or earliest available data) to 2005:4 as our sample period. Our estimate of γ is 0.64 percent with a standard deviation of 0.06 percent.[23] The positive γ indicates convergence.

Our forecast for country i's log GDP per capita at time t is

$$\ln \widehat{GDP}_t^i = \ln GDP_{t-1}^i + \hat{\bar{g}} + \hat{\gamma} \left(\ln \widehat{GDP}_{t-1}^{EU} - \ln GDP_{t-1}^i \right) \qquad \forall t \leq 2006{:}1$$
$$\ln \widehat{GDP}_t^i = \ln \widehat{GDP}_{t-1}^i + \hat{\bar{g}} + \hat{\gamma} \left(\ln \widehat{GDP}_{t-1}^{EU} - \ln \widehat{GDP}_{t-1}^i \right) \qquad \forall t > 2006{:}1.$$

[23]Including all countries would give $\hat{\gamma} = 0.61$ percent.

Table A1: TABLE A1

	Government Purchases		Tax Revenue		Primary Balance		GDP		
	$Govt_1$	$Govt_2$	Tax_1	Tax_2	PB_1	PB_2	Convergence	Hugging	Shrinkage
Belgium	0.136	0.100	−0.027	−0.067	−0.012	0.015	−0.102	−0.122	−0.123
Bulgaria	−0.458	−0.660	−0.007	−0.033	−0.009	0.019	−0.282	−0.191	−0.243
Czech Rep	−0.095	−0.239	−0.019	−0.132	−0.005	0.039	−0.068	−0.120	−0.198
Denmark	−0.001	0.003	−0.014	−0.021	−0.040	−0.035	−0.138	−0.156	−0.158
Germany	0.073	0.093	0.059	0.075	0.003	0.041	−0.030	0.010	−0.004
Estonia	0.177	0.128	0.263	0.379	0.031	0.042	−0.098	−0.386	−0.381
Ireland	−0.201	−0.056	0.008	0.024	−0.052	−0.046	−0.161	−0.451	−0.461
Greece	−0.175	−0.297	0.011	0.189	−0.034	−0.014	−0.310	−0.264	−0.249
Spain	−0.053	−0.098	−0.199	−0.162	−0.072	−0.063	−0.188	−0.231	−0.233
France	−0.074	−0.038	−0.056	−0.057	−0.005	−0.009	−0.117	−0.105	−0.105
Italy	0.010	−0.033	−0.033	0.081	0.067	0.085	−0.203	−0.184	−0.170
Cyprus	−0.266	−0.210	−0.116	−0.158	0.034	0.030	−0.243	−0.200	−0.218
Latvia	−0.086	−0.172	0.082	0.144	0.042	0.085	−0.072	−0.420	−0.495
Lithuania	0.147	0.159	−0.155	−0.072	−0.042	−0.063	−0.132	−0.258	−0.309
Luxembourg	−0.016	−0.042	0.001	0.023	0.078	0.105	0.019	−0.257	−0.252
Hungary	−0.259	−0.351	0.038	−0.077	0.105	0.158	−0.206	−0.266	−0.294
Netherlands	0.143	0.153	−0.005	0.017	−0.015	0.017	−0.040	−0.119	−0.121
Austria	−0.031	0.005	−0.023	0.007	−0.004	0.011	−0.037	−0.085	−0.087
Poland	0.116	0.119	0.295	0.223	0.011	0.001	0.003	0.029	0.068
Portugal	−0.218	−0.183	0.021	0.063	0.036	0.041	−0.209	−0.216	−0.200
Romania	−0.139	−0.324	0.122	−0.021	−0.044	−0.043	−0.254	−0.202	−0.293
Slovenia	−0.020	0.026	−0.108	−0.086	−0.041	−0.052	−0.114	−0.201	−0.193
Slovakia	0.141	0.090	0.058	0.061	−0.051	−0.081	0.033	−0.012	0.008
Finland	−0.005	0.001	−0.107	−0.108	0.004	0.024	−0.112	−0.108	−0.122
Sweden	0.014	−0.026	−0.018	−0.015	−0.006	0.039	−0.058	−0.070	−0.079
UK	0.148	0.133	0.013	−0.034	−0.006	0.046	−0.110	−0.197	−0.198
Norway	0.006	0.045	−0.067	−0.056	−0.042	−0.035	−0.050	−0.183	−0.187
Switzerland	0.003	−0.021	−0.099	−0.113	0.022	0.024	−0.014	0.004	0.002
USA	0.102	0.079	0.008	0.042	−0.022	−0.016	−0.042	−0.149	−0.150

Notes: Table displays the log-difference between the actual time series and the forecast, averaged over 2010 - 2013, for government purchase (Govt), tax revenue (Tax), primary balance (PB) and GDP. Different columns use different forecast methods (see text for details).

Table A2: AUSTERITY AND GDP UNDER ALTERNATIVE FORECAST AND TREND SPECIFICATIONS

	Government Spending Shortfall											
	$Govt_1$						$Govt_2$					
	All countries		Fixed		Floating		All countries		Fixed		Floating	
	β_1	R^2	β_1	R^2	β_1	R^2	β_1	R^2	β_1	R^2	β_1	R^2
Convergence	−0.42	0.48	−0.40	0.48	−0.46	0.49	−0.34	0.48	−0.34	0.48	−0.35	0.58
	(0.08)		(0.10)		(0.18)		0.07		0.08		0.11	
Hugging	−0.25	0.10	−0.19	0.06	−0.37	0.25	−0.17	0.07	−0.14	0.05	−0.25	0.23
	(0.14)		(0.17)		(0.24)		0.12		0.15		0.17	
Shrinkage	−0.32	0.14	−0.23	0.08	−0.58	0.38	−0.25	0.13	−0.18	0.07	−0.42	0.42
	(0.15)		(0.18)		(0.28)		0.13		0.16		0.19	

	Government Tax Revenue											
	Tax_1						Tax_2					
	All countries		Fixed		Floating		All countries		Fixed		Floating	
	β_1	R^2	β_1	R^2	β_1	R^2	β_1	R^2	β_1	R^2	β_1	R^2
Convergence	0.16	0.03	0.26	0.07	−0.07	0.01	0.09	0.01	0.08	0.01	0.25	0.09
	(0.17)		(0.22)		(0.28)		0.15		0.17		0.30	
Hugging	−0.04	0.00	−0.29	0.05	0.19	0.05	−0.21	0.05	−0.35	0.13	0.39	0.18
	(0.22)		(0.29)		(0.31)		0.19		0.21		0.32	
Shrinkage	−0.01	0.00	−0.26	0.04	0.25	0.06	−0.14	0.02	−0.32	0.09	0.62	0.28
	(0.24)		(0.31)		(0.39)		0.21		0.24		0.38	

	Government Primary Balance											
	PB_1						PB_2					
	All countries		Fixed		Floating		All countries		Fixed		Floating	
	β_1	R^2	β_1	R^2	β_1	R^2	β_1	R^2	β_1	R^2	β_1	R^2
Convergence	0.06	0.00	0.21	0.01	−0.33	0.03	0.00	0.00	0.14	0.01	−0.37	0.06
	(0.42)		(0.53)		(0.73)		0.32		0.42		0.53	
Hugging	−0.28	0.01	−0.38	0.02	−0.24	0.01	−0.28	0.02	−0.32	0.02	−0.47	0.08
	(0.54)		(0.69)		(0.83)		0.41		0.54		0.60	
Shrinkage	−0.26	0.01	−0.40	0.02	−0.09	0.00	−0.33	0.02	−0.38	0.02	−0.46	0.05
	(0.60)		(0.74)		(1.05)		0.46		0.58		0.76	

Note: Reported standard errors in parentheses are (untreated) OLS errors.

The estimated growth rate of country i's GDP per capita at time t is

$$\hat{g}_t^i = \hat{\bar{g}} + \hat{\gamma}\left(\ln \widehat{GDP}_{t-1}^{EU} - \ln GDP_{t-1}^i\right) \qquad \forall t \leq 2006{:}1$$
$$\hat{g}_t^i = \hat{\bar{g}} + \hat{\gamma}\left(\ln \widehat{GDP}_{t-1}^{EU} - \ln \widehat{GDP}_{t-1}^i\right) \qquad \forall t > 2006{:}1.$$

B Trade preference weights

The preference parameters $\omega_{n,j}$ are calibrated to the share of imports y_n^j over domestic absorption in the data:

$$\omega_{n,j} = \frac{y_n^j}{GO_n - NX_n}.$$

We use two different data sources to calibrate $\omega_{n,j}$ and therefore proceed in two steps:

1. We calibrate a country's overall import share using data on total imports to domestic absorption (measured in gross terms):

$$\omega_n = \frac{Im_n}{GO_n - NX_n}, \tag{B.1}$$

   where $\omega_n \equiv \sum_{j \neq n} \omega_{n,j}$ and $Im_n = \sum_{j \neq n} y_n^j$.

2. We calibrate the share of n's imports coming from j using bilateral trade data:

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

We use two different data sources because we want to capture the openness of an economy defined as its import to domestic absorption ratio, ω_n. We do not add up bilateral trade data to measure ω_n, but use a different data source, because bilateral trade data typically does not add up to imports and exports reported in national accounts data (due to different data sources, missing services,...).

Calculation of ω_n The denominator of (B.1) is domestic absorption in gross terms. We measure domestic absorption in gross terms rather than value added because trade is measured in gross terms, not in value added. This also ensures that $\omega_n \leq 1$. Data on imports, exports and gross output measured in current U.S. dollar comes from the World Input-Output Database (WOID).[24] Data is only available from 1995 - 2011, so we use the average value of Im_n/Y_n across 2000 to 2011 to measure ω_n. Data for Norway and Switzerland is not available in the WOID. Instead we use data from the OECD on imports, exports and gross output. For

[24] See Timmer, M. P., Dietzenbacher, E., Los, B., Stehrer, R. and de Vries, G. J. (2015),Â "An Illustrated User Guide to the World Input-Output Database: the Case of Global Automotive Production",Â Review of International Economics, 23: 575-605.

those two countries, we calculate ω_n as follows:

$$\omega_n = \frac{\frac{Im_n}{GDP_n}}{\frac{GO_n}{GDP_n} - \frac{NX_n}{GDP_n}}, \tag{B.2}$$

where Im_n/GDP_n and NX_n/GDP_n are taken from quarterly national accounts (CARSA: Gross domestic product - expenditure approach) and GO_n/GDP_n is taken from the non-financial accounts by sector dataset (14A), all measured in national currency in current prices.

We calculate ω_n for the rest of the world (RoW) as described in (B.2). The three fractions in (B.2) are measured as follows:

- $\frac{GO_{RoW}}{GDP_{RoW}}$: We do not observe gross output for RoW. Instead, we assume that the gross output to GDP ratio is 1.8, which is roughly the value for the U.S.

- $\frac{NX_{RoW}}{GDP_{RoW}}$: For the denominator, we take real world GDP from the worldbank database, in 2005 U.S. dollar and converted into 2005 euros.[25] For net exports for the rest of the world, we use data on net imports of all countries in our sample:

$$NX_{RoW} = -\sum_{n \neq RoW} \left(Ex_n - Im_n\right),$$

where Ex_n and Im_n are measured in 2005 euros (either from OECD, QNA, 'VPVOBARSA' or from Eurostat, namq_10_gdp). We therefore impose that world net exports equal zero. This is not true in the data and we will correct for this when calculating Im_{RoW}.

- $\frac{Im_{RoW}}{GDP_{RoW}}$: We do not directly observe RoW's imports. We use exports to the RoW based on bilateral trade data, but adjust the term to ensure that world net exports equal zero. In particular, let $s^{Ex}_{RoW,n}$ denote the observed share of country n's exports that goes to RoW, and similarly, $s^{Im}_{n,RoW}$ is the share of country n's imports from RoW (see below). We calculate

$$Im_{RoW} = \sum_{n \neq RoW} \left(s^{Im}_{n,RoW} Im_n\right) + 0.5 \left(\sum_{n \neq RoW} \left(s^{Ex}_{RoW,n} Ex_n - s^{Im}_{n,RoW} Im_n\right) - \sum_{n \neq RoW} \left(Ex_n - Im_n\right)\right).$$

The first term $\sum_{n \neq RoW} \left(s^{Im}_{n,RoW} Im_n\right)$ are exports to RoW. The second term adjusts this term so that world net exports equal zero in our steady-state calibration. The adjustment is minor and changes the average import share from 8.3 percent to 8 percent.

Calculation of $\omega_{n,j}/\omega_n$ We use bilateral trade in goods data to calculate the share of n's imports coming from j. Our main data source is the BACI dataset from CEPII that provides harmonized trade data for all countries in our sample.[26] The BACI trade dataset is harmonized in the sense that it only reports one value for any given trade flow instead of reporting different values reported by importing and exporting countries. The dataset

[25] This section for RoW uses real values. Later on, I might want to switch towards nominal values.

[26] See http://www.cepii.fr/cepii/en/bdd_modele/bdd.asp.

lumps Belgium and Luxembourg together. To separate them out, we use Eurostat trade data (Member States trade by BEC product group since 1999 (ext_st_28msbec)). We calculate from the Eurostat trade data the proportion of Belgium-Luxembourg trade with country j that can be attributed to Belgium and Luxembourg separately, and then multiply the BACI trade data for Belgium-Luxembourg by that fraction.

Denote the value of a trade flow from j to n $\bar{y}_n^j$. Then, we calculate the share of imports coming from j as

$$\frac{\omega_{n,j}}{\omega_n} = \frac{\bar{y}_n^j}{Im_n},$$

where Im_n is the sum of country n's bilateral imports, in nominal value.

We also use the share of n's exports that goes to RoW, $s_{RoW,n}^{Ex}$. That share is calculated as a residual using country n's total exports and country n's exports to countries $j \neq RoW$:

$$s_{RoW,n}^{Ex} = 1 - \frac{\sum_{j \neq RoW} \left(\bar{y}_j^n\right)}{Ex_n}.$$

Similarly, the share of country n's imports from RoW, $s_{n,RoW}^{Im}$, is

$$s_{n,RoW}^{Im} = 1 - \frac{\sum_{j \neq RoW} \left(\bar{y}_n^j\right)}{Im_n}.$$

All shares, $\omega_n, \omega_{n,j}, s_{RoW,n}^{Ex}$ and $s_{n,RoW}^{Im}$ are calculated separately for each time period. Then an average over 2003 - 2011 is taken.