MODELLING THE SUSTAINABILITY OF PUBLIC SECTOR DEBT AND NET FOREIGN ASSET POSITIONS

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Abstract

The European Sovereign Debt crisis in 2010 not only brings the sustainability of public finance to the forefront, but also the sustainability of external balances. Chapter 2 of this thesis proposes an approach to measuring fiscal sustainability of a country; Chapter 3 investigates the divergent external imbalances in Europe, and Chapter 4 proposes the measures of external sustainability for a country.

Chapter 2 proposes a measure of public sector debt sustainability based on probabilistic statements of various future events relating to debt sustainability. It illustrates the approach using data for 10 developed countries over the period 1958-2010. The approach accommodates various alternative definitions of sustainability, which is new in the literature. The approach employs a Global cointegrated Vector Auto Regression model, modelling both long-run relations and cross-country interactions. Applying our approach on an empirical sample including eight EU countries, shows that our measures offer a multi-dimensional description of fiscal sustainability.

Chapter 3 characterises the long-run time series properties of net foreign assets in twelve EU countries over the period 1970-2011. Using a multi-country restricted VAR model, we establish that shocks to net foreign asset persist over time. We then measure the size and the source of the permanent effects of the shocks. We find, the current account drives the net foreign assets in the long-run. Unanticipated changes in cross-border finance flows have a significant permanent effect on net foreign assets across the EU economies, more than output shocks and dollar exchange rate shocks.

Chapter 4 measures the likelihood of sustainability of the net foreign assets and the current accounts. In response to the sovereign debt crisis, the European Commission includes both the stock and flow external balances under its surveillance. We illustrate our measure by implementing the introduced policy. Our sustainability likelihoods are based on a formal model incorporating behavioural feedbacks and cross-country movements. Illustrating on the EU empirical sample adopted in Chapter 3, our measures not only describe countries' sustainability of external balances but also serve as early warning indicators.

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Chapter 1

Introduction

1.1 Motivation

The European Sovereign Debt crisis in 2010 and 2011 saw Greece, Ireland, Portugal and Spain being shun off from the bond market (Lane, 2012). Neighbouring countries, despite not experiencing the bond market attack, the sovereign debt crisis provided a case for fiscal consolidation, which many countries pursued. The European Sovereign Debt crisis originated from the Global Financial Crisis in the U.S. nearly three years earlier—the financial crisis started in August 2007 and entered into an acute phase in September 2008 with the collapse of Lehman Brothers. Europe shook as much as the U.S., as European banks were highly exposed to the losses in U.S. asset-backed securities market (Shin, 2012). As a consequence of the crisis, countries fell into recessions, falling tax revenues and higher government spending including banks' bail out in several countries saw public debt-to-GDP soar. That, and the European Sovereign Debt crisis, in effect, has brought the sustainability of public finance to the forefront of policy debate and academic literature (Bussière, 2013).

The crisis-hit countries (Greece, Ireland, Portugal and Spain), however, did not accumulate high debt-to-GDP ratio before the financial crisis—in

fact, Ireland and Spain debt ratios were falling during the pre-crisis years due to positive economic growths both countries enjoy[1]. Rather, the crisis-hit countries were common in their high net foreign liability positions, which were in the vicinity of 100% of GDP. In contrast, Italy whose debt ratio has been near 100% of GDP before and after the crisis; with its relatively lower net foreign liabilities, was not shun off from the bond market. This highlights the role of country risk during the crisis, measured by the net foreign assets-to-GDP[2].

The cause of the European Sovereign Debt crisis, agreed among economists, is the persistent current account imbalances amongst EU countries, which led to the high net foreign liability position in the crisis-hit economies (Baldwin & Giavazzi, 2015)[3]. The current account is the flow external balance; whilst the net foreign assets is the stock external balance, at a given time. The current account balance is also the saving-investment balance of an economy, that is explained in chapter 3. The crisis-hit countries that ran persistent current account deficits, have been borrowing from the rest of the world. On the flip side are EU countries that ran current account surpluses, prior to the crisis, lending to the rest of the world, including the EU deficit countries. This intra-EU imbalances between the surplus and deficit economies—over-lending countries and over-borrowing countries—was termed as 'competitiveness problems' by the European Commission (Commission, 2012). The term, competitiveness is in reference to the trade component of the current account, where the traded sectors of the surplus

[1]The bailout of the banking sector, and the halt in the booming housing sectors in both countries, together with falling income receipts as a consequence of recession were the primary reasons debt ratios soared in both countries. (Baldwin & Giavazzi, 2015)

[2]The net foreign assets is the net balance of a country's international balance sheet; it records the activities of households, corporates and the government of a country; the net foreign assets-to-GDP measures the country risk—indebtedness of households, corporates and government aggregated, a nation's in short.

[3]Leading up to the crisis, the deficit countries that rely on foreign borrowing saw sudden stop in capital flows i.e. being shun off from bond markets; as a consequence, underwent painful external adjustment cost, in the form of output and expenditure losses. (Lane & Milesi-Ferretti, 2014)

economies are deemed too competitive relative to the traded sectors of the deficit economies.

The persistent and growing net flow imbalances (current accounts) and stock imbalances (net foreign assets) developed alongside two prominent global environments—first, financial integration, measured by cross-border finance flows[4] accelerates in Europe; in fact, the degree of financial integration in Europe has been the most prominent in the world (Lane & Milesi-Ferretti, 2008a); second, current account imbalances emerge and persist between countries since the mid-1990s, termed as the 'global imbalances' (Blanchard & Milesi-Ferretti, 2010)[5]. Countries' size of international balance sheets have expanded significantly as a consequence of financial integration. This coincides with easy financial environment, such as the convergence of bond yields in European economies, which could contribute to growing external imbalances as it encourages borrowings in the deficits countries (Hale & Obstfeld, 2014). The global imbalances, i.e. global saving-investment balances reconciled via world interest rates, can play a role in domestic economic developments, on both the fiscal and external balances. We consider these global developments in the thesis chapters.

As a consequence of the sovereign debt crisis, fiscal councils surge in numbers—from 10 to 40 between 2008 and 2013—as found by a recent IMF study, particularly in Europe (Debrun & Kinda, 2014)[6]. In recognition of the causes of the sovereign debt crisis relating to the external imbalances, the European Commission introduces a new surveillance framework—the

[4]These flows include different financial instruments: portfolio equity, portfolio debt, foreign direct investments and non-portfolio financial instruments including cross-border lendings between banks.

[5]Blanchard and Milesi-Ferretti (2011) offer a narrative history of the global imbalances that are different over a five-year horizon. Other explanations put forward to explain the global imbalances include the financial underdevelopment hypothesis (see Mendoza, Quadrini, and RÃos-Rull (2009); Caballero, Farhi, and Gourinchas (2008)) and the global saving gluts hypothesis (Bernanke et al., 2007).

[6]In the U.K. for instance, the Office of Budget Responsibility was established in 2010 to"report and analyse the fiscal sustainability of public finance in the UK" (OBR, 2015).

Macroeconomic Imbalance Procedure—which monitors countries' external balances, including the net foreign assets and the current account balances as part of the annual surveillance framework in the conventional European semester (Commission, 2012).

The European Sovereign Debt crisis is the impetus of the thesis; the main themes brought forth by the crisis motivate the next three chapters. First, the prominent theme of the crisis is the sustainability of public finance; chapter 2 proposes a new approach to measure fiscal sustainability, building on existing literature. Second, the divergent net foreign asset position in Europe elevates the country risk in crisis-hit countries; chapter 3 investigates the long-run drivers of the net foreign assets in Europe, including the contribution of the financial integration. The policy response, the enact of Europe's 'six pack' rolls out the Macroeconomic Imbalance Procedure addresses the sustainability of external balances; chapter 4 proposes measures of external sustainability—illustrating the measures by implementing the procedure.

1.2 Thesis Summary

Chapter 2 proposes a new and relatively straightforward measure of public sector debt sustainability based on a formal model of debt dynamics and probabilistic statements of the likely occurrence of various future events relating to debt sustainability. We then illustrate the approach using data for 10 developed countries over the period 1958-2010. The approach places the time series modelling of debt centre-stage, compared to the more ad-hoc projections of fiscal variables used in previous sustainability indicators. In producing a sustainability index, we employ a Global cointegrated Vector Auto Regression (GVAR) model of the debt ratio, real interest rate and output growth in a multi-country setting, recognizing that different

countries' debt requirements and the market's tolerance for their debt are inter-related.

The contributions are several: first, we propose a new measure of sustainability via event probability forecasting, which accommodates various alternative definitions and views of sustainability; second, we evaluate the forecasting performance of our model that underpin our measure, demonstrating the relevance of cross-country interactions and long-run relations; third, we illustrate our approach on an empirical sample which include eight countries in Europe, shows that our measures offer a multi-faceted description of fiscal sustainability.

Chapter 3 studies the long-run evolution of net foreign assets-to-GDP in twelve countries in Europe over the period 1970-2011. First, we empirically establish the shocks to the net foreign assets-to-GDP persist. We study the time series properties of the components of net foreign assets-to-GDP—the economy's growth rate, the current account-to-GDP and the net valuation changes underlying the assets and liabilities. We find, the current accounts are nonstationary whilst the net valuation changes are stationary; in other words, the current accounts drive the net foreign assets in the long-run. We then characterize the effects in which the shocks persist on net foreign assets via persistence measures developed in Lee, Pesaran, and Pierse (1992). Later, we identify three common shocks: financial integration, economic output movements and exchange rate movements; decomposing the persistence measures of the net foreign assets by each of the shocks. We find, the permanent shocks to the financial integration are important driver of net foreign asset position across our empirical sample of European countries.

The contributions are several—the study differs by focussing on time series properties of net foreign assets; the literature has studied the cross-country variation of net foreign assets (Lane & Milesi-Ferretti, 2002). The study also differs by focussing on the long-run evolution of net foreign

assets. The two main findings are: current account matters for the long-run evolution of net foreign assets, in answering a recent question posed in the academic literature (Obstfeld, 2012) as the valuation channel grows in importance (Gourinchas & Rey, 2014). Second, financial integration contribute to the divergence of net imbalances in these European countries which is discussed in the motivation.

Chapter 4 proposes an approach to measuring the sustainability of a country's external balances, by providing the likelihood of sustainability and is based on a formal model. We illustrate the measure to the Macroeconomic Imbalance Procedure which defines sustainable indicative thresholds for the net foreign assets-to-GDP and the current accounts-to-GDP. The procedure has been implemented on EU countries since 2012, we therefore measure external sustainability based on the empirical sample in the previous chapter, investigated for the drivers of net foreign assets in the context of European countries.

There are three contributions: first, we propose a new approach to measuring external sustainability i.e. probabilistic statements of the likely occurrence of future sustainability events—in our illustration, event forecasts relating to the Macroeconomic Imbalance Procedure. Second, illustrated with the empirical sample, we evaluate the forecasting performance of the model which generates our measure, investigating the role of behavioural feedbacks and the role of cross-country interactions. Third, our results indicate the measures are useful description of the sustainability of external balances and could serve as early warning indicators to the European Commission, as our measures shows forecasting value.

Chapter 2

Sustainability of Public Sector Debt — Measurement Using Event Probability Forecasts in OECD Countries

2.1 Introduction

The European Sovereign Debt crisis has brought the sustainability of public finance to the forefront in both the policy debate and the academic literature. In its aftermath, countries are engaged in fiscal austerities as the priorities of fiscal policies shift toward addressing the sustainability of public finance, particularly in EU countries (Baldwin & Giavazzi, 2015). Against the same background, there has been a surge in the establishment of national fiscal councils, tasked with the independent projection of fiscal policies and the evaluation of policy makers' announced fiscal targets (Debrun & Kinda, 2014). Sustainability analysis in policy-making takes the form of fiscal indicators which are typically either expressed in terms of the feasibility of achieving a specified debt target or in terms of the adjustment

required to achieve a specified debt target (see Wyplosz (2007) for a review of IMF's Debt Sustainability Assessment and other approaches).

This chapter proposes a new and relatively straightforward measure of public sector debt sustainability based on a formal model of debt dynamics and probabilistic statements of the likely occurrence of various future events relating to debt sustainability. We then illustrate the approach using data for 10 developed countries over the period 1958 - 2010. The approach places the time series modelling of debt centre-stage (compared to the more ad-hoc projections of fiscal variables used in previous sustainability indicators) and in producing a sustainability index, it employs a Global cointegrated Vector Auto Regression (GVAR) model of the debt ratio, real interest rate and output growth in a multi-country setting, recognizing that different countries' debt requirements and the market's tolerance for their debt are inter-related.

The contributions are several: first, we propose a new measure of sustainability via event probability forecasting, which accommodates various alternative definitions and views of sustainability; second, we evaluate the forecasting performance of our model that underpin our measure, demonstrating the relevance of cross-country interactions and long-run relations; third, we illustrate our approach on an empirical sample which include eight countries in Europe, shows that our measures offer a rich and complete description of fiscal sustainability.

Our measures of sustainability are based on probabilistic statements of the likely occurrence of various future events relating to debt sustainability. Having defined the relevant sustainability events, the probability statements are simply the probability of the event based on estimated density forecasts. In our illustrative example, we consider two simple events and two more complicated joint events. The first simple event is defined in terms of the future debt ratio; the second simple event is defined in

terms of the present discounted future debt ratio. The respective threshold we compare the debt ratio and the discounted debt ratio defines sustainability. As our forecast horizon is finite, the sustainable debt threshold is arbitrary, rather than guided by theory (Wyplosz, 2007). We select the debt thresholds in relation to the literature.

More specifically, the ***debt sustainability index*** is the probability forecast of the debt ratio in five years' time achieving either of the following debt thresholds: maintaining today's debt-to-GDP, staying below the 60% debt-to-GDP and staying below the 90^{th} percentile of historical debt distribution. The ***discounted debt sustainability index*** is the probability forecast of the present discounted debt ratio in five years' time maintaining today's debt-to-GDP. This debt threshold—maintaining today's debt-to-GDP in the present value sense—is selected such that we can focus on the flow dimension of fiscal sustainability, which is explained in detail in the theoretical framework.

The two more complicated joint events are based on the simple events but taking into account the economies' "dynamic efficiency / inefficiency". This is explained in detail below but here we note that we can produce an ***augmented debt sustainability index*** which looks at a joint event involving debt sustainability and "macro stability" and an ***augmented discounted debt sustainability index*** based on discounted debt and stability.

We illustrate the usefulness of our sustainability indices through an analysis of 10 countries: Belgium, Canada, Denmark, France, Germany, Ireland, Italy, Netherlands, the UK and the US—eight countries in Europe and two countries in North America. The sample observations range between 1958 and 2010, with an annual data frequency. As mentioned, the underlying modelling exercise follows the GVAR approach of Pesaran, Schuermann, and Weiner (2004) and this is used to generate point and event

probability forecasts which are ultimately used to construct the index.

In developing the indexes, we undertake a forecast evaluation exercise which compares the point forecasts and forecasts of events against realizations between 1990 and 2010. It finds both the cross-country interdependencies and the long-run relations incorporated in our underlying GVAR model make an important contribution to the forecasting performance of the model. Our sustainability indexes, generated by our global cointegrated model are calculated for the years between 1990 to 2010. The debt sustainability index and the augmented debt sustainability index as well as the discounted debt index fall sharply during the crisis years, as a result of the financial shock in 2008 and sovereign debt crisis in 2009. The augmented indexes differ however, indicating the relevance of the interest rate and output growth considerations.

The rest of the chapter is organised as follows: section 2.2 describes the theoretical framework behind the evolution of debt ratios; it motivates the long-run cross-country relations between public debt and real interest rates; and it defines the sustainability concepts underpin our measure. Section 2.3 describes the modelling framework underlying our measure. Section 2.4 describes our approach of offering a sustainability measure via probability event forecasting. Section 2.5 describes the data; followed by the analysis of the cointegrated VAR. Section 2.6 describes the forecast evaluation exercise, our sustainability indexes and discusses the results.

2.1.1 Related Literature

There are two broad approaches of sustainability analysis, one focussing on backward looking and the other on forward looking behaviour. The backward looking approach includes the econometric (unit root and cointegration) tests on public debt, revenue and expenditure (see Camarero, Carrion-i Silvestre, and Tamarit (2015)) and fiscal reaction functions (see

Mauro, Romeu, Binder, and Zaman (2013)). Here, fiscal sustainability is inferred based on the historical behaviours of fiscal variables. In contrast, the forward-looking approach concentrates on producing 'fiscal indicators'. Here, fiscal sustainability is expressed based on the projections of fiscal variables. Our index is closer to the latter approach and in what follows, we define the following fiscal indicators and compare our measure:

- the fiscal gap indicator — the change in primary balance required to achieve a debt target over a specified horizon, one to five years; used by OBR (2015).

- the S1 indicator — the change in primary balance required to achieve the Maastricht debt criterion, 60% of GDP over a specified horizon, one to five years; used by Commission (2014).

- the inter-temporal budget indicator, equivalently the S2 indicator — the change in primary balance required to eliminate the existing debt over the infinite horizon, that is fifty years in practice; used by OBR (2015).

- the tax gap indicator — the change in the tax rate required to maintain today's debt-to-GDP over a specified horizon, one, three and five years; proposed by Blanchard, Chouraqui, Hagemann, and Sartor (1991).

- the index of current fiscal stance — the feasibility of maintaining today's debt over one year; proposed by Polito and Wickens (2012).

Amongst fiscal indicators, the several dimensions that distinguish them are: the time horizon the forecasts, the debt target specified, the generation of the forecasts (model- vs. non model-based) and the type of forecasts (point vs. density forecasts). Fiscal policies are political decisions; the electoral cycle in advanced economies occurs five years on average, the practical

time horizon therefore ranges between one- to five-years (OBR, 2015). The practical time horizon also serves the purpose of holding policy makers to account (Polito & Wickens, 2012)[1]. Our proposed measure therefore uses a finite forecast horizon, five years. The practical definition of sustainability in the finite horizon is necessarily *arbitrary* (Wyplosz, 2007). A common debt target is maintaining today's debt-to-GDP (the tax gap indicator and the index of current fiscal stance) or the legal debt ratio (the S1 indicator).

The projections of government revenue, expenditure, real interest rate and output growth can be generated either in an ad hoc manner[2] or based on a model. The projections of the fiscal variables are determined endogenously, in response to the ad-hoc criticism of projections underlying many indicators (Leeper, 2010). Our measure sits with the model-based fiscal indicator literature. The index of current fiscal stance uses an unrestricted VAR of fiscal variables as the model of economy; our model is the global cointegrated VAR model which accounts for cross-country interdependencies in the short-run and in the long-run.

Our measure, via the event probability forecasting approach not only captures the central projections of fiscal variables, but also the uncertainty surrounding the projections. In a similar vein, Celasun, Debrun, and Ostry (2006) generates fan charts for primary surpluses in emerging economies uses this simulation approach, which is part of the IMF's debt sustainability assessment.

[1]In practice, the inter-temporal budget gap is not very useful because it miscarries the reality that governments wish to eliminate debt entirely.

[2]In the tax gap indicator, the S1 and S2 indicators, the projections can be provided in an ad hoc manner which excludes economic feedbacks amongst the fiscal variables. Generally, revenue is assumed to be constant and equal to the current value over the projection horizon; government bond yield, inflation and output growth are assumed to be constant and equal to some pre-determined values over the projection horizon (Polito & Wickens, 2012). For instance, OBR (2015) calculates the fiscal gap indicator under three scenarios: $r-g=0.3\%$, $r-g=1\%$ and $r-g=-1\%$, in each case, the government revenues and spendings remain the same in each case.

2.2 Theoretical Framework: The Sustainability of a Country's Public Debt

This section reviews some key theoretical concepts and definitions within the existing literature. First, I will describe some of the literature outlining the factors that, in theory, influence the evolution of public debt with the dynamic equation for public debt. Second, I will motivate the cross-country interactions amongst the variables of interest — public debt, interest rate and output growth. Finally, I will describe indicators of sustainability from the literature.

2.2.1 Debt Dynamics and Sustainability

Barro's (1979) paper on the determinants of public debt influentially argued that welfare-maximising governments will smooth out the burden of taxation intertemporally so that deficits will display unit root characteristics. The argument relies on there being incomplete markets since the government could insure against fiscal shocks through variable pay-outs in state contingent assets if there were complete markets. But there is reasonable evidence to support the incomplete markets view, and the characterisation of deficits as being highly persistent is also consistent with the political economy view which emphasises stickiness in spending and taxation decisions[3].

The observation that changes in tax and spending decisions can persist, and that associated debt:gdp ratios do not need to be mean-reverting, is entirely consistent with satisfying the government's intertemporal budget constraint. This constraint does serve as an important limitation on

[3]See Marcet and Scott (2009) for a recent discussion on the empirical relevance of incomplete markets; and Alesina and Perotti (1994), or Eslava (2006) for surveys of political economy considerations.

government behaviour however and is given by

$$\widetilde{B}_t = (1 + R_t)\widetilde{B}_{t-1} - \widetilde{S}_t, \tag{2.1}$$

where $\widetilde{B}_t$ is nominal stock of outstanding debt at the end of period t, $\widetilde{S}_t$ is the nominal primary surplus, reflecting the taxes minus the current value of spending on goods and services and transfers during period t, and R_t is the nominal interest rate (nominal government bond yields) on the debt during the period. The change in the stock of debt, $\Delta\widetilde{B}_t = R_t\,\widetilde{B}_{t-1} - \widetilde{S}_t$, is usually termed the 'government deficit'. To accommodate the fact that economies grow over time, the dynamic budget constraint is usually written in terms of ratios to GDP as follows

$$\frac{B_t}{Y_t} = \left(\frac{1 + R_t - \pi_t}{1 + g_t}\right)\frac{B_{t-1}}{Y_{t-1}} - \frac{S_t}{Y_t},$$

or equivalently,

$$\begin{aligned} b_t &= \frac{1 + r_t}{1 + g_t}b_{t-1} - s_t && (2.2)\\ &\approx (1 + r_t - g_t)b_{t-1} - s_t \\ &= (1 + r_t^g)b_{t-1} - s_t && (2.3) \end{aligned}$$

where B_t, S_t and Y_t denote debt, primary deficit and output in constant prices respectively, b_t is the debt:GDP ratio, s_t is the primary surplus:GDP ratio, π_t is inflation, $g_t = \log(Y_t) - \log(Y_{t-1})$ is output growth, $r_t = R_t - \pi_t$ is the real rate of interest and $r_t^g = (r_t - g_t)/(1 + g_t)$ is the 'growth-corrected real interest rate'.

Writing expression (2.2) at some point in the future, $t + h$, and substituting recursively back to time t, we find the debt:GDP ratio in time $t + h$ is equal to the value of the ratio at t compounded according to the rates holding over the period (r_{t+k}^g, $k = 1, .., h$) plus the sum of the succes-

sive primary surpluses compounded in the same way. Equivalently, writing $q_h = \Pi_{j=1}^{h}(1 + r_{t+j}^{g})^{-1}$ and $q_0 = 1$, the recursive substitution provides

$$q_h b_{t+h} = b_t - \sum_{k=1}^{h} q_k s_{t+k} \tag{2.4}$$

so that the discounted value of the debt ratio at $t + h$ is equal to the current debt ratio plus the sum of the discounted future primary surpluses. The most frequently-used definition of debt sustainability precludes governments playing a Ponzi game in which it pays off past loans with new loans so that

$$\lim_{h \to \infty} E\left[q_h b_{t+h} | \Omega_t\right] = 0 \tag{2.5}$$

where $E[.|\Omega_t]$ is the expectations operator and Ω_t denotes the information available at time t. Focusing on the dynamic budget constraint, then, a sustainable fiscal policy might be defined a set of policy rules and inherited debt that delivers debt sustainability; that is generates a sequence of expected debt and deficits over the future which ensure the discounted value of the debt eventually goes to zero.

A number of points arise from the algebra of (2.4) and (2.5). *First*, the dynamic budget constraint makes it clear that a sustainable fiscal policy can be described as a programme of future tax and spending intentions which, given projections for interest rate payments and growth, translate to an intended timepath for debt, or the programme can be defined by intended debt levels and this can then translate to an implied path for primary surpluses. In policy terms, we can only target one of s_{t+h} or b_{t+h}. *Second*, we note that if both (2.4) and (2.5) hold, then $\lim_{h\to\infty} E\left[\sum_{k=1}^{h} q_k \, s_{t+k} \mid \Omega_t\right] = b_t$; that is, the current value of the debt has to be matched by the sum of expected future discounted primary surpluses for a sustainable fiscal policy. *Third*, the discussion above is relevant whether the growth-corrected real rate r_t^g is positive or negative. If r_t^g is always positive, then a positive

current debt level requires the government to run primary surpluses at some point in the future if (2.5) holds. Negative values of $r_t^g$are often considered implausible on theoretical grounds since this implies the economy suffers 'dynamic inefficiency'; this means that transfers can increase the utility of one generation without reducing the utility of other generations even though the welfare losses could be readily avoided by issuing debt. However, negative values for r_t^g are frequently observed in practice so the possibility should not be dismissed on *a priori* grounds. This will mitigate against the need for primary surpluses, depending on the size and duration of the negative values, and certainly debt sustainability is achieved, for any given level of current debt, with a lower sequence of primary surpluses if r_t^g is negative over some period.

A *fourth* point arising from (2.4) and (2.5) is that satisfaction of the dynamic budget constraint is consistent with a very wide range of time series representations for b_t and/or s_t. For example, as established in Bohn (1995), debt series can be integrated of any order and still be consistent with intertemporal budget balance. This is because the h-period-ahead forecast of debt increases at most as a polynomial in time of order h while the discount factor increases exponentially[4]. The time series evidence suggests strongly that debt:GDP ratios are intergrated of order one, $I(1)$, so that shocks do indeed persist and the series needs to be differenced once to achieve stationarity[5]. In practice, it is unrealistic to believe that debt could grow without bounds since, although algebraically possible if there is a corresponding growth in primary surpluses, there is likely to be a limit

[4]Early tests of debt sustainability focused on special cases of integratedness in debt. Hamilton and Flavin (1986) noted that, in the case that the conditional expectations of the real rate are constant, stationarity in primary deficits and intertemporal budget balance requires the debt ratio to be stationary also. But Trehan and Walsh (1991) note that the conclusion does not generalise to the case where interest rates vary, noting that stationarity of the change in the debt ratio is sufficient to ensure intertemporal budget balance.

[5]See, for example, Afonso and Rault (2010) for study of the persistence of shocks to debt ratios in various EU economies

on the level of debt that financial markets and/or the electorate would tolerate[6]. Nevertheless, the characterisation of debt as an $I(1)$ process seems empirically relevant over the range of debt values observed in most developed economies over long periods and so this will be a realistic feature of any fiscal policy that is consistent with historical experience.

2.2.2 Cross-Country Interdependencies

The dynamic budget constraint of (2.5) highlighted that the sustainability of fiscal policy depends not only on the programme of planned primary deficits or surpluses but also on real interest rates and output growth. Fiscal policy sustainability therefore depends on the financial markets—the investors willingness to hold debt—on economic growth and on government's tax and spending decisions. The influence of financial markets and output growths is likely to introduce cross-country interdependence in the determination of fiscal policy sustainability. In addition, government tax and spending decisions will be correlated across countries (as all countries react to the effects of the global financial crisis, for example).

Demand for Government Bond The sustainability of an expansionary fiscal policy in one country may be more likely if other countries are engaging in expansionary policy at the same time because of the competition for funds in global financial markets. Adopting Branson (1980)'s Portfolio Balance approach, for example, domestic and foreign government bonds are typically considered to be close but imperfect substitutes. In this case, the demand for domestic government bonds depends on the rate of return on the bonds relative to the return on foreign bonds as well as expected movements in the country's exchange rate, domestic income and

[6]See Eton and Gersovitz, 1981, Cohen and Sachs (1986) or Arellano, 2008, among others, for discussion of strategic default in which the limits to debt accumulation are derived on the basis of optimal lending strategies.

other global influences (such as the abundance of savings from China or oil exporters experienced over the last decade, for example, have lowered interest rates globally). Short-run influences on the demand for bonds also include speculation or transitory changes in perception of risk but we might capture the asset demand relationship by writing

$$B_{it} = \widetilde{f}(r_{it} - r^*_{it},\, Y_{it},\, Q_t)\exp(\widetilde{\eta}^b_{it}), \qquad f_1 > 0,\, f_2 > 0,\, f_3 > 0 \tag{2.6}$$

where the 'i' subscript now relates to country i, the '$*$' superscript here refers to the rest of the world, excluding country i and Q_t refers to the global influences and $\widetilde{\eta}^b_{it}$ refer to stationary disturbances that capture the transitory, but potentially long-lasting, deviations of bond holdings from their equilibrium demand (including exchange rate movements). These stationary disturbance might themselves capture significant cross-country interdependencies, as speculative bubbles are passed across national boundaries. Moreover, assuming that comparable relations will hold for the demand for bonds in all other countries, we would find the composite demand for bonds in the rest of the world explained by

$$B^*_{it} = \widetilde{f}^*(Y^*_{it},\, Q_t)\exp(\widetilde{\eta}^{*b}_{it}) \tag{2.7}$$

Substituting out Q_t in equation (2.6), we have

$$B_{it} = \widetilde{f}(r_{it} - r^*_{it},\, Y_{it},\, B^*_{it},\, Y^*_{it})\exp(\widetilde{\eta}^b_{it}),$$

Writing in terms of debt ratios,

$$b_{it} = f(r_{it} - r^*_{it},\, b^*_{it},\, Y_t,\, Y^*_t)\exp(\eta^b_{it}) \tag{2.8}$$

where η_{it}^{b} is now a composite stationary disturbance. Hence, the demand for domestic bonds over the long-run will be influenced by the debt levels in the rest of the world through the presence of common global influences. Expression (2.8) therefore provides a long-run constraint which implies a degree of international interdependence (from the financial markets) in designing a sustainable fiscal policy.

Uncovered Interest Parity The real interest rate determines the evolution of debt ratio as expressed in the dynamic equation of debt ratio (2.2). The long-run economic theory of interest rates is the interest rate parity which describes the parity holding between domestic government bonds and foreign government bonds:

$$(1 + R_t) = (1 + R_t^*)(1 + \frac{E_{t+1}^e - E_t}{E_t}) \exp(\widetilde{\eta}_{it}^{uip}) \tag{2.9}$$

where R_t^* is the nominal interest rate paid on foreign bonds during period t, E_t is the effective exchange rate, defined as the domestic price of a unit of foreign currency at the beginning of period t (an increase in the exchange rate represents a depreciation of the home country currency), $\widetilde{\eta}_{it}^{uip}$ is the risk premium associated with the effects of bond and foreign exchange uncertainties on risk-averse agents. The parity condition therefore describes any differential in interest rates across countries must be offset by expected exchange rate changes to eliminate the scope for arbitrage.

These two long-run constraints—the asset demand constraint (2.8) and the uncovered interest parity (2.9)—are long-run cross-country influences on the evolution of a country's public debt.

2.2.3 Sustainability Concepts

Here we discuss the sustainability concepts which underlie the discounted debt sustainability index, the augmented debt sustainability index and the

augmented discounted debt sustainability index.

Discounted Debt Ratio The discounted debt defines the sustainability definition in the infinite-horizon (equation (2.5)). Discounting future debt encapsulates all the fiscal variables in the government budget constraint—debt ratio, primary surpluses, real interest rates and output growth rates. It is useful therefore to use the discounted debt in the fiscal index of the finite horizon. We propose comparing the discounted debt ratio with the current debt ratio as a threshold:

$$q_h b_{t+h} \leq b_t$$

substituting both the discounted debt and debt ratio with the sum of discounted surpluses in government budget constraint (2.2),

$$\sum_{k=1}^{h} q_k s_{t+k} \geq 0 \tag{2.10}$$

equivalent to assessing whether discounted future primary balances are zero over the forecast horizon. It is worth pointing out the similarities and the differences in first, the comparison between $q_h b_{T+h} = 0$ when $h \to \infty$ and $q_h b_{T+h} \leq b_T$ when h is finite; second the comparison between $q_h b_{T+h} \leq b_T$ and $b_{T+h} \leq b_T$. In the first comparison, both encapsulate different variables in the government budget constraint with the use of discounted debt; the definition of sustainability differs: sustainability in the infinite-horizon eliminates the debt, sustainability in the finite-horizon maintains the debt in present value sense—to elaborate on that, we come to the second comparison.

We compare against the same benchmark in both cases. The definition of sustainability differs — maintaining the debt ratio in present value sense implies, the future debt ratio could be higher than the current debt ratio,

as long as the increase in debt is induced by the beginning debt ratio (at time t). The different definition of sustainability can be stated in terms of primary balances—in the constant debt ratio, surpluses have to be balanced and sufficient to cover the change of the beginning debt ratio; in the discounted debt ratio, surpluses have to be balanced but does not need to cover the change of the beginning debt ratio.

Stable Case The stable case is a sufficient condition of fiscal sustainability in the finite horizon. In contrast, the long-run equivalent of the unstable case—dynamic efficiency is needed for sustainability in the infinite horizon—the transversality condition is not defined for dynamic inefficiency[7].

To understand the implication of the stable case on fiscal sustainability, use equation (2.4) and equate the forecast horizon to five:

$$b_{t+5} = \Pi_{j=1}^{5}(1 + r_{t+j}^{g})b_t - \sum_{k=1}^{5} \Pi^{k}(1 + r_{t+k}^{g})s_{t+k} \tag{2.11}$$

The unstable case is when $\Pi_{j=1}^{5}(1+r_{t+j}^{g})$ is larger than unity and the stable case is when $\Pi_{j=1}^{5}(1 + r_{t+j}^{g})$ is lower than unity—the stable case implies, in equation (2.11), a stable evolution of debt ratio, assuming the surplus series (s_t) is not explosive. In the finite horizon, the stable case implies two things: the existing debt ratio would fall as a percentage of GDP; moreover, increasing debt ratio is welfare-enhancing. Therefore, the stable case suffices the sustainability of public debt.

Fiscal indicators have not considered the stable case explicitly—the

[7]Dynamic efficiency is a general macroeconomic condition which states the long-run real interest rate is higher than the long-run economic growth rate. In this context, the interest rate is government bond yield. Dynamic efficiency based on government bond yield is hard to maintained empirically. Geerolf (2013) find evidence of dynamic inefficiency in government debt—since the early 2000s, long-term real interest rates have remained low sparking the global saving gluts hypothesis (Bernanke et al., 2007); more recently, the ideas of secular stagnation—the stable case—has gained grouund to describe the post-crisis recovery of the advanced economies (see Teulings and Baldwin (2014)).

tax gap indicator (Blanchard et al., 1991) calculates the required change of primary surplus assuming the unstable case (ruling out stable case); the model-based fiscal indicator (Polito & Wickens, 2012) allows the the discount rate to be time-varying, however only examined the case of stable debt—also, the forecast horizon of their fiscal index is one year, therefore the stable case is perhaps not considered as an explicit case of sustainability.

2.3 Modelling the Dynamics of Debt-to-GDP

This section presents our original approach—probability event forecasting—to measure the fiscal sustainability of a country. In order to do that, we first describe the modelling framework which generates the probability forecasts, as well as the long-run structural modelling approach that includes the long-run relationships discussed in section 2.2.2 to the modelling framework.

2.3.1 The GVAR Modelling Framework

The evaluation of fiscal policy sustainability requires a model of debt, output and interest rates at home and abroad. This type of exercise is often conducted using detailed national economic models, taking the foreign variables as exogenous, or using linked systems of national macroeconometric or calibrated models. The analysis is costly, complex and difficult to interpret, especially when the cross-country interactions are important. An alternative approach is to carry out the analysis using a Global VAR as outlined in Garratt, Lee, Pesaran, and Shin (2012).

In the GVAR approach, the variables of interest in country i ($i = 1, ..., n$) are stacked in the vector $\mathbf{x}_{it}$. $\mathbf{x}_{it}$ is explained in terms of its own lagged values and current and lagged values of the vector of foreign variables, $\mathbf{x}^*_{it}$. $\mathbf{x}^*_{it}$ is constructed as a weighted sum of the variables in the rest

of the world—$\mathbf{x}^*_{it} = \sum_{j \neq i} w_{ij}\mathbf{x}_{jt}$, where w_{ij} $(j = 1, ..., n)$, is a set of weights specific to country i and reflects the importance of other countries from country i's perspective. Each of the individual country VARs is able to capture the dynamics arising from the interactions between the domestic variables and foreign variables. Further, having estimated the country-specific systems, these can be amalgamated (unpacking the $\mathbf{x}^*_{it}$ in terms of their constituent parts) to provide a global system that describes the simultaneous determination of all the countries' $\mathbf{x}_{it}$ considered together.

Specifically, for country i, suppose we obtain a first-order VAR relationship between domestic and foreign variables, augmented VAR denoted as VARX (Pesaran, Shin, & Smith, 2000):

$$\mathbf{x}_{it} = \mathbf{a}_{0i} + \mathbf{a}_{1i}\mathbf{x}_{i,t-1} + \mathbf{a}_{2i}\mathbf{x}^*_{it} + \mathbf{a}_{3i}\mathbf{x}^*_{i,t-1} + \varepsilon_{it} \tag{2.12}$$

where $\mathbf{x}_{it}$ is $k \times 1$, k is the number of the domestic and foreign variables. Then, writing $\mathbf{z}_{it} = (\mathbf{x}_{it}, \mathbf{x}^*_{it})'$ which is $2k \times 1$, and placing the n country-specific vectors in a single vector $\mathbf{z}_t = (\mathbf{x}_{1t}, \mathbf{x}_{2t}, \ldots, \mathbf{x}_{nt})'$ which is $(2k \times n) \times 1$, we can write

$$\mathbf{z}_{it} = \mathbf{W}_i\mathbf{z}_t \tag{2.13}$$

where $\mathbf{W}_i$ is a $2k \times (2k \times n)$ matrix constructed using the known weights w_{ij}. Expressing equation (2.12) in terms of $\mathbf{z}_{it}$

$$\mathbf{A}_i\mathbf{z}_{it} = \mathbf{a}_{0i} + \mathbf{B}_i\mathbf{z}_{i,t-1} + \varepsilon_{it}$$

where $\mathbf{A}_i = (\mathbf{I}_k, -\mathbf{a}_{2i})$ and $\mathbf{B}_i = (\mathbf{a}_{1i}, \mathbf{a}_{3i})$. Using equation (2.13), each country VARX can be expressed in the form:

$$\mathbf{A}_i\mathbf{W}_i\mathbf{z}_t = \mathbf{a}_{0i} + \mathbf{B}_i\mathbf{W}_i\mathbf{z}_{t-1} + \varepsilon_{\mathbf{it}}$$

Crucially in the expression, $\mathbf{z}_t$ is common to all national systems—therefore

we can obtain a Global VAR, defined with respect to the vector $\mathbf{z}_t$, where $\mathbf{G}$ and $\mathbf{H}$ matrices stack the $\mathbf{A}_i$ and $\mathbf{B}_i$ matrices country-by-country:

$$\mathbf{G}\mathbf{z}_\mathbf{t} = \mathbf{a_0} + \mathbf{H}\mathbf{z}_{\mathbf{t-1}} + \varepsilon_\mathbf{t} \tag{2.14}$$

where $\varepsilon_\mathbf{t} = (\varepsilon_{\mathbf{1t}}, \varepsilon_{\mathbf{2t}},..., \varepsilon_{\mathbf{nt}})'$, $\mathbf{G} = (\mathbf{A}_1\mathbf{W}_1, \mathbf{A}_2\mathbf{W}_2, \ldots, \mathbf{A}_n\mathbf{W}_n)'$, $\mathbf{H} = (\mathbf{B_1W_1}, \mathbf{B_2W_2},..., \mathbf{B_nW_n})'$. Inverting the $\mathbf{G}$ matrix and multiplying through equation (2.14), we obtain the GVAR model:

$$\mathbf{z}_\mathbf{t} = \widetilde{\mathbf{a}}_\mathbf{0} + \widetilde{\mathbf{H}}\mathbf{z}_{\mathbf{t-1}} + \widetilde{\varepsilon}_\mathbf{t} \tag{2.15}$$

where with $\widetilde{\mathbf{a}}_0 = \mathbf{G}^{-1}\mathbf{a}_0$, $\widetilde{\mathbf{H}} = \mathbf{G}^{-1}\mathbf{H}$ and $\widetilde{\varepsilon}_\mathbf{t} = \mathbf{G}^{-\mathbf{1}}\varepsilon_\mathbf{t}$. Suppose $\varepsilon_\mathbf{t}$ has variance-covariance matrix $\mathbf{\Omega}$, the variance-covariance matrix of $\widetilde{\varepsilon}_\mathbf{t}$ would be $\mathbf{\Sigma} = \mathbf{G}^{-\mathbf{1}}\mathbf{\Omega}\mathbf{G}^{-\mathbf{1}'}$.

The GVAR models the cross-country interdependencies via national VARX where the foreign variables are treated as weakly exogenous. Unpacking country-specific trade weight matrix and stacking the coefficients country-by-country, we obtain an internally consistent global system.

2.3.2 Long-Run Structural Modelling

The GVAR model above can readily accommodate the presence of long-run relationships between variables as suggested by the "long-run structural" modelling approach outlined in Garratt et al. (2012) monograph and Garratt, Lee, Pesaran, and Shin (2003). The long-run structural approach motivates restrictions from the theories of the long-run in the identification of the cointegrating VARX, which is described now.

The debt dynamics (section 2.2.1) describes the debt ratio, real interest rate, output growth and primary surpluses are the economic variables of interest; because the long-run relationships involves three of these four variables, the variable entering the VAR, $\mathbf{x}_{it} = (lb_{it}, ly_{it}, lr_{it})'$ are logarithmic

of debt ratio, logarithmic of gross real interest rate and logarithmic of output. These macroeconomic variables are generally $I(1)$ in levels—their first differences are stationary[8]. Assume $\mathbf{x}_{it}$ is $I(1)$, we would model the variables with VARX (2.12) in first difference, $\Delta\mathbf{x}_{it}$: the variables are growth of debt ratio, change of (net) real interest rate and output growth. The VARX captures feedbacks amongst debt ratio, real interest rate, output growth and their foreign counterparts.

A Cointegrating VARX We motivate a cointegrating VARX by first log-linearising the long-run relationships: bond demand constraint (2.8) and uncovered interest parity (2.9):

$$b_{it} = \beta_{i0} + \beta_{i1}(r_{it} - r^*_{it}) + \beta_{i2}y_{it} + \beta_{i3}b^*_{it} + \beta_{i4}y^*_{it} + \eta^b_{it} \tag{2.16}$$

and

$$r_{it} = \beta_{i5} + \beta_{i6}r^*_{it} + \eta_{\Delta e,it+1} + \eta^{uip}_{it+1} + \eta_{e,it+1} \tag{2.17}$$

the lower case denotes either real variable or logarithmic variable. (assume the stationarity of the expectation terms following Garratt et al. (2012).) The variables of the VARX are $\mathbf{x}_{it} = (lb_{it}, lr_{it}, ly_{it})'$, $\mathbf{x}^*_{it} = (lb^*_{it}, lr^*_{it}, ly^*_{it})'$ and $\mathbf{z}_{it} = (\mathbf{x}_{it}, \mathbf{x}^*_{it})'$—to incorporate the long-run relationships into the VARX, instead of working with a VARX in first difference, we work with a Vector Error Correction Model (VECM) with both the first difference and the level:

$$\Delta\mathbf{x}_{it} = \mu_i + \mathbf{\Pi}_i\mathbf{z}_{i,t-1} + \mathbf{\Gamma}_{1i}\Delta\mathbf{z}_{i,t-1} + \mathbf{\Gamma}_{0i}\Delta\mathbf{x}^*_{it} + \varepsilon_{it} \tag{2.18}$$

where $\mathbf{\Pi}_i$ is a k $\times$ 2k matrix of coefficients of the level terms, $\mathbf{z}_{i,t-1}$. Decomposing $\mathbf{\Pi}_i$ to two components: $\alpha_\mathbf{i}$, the error correction terms, and $\beta_\mathbf{i}$,

[8]We provide empirical support for these assumptions below.

the cointegrating vectors,

$$\Delta \mathbf{x}_{it} = \mu_i + \alpha_i \beta_i^{'} \mathbf{z}_{i,t-1} + \mathbf{\Gamma}_{1i} \Delta \mathbf{z}_{i,t-1} + \mathbf{\Gamma}_{0i} \Delta \mathbf{x}_{it}^{*} + \varepsilon_{it} \tag{2.19}$$

in particular, the linearised long-run relationships can be written in terms of $\beta_{\mathbf{i}}$:

$$\begin{pmatrix} 1 & -\beta_{i1} & -\beta_{i2} & -\beta_{i3} & \beta_{i1} & -\beta_{i4} \\ 0 & 1 & 0 & 0 & -\beta_{i6} & 0 \end{pmatrix} \tag{2.20}$$

This system (2.18) accommodates the long-run relations reflecting the asset demand constraint and the real interest rate parity. The long-run structural modelling Garratt et al. (2012) motivates a cointegrating VARX—effectively embedding the effects of the deviation-from-equilibrium terms η_{it}^{b} and $\eta_{e,it+1}$ in an otherwise unconstrained VARX in first differences. However, by stating with the underlying theory in mind (as captured by (2.16) and (2.17)), the approach also provides theory-consistent over-identifying restrictions which can be investigated empirically.

Equation (2.18) can be readily written in the second-order equivalent form to (2.12) and then the individual country-specific relations can be stacked to provide a complete model of debt sustainability across all countries. Modelling the domestic and foreign debt ratios, outputs and interest rates simultaneously in this way provides a rich characterisation—short-run dynamics, long-run dynamics, cross-country interactions—of the historical data and provides a vehicle for forecasting future values of the variables in all countries.

2.4 Measuring the Fiscal Sustainability of a Country

We are now ready to introduce our proposed measure of sustainability—the four measures described at the beginning. Obviously forecasting is key to the production of our measure so it will be important to use models with good forecasts performance. In the empirical work, we will evaluate the forecasting performance of the different models based on point forecasts, density forecasts and especially event probability forecasts. I first describe the loss function then the forecast evaluation statistics associated with each type of forecast.

2.4.1 Density Forecasts

The GVAR model in equation (2.15) can be used to generate density forecasts. One way of generating density forecasts is to use the estimated variance-covariance of the model, Σ to simulate future paths for the $\mathbf{z}_{\mathbf{t}}^{'}$s $(t = T+1, \ldots, T+5)$, taking the estimated $\widetilde{\mathbf{a}}_0$ and $\widetilde{\mathbf{H}}$ as known. The errors are drawn from a standard Normal distribution.

The forecast horizon we choose to consider is five-step-ahead, as discussed previously. The density forecasts $\mathbf{z}_{\mathbf{t+5}}^{'}$ based on the information set at time t is denoted as $\hat{f}_t(\mathbf{z}_{\mathbf{t+5}}^{'}|\mathbf{\Omega_t})$—the density forecasts generated via this way provides a complete characterization of the stochastic uncertainty surrounding the forecasts.

Evaluating Density Forecasts Because only a realized draw is observed, evaluating the density forecasts follows various approaches. We can evaluate if the density forecasts are correctly specified via tests based on Probability Integral Transform (PIT). Assuming the density forecasts are correctly specified, we can evaluate density forecasts based on loss func-

tions, such as scoring rule that maps the density forecasts and the outcomes to the real line. We can evaluate the the features of density forecasts using calibration, resolution or sharpness. We will discuss these methods in turn.

The Probability Integral Transform (PIT) is the cumulative distribution function of the density forecast evaluated at the outcome. PIT-based tests rely on the idea where provided the sequence of conditional density forecasts is correctly specified at each period, the sequence of PIT values will be distributed as Uniform distribution in the support between 0 and 1. Misspecified densities lead to violations of this property therefore provides the basis for a test of correct specification of the density forecasts. Diebold, Gunther, and Tay (1998) suggest examining the histograms of PIT values. To more formally test the hypothesis of correct specification, we can use a Kolmogorov-Smirnov or Cramer-von-Mises test (see Rossi and Sekhposyan (2015)).

The correctly specified density forecasts is preferred over a misspecified density forecasts by any loss function. The loss function of the density forecasts is known as scoring rules and reward forecasters for making more accurate predictions, i.e. predictions that are "closer" to the observed outcome get a higher score, where closeness depends on the shape of the scoring rule (Elliott & Timmermann, 2016). Scoring rules, $S(p, y)$, are mappings of predictive probability distributions, p, and outcomes, y, to the real line.

Several scoring rules have been used in the literature (Gneiting & Raftery, 2007)[9], for instance the logarithmic score and the quadratic or Brier score for instance:

$$\begin{aligned} \log S(p, y) &= \log p(y) \\ S(p, y) &= 2p(y) - (\int p(y)^2 \mu(dy))^{1/2} \end{aligned}$$

[9]Gneiting and Raftery (2007) provide a survey of scoring rules and discuss their properties.

where S is the scoring rule, p is the density forecast and y is the realization. Both are proper scoring rules[10]. We use the logarithmic score in this chapter; with T density forecasts and realizations, and five-step-ahead forecast horizon, the average log score (ALS) is:

$$\text{ALS} = \sum_{t=1}^{T} \log p_t(y_{t+5})/T \tag{2.21}$$

Besides evaluating density forecasts using loss function, the features of density forecasts can be evaluated using calibration, resolution and sharpness (Elliott & Timmermann, 2016; Mitchell & Wallis, 2011).

Comparing Density Forecasts Amisano and Giacomini (2007) compare two density forecasts, $p_1(y)$ and $p_2(y)$, using the log scoring rule. They base density evaluations on the studentized weighted average differences in log scores. Similarly, here we compare density forecast generated with the forecast model m and the benchmark model, Random Walk (RW) using the scaled difference in average log score:

$$\text{scaled difference in ALS} = \frac{\text{ALS}_{\text{RW}} - \text{ALS}_{\text{m}}}{\text{ALS}_{\text{RW}}} \tag{2.22}$$

2.4.2 Probability Event Forecasts

We can convert the density forecasts into event probability forecasts, $\hat{\Pr}(\Im_{t+5}|\Omega_t)$—$\Im_{t+5}$ is the five-step-ahead event forecast, Ω_t is the information set at time t—which constitutes our approach to measuring sustainability. Practically, the event probability forecasts is obtained by the proportion of simulations satisfying the event out of the total simulations. In what follows I am defining five events:

- Stable Debt event (sust^{SD}): sustainability is achieved at time T, if

[10] A scoring rule is called strictly proper if the forecaster's best probability distribution is p_0, where p_0 is the probability distribution used to evaluate its "goodness of fit" of p (predictive probability distribution).

the time—$T+5$ debt ratio is lower or equal than debt ratio at time-T ($\Im_{t+5} = d_{T+5} \leq d_T$).

- Maastricht Debt event (sust^{M}): sustainability is achieved at time T if the time—$T+5$ debt ratio is lower or equal than 60% ($\Im_{t+5} = d_{T+5} \leq 60$).

- Below Peak Debt event (sust^{BPD}): sustainability is achieved if the time-$T+5$ debt ratio is lower or equal than the ninetieth percentile of the historical debt distribution ($\Im_{t+5} = d_{T+5} \leq d_{\tau=0.90|T}$).

- Discounted Debt event (sust^{DD}): sustainability is achieved if the discounted time-$T+5$ debt ratio is lower or equal than debt ratio at time-T ($\Im_{t+5} = \frac{d_{T+5}}{\Pi_{i=1}^{5}(1+r_{T+i}-g_{T+i}} \leq d_T$).

- Stable Case event (sust^{SC}): sustainability is attained if the time-$T+5$ discounted compound growth-corrected interest rates are lower or equal than unity ($\Im_{t+5} = \Pi_{j=1}^{5}(1 + r_{T+j} - g_{T+j}) < 1$).

The 'Stable Debt' event is defined, drawing in line with the tax gap indicator and the fiscal index of the current stance. In the case of the 'Maastricht Debt' event, this threshold is motivated because eight of ten countries in the empirical sample are European countries; this event also underlies the S1 indicator of the European Commission. With the 'Below Peak Debt' event, whilst we do not observe the fiscal limit[11] beyond which fiscal policy is unsustainable, we could use an arbitrarily high historical debt limit to gauge a high level of debt ratio observed in history but is deemed sustainable. In comparison with the 'Maastricht Debt' event, the

[11]Ghosh, Kim, Mendoza, Ostry, and Qureshi (2013) use the fiscal reaction function—reduced-form regressions of surpluses on debt developed based on Bohn (1995)—introduce non-linear relationship between the debt and primary balance find a "fiscal fatigue" phenomenon across countries; based on that, they compute a fiscal limit (defined in terms of a debt threshold), beyond which the government can no longer service its debt because fatigue sets in. Bi and Leeper (2013) argue the calculation of fiscal limit is subject to the Lucas critique therefore uses a real business cycle to derive a country's fiscal limit endogenously from an economy's dynamic Laffer curve which varies with the economic environment.

debt targets underlying both the 'Stable Debt' and 'Below Peak Debt' events change with time.

The two advantages of the discounted debt ratio, as discussed in section 2.2.3: first, it summarizes fiscal variables of the government budget constraint; second, by comparing the discounted debt with the current debt, it defines flow dimension of fiscal sustainability. This motivates the 'Discounted Debt' event. The 'Stable Case' event is motivated from the discussion of the stable case in section 2.2.3.

As described in the introduction, there are four sustainability indexes, which are event probability forecasts defined in terms of either of these single events or a union of these events. The *debt sustainability index* is the union of 'Stable Debt', 'Maastricht Debt' and 'Below Peak Debt' events. The *discounted debt sustainability index* is the 'Discounted Debt' event. As fiscal sustainability is achieved with the stable case, we consider the union of the 'Stable Case' event with the union of events underlying the debt sustainability index—this defines the *augmented debt sustainability index*. Similarly, we consider the union of the 'Stable Case' event with the event underlying the discounted debt sustainability index—this defines the *augmented discounted debt sustainability index*.

2.4.3 Binary Event Forecasts

We can convert the probability event forecasts to binary forecasts by deciding the threshold probability for sustainability and non-sustainability. The economic loss function becomes very simple because there are only four outcomes; two of which are correct forecasts, two of which are not[12]: where Y is the realization, 1 and -1 are the two categories i.e. sustainable (1) or not (-1) and f is the forecast; TP is true positive, FP is false positive, FN is false negative and TN is true negative (positive and negative are referenced

[12]Writing down a loss function becomes a question of how to trade off between two possible mistakes.

		Y = 1	Y = -1
Forecasts	f = 1	TP	FP
	f = -1	FN	TN

for the forecasts). As illustrated on the table, the correct forecasts are true positive and true negative; the incorrect forecasts are false positive and false negative.

Evaluating Binary Forecasts A straightforward statistics is the accuracy rate, i.e. the proportion of correctly forecasted events realized in both the positive and negative cases to the total number of forecasts:

$$\text{Accuracy rate} = \frac{\text{TP} + \text{TN}}{\text{TP} + \text{TN} + \text{FN} + \text{FP}}$$

The accuracy rate is a summary statistic of a model's ability to predict the events. In addition, the Kuipers Score is the difference between the true positive rate and the false positive rate (Pesaran, 2015): the true positive rate is the proportion of times where y = 1 (sustainable realizations) is corrected predicted; the false positive rate is the proportion of times where y = 1 is wrongly predicted:

$$\text{Kuipers Score} = \frac{\text{TP}}{\text{TP} + \text{FN}} - \frac{\text{FP}}{\text{FP} + \text{TN}}$$

A positive Kuipers Score implies the model returns more true positives than false positives; vice versa for a negative Kuipers Score. The Kuipers Score is however not defined if either the true positive rate or the false positive rate is not defined—for instance, evaluating an event that has occurred only in either the positive case (1) or the negative case (-1). With such instance, the Kuipers Score is not calculable.

Furthermore, the Receiver Operator Characteristic (ROC) curve provides a popular way to evaluate binary forecasts (Elliott & Timmermann,

2016) as it highlights the role of the threshold probability. The ROC curve is plotted on two bases: first, all the numbers (TP,FP,TN,FN) on the table are functions of the threshold probability; second, there is a positive relationship between the true positive rate and the false positive rate. To see this, suppose if we increase the threshold probability. Increasing the threshold probability results in fewer positive forecasts and more negative forecasts. Therefore, this reduces both the true positive rate and the false positive rate. Tracing the curve that relate the two measures as a function of threshold where moves to the right decreases the threshold produces the ROC curve. The closer this curve is to being a step function that immediately shifts to 1 as threshold moves away from one, the better. A common measure for the ROC curve is the area under the curve.

Pesaran and Timmermann (2009) consider a range of dependency tests for multicategory forecasts; in this case, two categories: sustainable (1) and not sustainable (-1). The null hypothesis is the realizations (Y) and the forecasts (f) are independent; if we do not reject the null, there is no forecast-ability on the realizations. Pesaran and Timmermann (1992) derive a simple test statistic based on the canonical correlation between y_{t+1} and $f_{t+1|t}$, however only for serially independent realizations. For serially dependent realizations, Pesaran and Timmermann (2009) show that a predictability test can be constructed using canonical correlations of suitably filtered versions of y and f after accounting for the effect of lagged values of $(\mathrm{y}', \mathrm{f}')'$. In the following the text, we refer the Pesaran Timmermann (PT) static test for serially independent realizations and the PT dynamic test for serially dependent realizations.

2.5 Empirical Illustration: Sustainability Measures for Ten OECD Countries

In this section, I describe the empirical analysis of public debt, interest rate and output growth in the ten OECD countries: Belgium, Canada, Denmark, France, Germany, Ireland, Italy, Netherlands, the UK and the US. The data begins from 1958 and ends in 2010. In what follows, I describe their overall time series properties and investigate the evidence for the presence of the theory-based long-run relations.

2.5.1 Data Description and Time Series Characterization

Public Debt The public debt data that is available differs across our sample of countries in two dimensions: 1. general government versus central government and gross debt versus net debt. In the first dimension, general government debt (headline government debt) includes central government debt and local government debt. The data availability of general government debt—length of data—is however shorter than central government debt. In the second dimension, net debt excludes the debt owned by public institutions—the central bank for instance—but gross debt does not. Reinhart and Rogoff (2011) compile all types of government debt dataset—but use the longer debt data in their analysis: we follow the same approach[13].

The broad properties of the public debt series are described in Table 2.2. Countries' historical evolution of public debt differs: we see the average debt ratio varies between 20% (Germany) and 79% (Belgium). The

[13]Belgium's, Canada's, Denmark's, France's, Germany's, Ireland's and the US'S government debt data are gross central government debt. Italy's and the Netherlands' debt data are gross general government debt. The UK's debt data is net central government debt.

standard deviation of the debt ratio ranges between 11% (Germany) and 34% (Italy) across countries—but for most countries, the debt ratios have moved significantly during this fifty-three years period (Figure 2.1)—half of the countries (Belgium, Denmark, France, Ireland, Italy and the UK) have standard deviation above 20%.

Real Interest Rate The real interest rate used in our empirical work is the ten-year government bond yields deflated contemporaneously by annual inflation rates: ten-year yields are sourced from the International Financial Statistics of the IMF and annual inflations are sourced from Reinhart and Rogoff (2011).

The average real interest rates are more similar between countries than the average debt ratios are between countries (Table 2.3)—Germany has the lowest average real interest rate (2.19%); Belgium has the highest average real interest rate (3.43%). The variability of real interest rates is also similar between countries—Italy has the highest standard deviation of real interest rates (3.26%); Canada has the lowest standard deviation of real interest rates (2.07%).

Output Growth The output growth is measured by the growth rate of the real GDP. The data is sourced from the Total Economy Database (TED) maintained by the Conference Board, previously the the Groningen Growth and Development Centre. The average output growth ranges between 2.45% (Denmark) and 4.27% (Ireland) in the ten countries (Table 2.4). The average variation of output growths during the sample period is similar between countries—between 2.05 (Belgium) and 3.13 (Ireland).

Unit Root Tests We test the stationarity of the variables with the Dickey-Fuller unit root tests (Dickey & Fuller, 1979). The Augmented Dickey-Fuller (ADF) regression augments the Dickey-Fuller regression by

including the lags of the dependent variables. We run four ADF regressions for each country, with increasing order of augmentation[14]—the number of lagged dependent variable. The ADF regression includes a constant term and a linear trend. The null hypothesis is that the variable is a unit root process. The critical values are computed based on MacKinnon (2010).

We also use the Im, Pesaran and Shin (IPS) test (Im, Pesaran, & Shin, 2003)—panel unit root test statistics which has better power properties than the individual country ADF test[15].

If we do not reject the unit root null hypothesis of the variables, we test for unit root on the change (first difference) of the variables. The same ADF regression is used; but the regression includes only the intercept. The four augmentation orders of the ADF regressions are from zero to three. The critical values change as a result of a change in the deterministics, therefore the critical values are re-computed based on MacKinnon (2010).

Cross-section Augmented Dickey-Fuller (CADF) Test The economic variables could be correlated across countries, for instance if there is an unobserved common factor that affects all countries' public debts, real interest rates or output growths. Pesaran (2007) suggests a simple modification of the ADF test procedure in accounting for the presence of a common factor affecting the economic variables in all countries. The Cross-section Augmented Dickey-Fuller (CADF) test is based on the following regression:

$$\Delta y_{it} = a_i + \phi_i y_{i,t-1} + b_i \bar{y}_{t-1} + c_i \Delta \bar{y}_t + e_{it}$$

[14]The order of augmentation is used to deal with the problem of residual serial correlation.

[15]The IPS test statistic normalizes the cross-section mean of the ADF tests in the twelve countries. Using central limit theorems, Im et al. (2003) shows the test can be compared to the critical values from the standard Normal distribution.

where $\bar{y}_t = N^{-1} \sum_{i=1}^{N} y_{it}$ and $\Delta\bar{y}_t = N^{-1} \sum_{i=1}^{N} \Delta y_{it}$—the inclusion of both the cross-section mean of the dependent variable and the independent variables.

In addition, the panel unit root test is the cross-section average of the N individual CADF t-statistics, denoted as CIPS test (Pesaran, Smith, & Yamagata, 2013). The critical values for the CADF test depend on the length of both the cross-section and time series dimensions, obtained from Pesaran (2007).

In both the ADF and CADF regressions (Tables A.1, A.2, A.3, A.4)—when we account for common factor and when we do not—the debt ratio is a unit root process but the growth of the debt ratio is stationary: debt ratio is therefore an integrated of order one (I(1)) variable.

The findings of the ADF and CADF unit root tests contradict with one another. Based on the ADF unit root tests (Table A.5), the real interest rate is I(0); based on the CADF tests (Table A.7), the real interest rate is I(1). We do not reject the unit root characterization of the real interest rate in the ADF regression; the non-rejection of the unit root null is also supported by the IPS test statistic. When we control for common factor amongst the real interest rates (CADF regression) however, we reject the unit root characterization of the real interest rate ; the rejection of the unit root null is also supported by the CIPS test statistic. For the change of real interest rate, we reject the unit root hypothesis in both the ADF regression (Table A.6) and the CADF regression (Table A.8).

We reject the unit root characterization of output growth across countries when we account for common factor (Table A.9) and when we do not account for common factor (Table A.10). In short, based on these unit root tests findings, the debt-to-GDP and the real interest rate are I(1); the output growth is I(0).

Trade Weights The trade weights underlie the construction of foreign variables. The data is sourced from IMF's Direction of Trade Statistics, between 1980 and 2010. The trade weight of country, w_{ij} ij is the trade between country i and country j, of total trade between country i and every other country. Germany has an important weight in every EU countries (the highest weight in Belgium, Denmark, France, the UK, Italy and the Netherlands). France and the UK are also influential in other EU countries. The North American countries—Canada and the US—are influential for one another: the US dominates the trade weight for Canada—91% and Canada weighs more than half for the the US. Canada does not weigh importantly in other countries; the US however has a sizable weight in other countries.

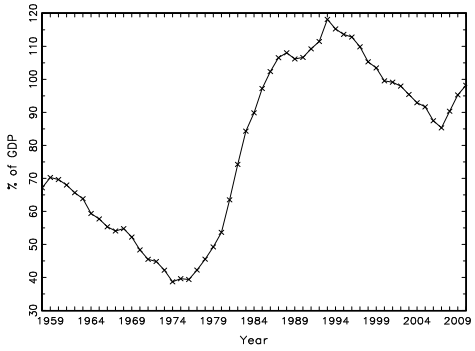
Table 2.1: Trade Weights, 1980-2010

	Bel	Can	Den	Fra	Ger	Ire	Ita	Net	UK	US
Bel	0.00	0.01	0.01	0.21	0.26	0.04	0.06	0.21	0.11	0.09
Can	0.01	0.00	0.00	0.01	0.02	0.00	0.01	0.01	0.03	0.91
Den	0.05	0.01	0.00	0.09	0.39	0.02	0.07	0.11	0.15	0.09
Fra	0.14	0.01	0.01	0.00	0.31	0.02	0.16	0.10	0.14	0.11
Ger	0.11	0.01	0.03	0.21	0.00	0.02	0.14	0.17	0.15	0.16
Ire	0.11	0.01	0.01	0.07	0.12	0.00	0.04	0.06	0.35	0.23
Ita	0.07	0.01	0.02	0.24	0.33	0.02	0.00	0.09	0.11	0.12
Net	0.17	0.01	0.02	0.12	0.36	0.02	0.07	0.00	0.14	0.10
UK	0.08	0.03	0.02	0.15	0.22	0.09	0.08	0.13	0.00	0.21
US	0.04	0.53	0.01	0.07	0.13	0.04	0.05	0.05	0.11	0.00

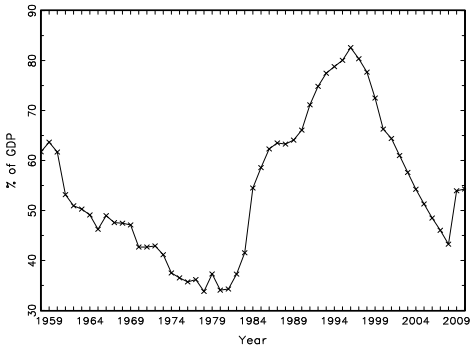
Source: Direction of Trade Statistics.

Figure 2.1: The Debt-to-GDP in Ten OECD Countries

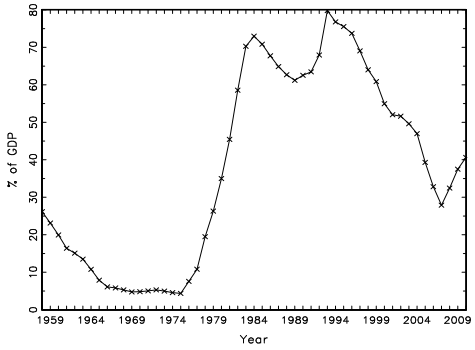
(a) Belgium



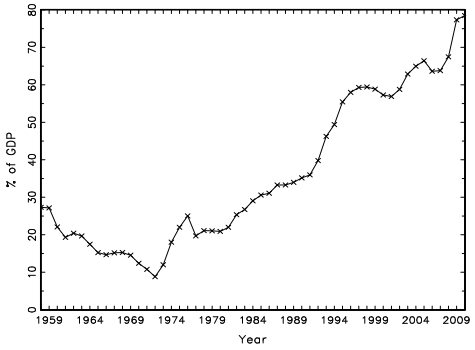
(b) Canada



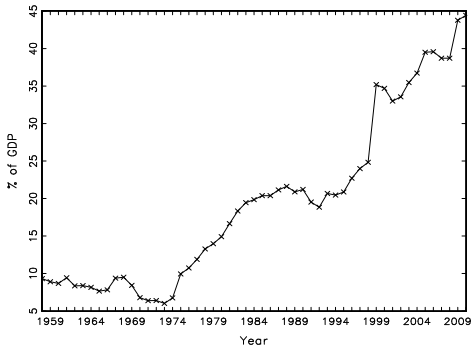
(c) Denmark



(d) France



(e) Germany



(f) Ireland

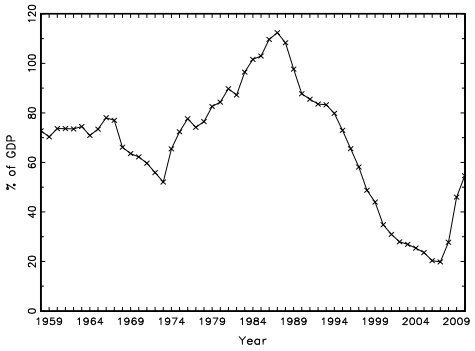


Figure 2.1: Continued

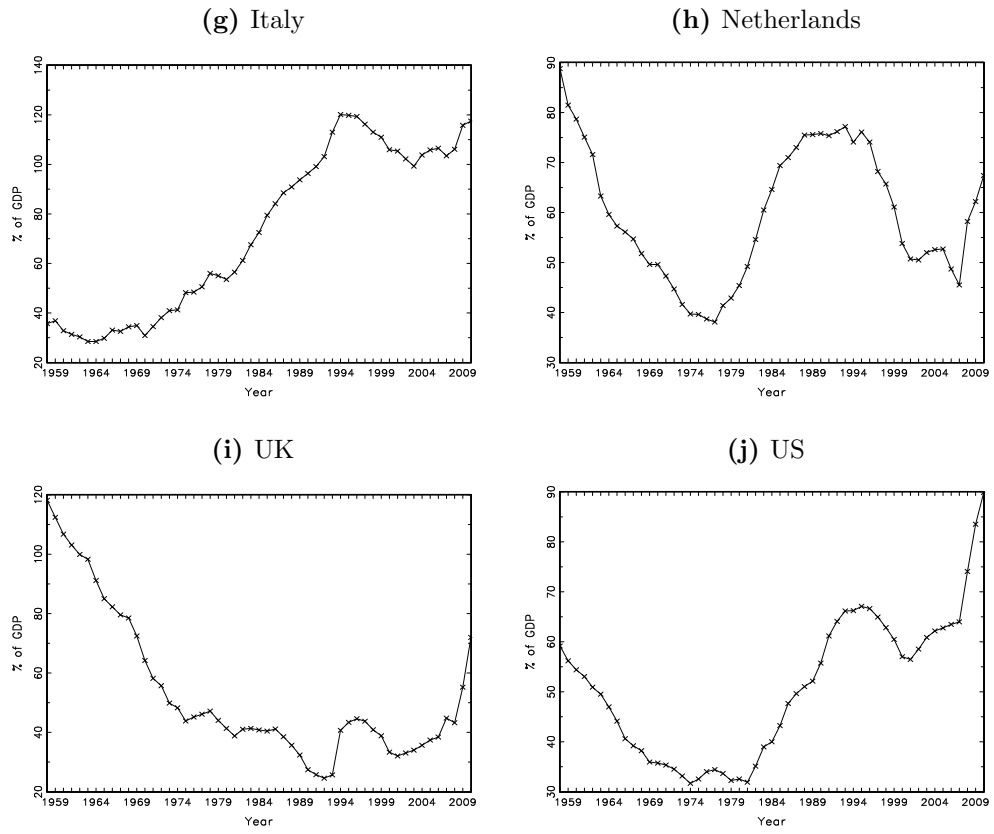


Table 2.2: Summary Statistics of the Public Debt, 1958-2010

	Mean (%)	St. Dev (%)	Min (%)	Max (%)
Bel	79.22	25.56	38.68	118.15
Can	54.53	13.99	33.80	82.60
Den	38.05	25.87	4.34	79.82
Fra	35.86	20.10	8.81	78.48
Ger	19.55	11.46	6.01	44.43
Ire	67.62	24.28	19.79	112.43
Ita	72.90	33.56	28.49	120.13
Net	59.79	13.38	38.10	88.80
UK	53.51	24.64	24.56	118.14
US	50.87	14.35	31.68	89.88

Note: The debt ratio data is sourced from Reinhart and Rogoff (2011).

Table 2.3: Summary Statistics of the Real Interest Rate, 1958-2010

	Mean (%)	St. Dev (%)	Min (%)	Max (%)
Bel	3.43	2.26	-3.91	6.99
Can	3.34	2.07	-1.83	8.14
Den	3.61	2.26	-0.49	8.91
Fra	2.52	2.50	-7.61	6.15
Ger	2.19	2.60	-4.59	6.75
Ire	2.76	2.99	-5.31	7.57
Ita	2.52	3.26	-8.07	7.58
Net	2.57	2.13	-1.30	7.21
UK	2.74	2.68	-8.31	6.20
US	2.50	2.09	-3.18	7.50

Note: The real interest rate is the ten-year government bond yields deflated by annual inflation: ten-year yields are sourced from IMF and annual inflations are sourced from Reinhart and Rogoff (2011).

Table 2.4: Summary Statistics of the Economic Growth, 1958-2010

	Mean (%)	St. Dev (%)	Min (%)	Max (%)
Bel	2.76	2.05	-2.88	6.81
Can	3.33	2.20	-3.09	6.92
Den	2.45	2.44	-5.35	8.94
Fra	2.88	2.02	-2.77	6.81
Ger	2.58	2.45	-5.26	8.31
Ire	4.27	3.13	-7.25	10.36
Ita	2.75	2.64	-5.36	8.09
Net	3.03	2.21	-3.60	8.08
UK	2.35	2.04	-5.00	6.51
US	3.13	2.20	-3.55	7.16

Source: Total Economy Database (TED).

2.5.2 Identifying Long-run Relationships in Cointegrating VARX

This subsection is the empirical analysis of equation (2.18): The purpose is to identify β_i (for each country) which is then included in the forecasting exercise. The cointegration analysis of the VARX proceeds in the following steps: first, we set up a cointegrated VARX for each country (involves the modelling choice of lag length and deterministics); second, we check if the estimated model is well-specified—if it is not, we re-specify the model; third, we test for cointegration; finally, we identify the long-run relationships provided *a priori* in equation (2.16) and equation (2.17).

Setting Up the Cointegrated VARX We specify the lag length two of the VECM, allowing a lagged first difference terms to capture short-run dynamics in addition to the long-run relationship(s). The lag length of two is justified on the lag length reduction tests (Juselius (2006) p66) and the serial correlation tests. We specify the deterministics (μ in equation (2.18)) to the case—restricted intercepts and no trends—rule out linear trend in debt ratio, real interest rate and output—economic theories do not typically suggest these variables trend linearly.

Across the country-by-country cointegrated VARX, output is not found to be helpful in identifying the bond demand relationship; we therefore exclude output as an endogenous variable with the estimation sample in mind and include output growth as an exogenous I(0) variable (Pesaran et al., 2000) in the cointegrated VARX model.

Checking the Model Subsequent to obtaining an estimated cointegated VARX model, we perform several checks on the model—we first check the stability of the VARX based on the characteristic roots of the VARX are less than unity (calculated with the companion form) to ensure that the

system is stable; we then check if the model is well-specified based on the model residuals satisfy—serial uncorrelation, homoscedastiity and normality. Table A.11 reports the preferred specification of the cointegated VARX for each country: endogenous variables, exogenous variables, dummy variables, lag length, rank of the Π matrix and the (corresponding: based on the rank of Π) modulus of the roots of the VARX[16]. TableA.12 summarizes the misspecification tests of the cointegrated VARX in each country.

Testing for Cointegration in VARX Model Subsequent to obtaining a well-specified model, we test for the cointegration rank r of the $\mathbf{\Pi}_i$ in the VECM model (2.18). Table A.13 reports the trace test statistic, 95% and 90% critical values from the simulated asymptotic distribution for the null hypotheses. In four countries (Belgium, Canada, France and the US), the trace tests reject the null hypothesis of rank equal to zero and the null hypothesis of rank equal to one—we therefore conclude that the data suggests the rank equal to two. In six countries (Denmark, Germany, Ireland, Italy, the Netherlands and the UK), the trace test rejects the null hypothesis of rank equal to zero but does not reject the null hypothesis of rank equal to one—the data suggests the rank equal to one[17]

Identification of Long-run Relations Subsequent to selecting the rank of the $\mathbf{\Pi}_i$ matrix in the VECM model, we identify the long-run relationships, β_i in equation (2.19). The advantage of the long-run structural modelling elaborated in section 2.2.2 can be seen here: equation (2.16) and (2.17) provide the normalizing restrictions—the debt ratio and the real interest rate and the over-identifying restrictions on β_i. Based on Table A.14, in three countries (Denmark, Germany the UK) the restrictions are just-

[16]The other deterministics column in Table A.11 is the direct implication of the misspecification test. An outlier is defined according to multiple times of the standardized residuals.

[17]with the exception of Netherlands, where the trace test statistic for the null hypothesis of rank equal to one is close with the 90% critical values, together with other information discussed in the following, we choose the rank in the Netherlands to be two.

identifying; in other countries, the restrictions are over-identifying therefore testable—the cointegrating vectors reported on Table A.14 are not rejected by the data[18].

The long-run relations (Table A.14) are summarized as follows: in five countries (Belgium, Canada, Denmark, France and the US), the government bond demand relationship is empirically identified, the cointegrating vectors differ across countries—in Canada, the bond demand relationship consists of the debt ratio and the real interest rate, in the four other countries, the bond demand relationship consists of the foreign debt ratio. The real interest rate is present (in the bond demand relationship) in Belgium, Canada and Denmark but absent in France and the US. In Denmark and France, the bond demand long-run relationship also includes the foreign real interest rate. Across countries, in the bond demand relationship, the debt ratio co-moves positively with the real interest rate and the foreign debt ratio but co-moves negatively with the foreign real interest rate.

The uncovered interest parity is empirically identified in all countries—the real interest rate co-moves positively with the foreign real interest rate. The difference of the cointegrating vectors across countries is the homogeneity restriction on the foreign real interest rate—in four countries (Canada, France, Ireland, Italy) the data does not reject the homogeneity restriction; in five other countries (Belgium, Germany, the Netherlands, the UK and the US), the data rejects the homogeneity restriction. In Denmark, the bond demand relationship embeds the positive co-movement between real interest rate and foreign real interest rate[19].

[18]For rank equals to two, the two cointegrating vectors have to be linearly independent of each other; the just-identifying restrictions in each cointegrating vector is two; for rank equals to one, the just-identifying restriction of the cointegrating vector is one.

[19]Subsequent to obtaining the identified cointegrating vectors, we revisit the rank determination modelling decision reporting (Table A.15) the the cointegration rank based on the trace test, the largest characteristic root of the restricted model and the statistical significance of the cointegrating coefficients. This is motivated by the fact that the number of cointegrating vectors is important Pesaran (2015) p921. The largest root of the restricted VAR model lie below unity—the largest root is 0.85 in Canada and the Netherlands). The cointegrating coefficients are statistically significant.

2.6 The Sustainability Indexes

We are now ready to illustrate our proposed measure of sustainability in our empirical sample. Before we do that, we investigate the forecasting performance of the global cointegrated model against simpler variants of the full model. We judge the forecasting performance based on statistical loss functions and event loss functions described in section 2.4.

In order to illustrate our measure, we undertake a rolling forecasting exercise between 1990 and 2010—the forecasting models roll through the estimation sample, beginning from 1958, generate five-year-ahead forecasts at each rolling. To compare the realizations with the forecasts in the forecast evaluation exercises, the evaluation sample reduces to 16 observations.

2.6.1 Forecast Models

In evaluating the global model (as described in section 2.3), there are three distinct aspects we focus on: cross-country interactions, long-run relationships and endogenous foreign variables. Therefore the following five forecast models:

- the global cointegrated VAR model (GVARc), the country-by-country estimated model is:

$$\Delta \mathbf{x}_{it} = \mu_i + \alpha_i \beta_i^{'} \mathbf{z}_{i,t-1} + \mathbf{\Gamma}_{1i} \Delta \mathbf{z}_{i,t-1} + \mathbf{\Gamma}_{0i} \Delta \mathbf{x}_{it}^{*} + \varepsilon_{it}$$

  where the notations and the global system is solved following section 2.3.1.

- The global VAR model (GVAR), the estimated model is same as GVARc except feedbacks from cointegrating vectors are excluded:

$$\Delta \mathbf{x}_{it} = \mu_i + \mathbf{\Gamma}_{1i} \Delta \mathbf{z}_{i,t-1} + \mathbf{\Gamma}_{0i} \Delta \mathbf{x}_{it}^{*} + \varepsilon_{it}$$

the global system is solved following section 2.3.1.

- The augmented cointegrated VAR model (VARXc), the estimated model is same as GVARc but it is not solved as a global system therefore foreign variables are specified and forecasted as autoregressive model in first difference:

$$\Delta \mathbf{x}_{it}^{*} = \mu_i + \sum_{j=1}^{p} \mathbf{\Gamma}_{ji} \Delta \mathbf{x}_{i,t-j}^{*} + \nu_{it}$$

  where p is the lag order of the autoregressive model and $\mathbf{\Gamma}_{ji}$s are diagonal matrices. Lag length p is selected such that the no serial correlation assumption of the residuals is satisfied.

- The augmented VAR model (VARX) — the national starred model, the estimated model is same as GVAR but it is not solved as a global system; similarly, the foreign variables are specified and forecasted as autoregressive model in first difference.

- The VAR model, the estimated model is same as GVAR and VARX except feedbacks from foreign variables are excluded.

$$\Delta \mathbf{x}_{it} = \mu_i + \mathbf{\Gamma}_{1i} \Delta \mathbf{x}_{i,t-1} + \varepsilon_{it}$$

- The random walk with drift which is the benchmark model[20].

$$\Delta \mathbf{x}_{it} = \mu_i + \varepsilon_{it}$$

[20] Assessing if cross-country interactions improve forecast performance or not, I compare the national starred model with the national model. Assessing if cointegrating vectors of public debt, interest rate and their foreign counterparts improve forecast performance or not, I compare the national cointegrated starred model with the national starred model. Assessing if endogenizing foreign variables improve forecast performance or not, I compare the global model with the national starred model.

In each forecast model the deterministic includes a constant, μ_i—the model is estimated in first difference, the constant is effectively a linear trend in level[21]. We include the long-run relationships—via the country-specific cointegrating vector, $\beta_i^{'}$ obtained from the full-sample cointegrated VAR in section 2.5.2—in the cointegrated models (GVARc and VARXc). The error correction coefficients, α_i are estimated in each rolling window; this approach of including the long-run relations follows Garratt et al. (2012) p265-266.

The other deterministic in the forecasting exercise corrects for outliers: in each rolling window, if the residual of the last observation is more than 3.15[22] multiple times of the standardized residuals, the program includes an additive dummy and re-estimates the model, effectively dummying out the extreme observation in the estimation.

Both VARXc and VARX models involve six equations to generate the forecasts of the (three) endogenous variables. In the global models, the exogenous variables are endogenized where all country-by-country models are stacked; therefore, thirty equations are used to generate thirty endogenous variables, three variables for each of the ten countries. The global model has the advantage of being internally consistent over the augmented model.

The forecasting programs automate a search procedure (in each rolling window) on the estimated coefficients—coefficients whose T-values are less than one in absolute term are dropped. This is motivated by the parsimony principle which improves forecast performance (lowering the Root Mean Square Forecast Error) (Clements & Hendry, 1998). The search procedure drops a variable one at time, starting with the longest lags and on the

[21]In identifying the cointegrating vector, the restricted constant option is selected such that the trending behaviour is modelled as stochastic trends that are cancelled out with cointegrating vectors. In forecasting, the inclusion of a constant is justified on the finite forecast horizon and the general role of an intercept in regression.

[22]3.15 is a function of the sample size and is calculated in CATS in RATS (Dennis, Hansen, Johansen, & Juselius, 2006).

dependent variables before the exogenous variables[23].

2.6.2 Forecast Evaluation

We now evaluate the forecasting performance of the different models, first the point and density forecasts evaluation then the binary forecasts evaluation.

Point and Density Forecasts Evaluation Based on the point forecasts, the best system across the three variables is the system with long-run relationships (see table 2.5)—in some countries, the GVARc model is the best model; in some countries, the VARXc is the best model. The forecast comparison also shows the best model in each country includes cross-country interdependencies in forecasting the three variables.

The scaled ALS difference, defined in equation (2.21) ranks the density forecasting performance of each system. The global systems (Table 2.6) are the best model in forecasting the three variables—the scaled ALS difference is highest in forecasting the debt ratio and lowest in forecasting the real interest rate—the real interest rate is a financial variable where the random walk is a good characterisation.

Binary Forecasts Evaluation For the event forecasts underlying the debt sustainability index (Table 2.7), the GVARc has the highest accuracy rate in six countries—in countries where it is not the highest, it is close to the highest. The same is true for the event forecasts underlying the augmented debt sustainability index (Table 2.8).

[23]To illustrate, in the VARX(1) model, the procedure first searches amongst the coefficients of lagged public debt, lagged interest rate and lagged output growth; followed by lagged foreign public debt, lagged foreign interest rate and lagged foreign output growth; finally the contemporaneous coefficients of the foreign variables conditioned on the lagged foreign variable respectively—the contemporaneous coefficient is not dropped if the lagged coefficient remains. Each time a coefficient is dropped, the regression is re-estimated prior to the next search.

For the event forecast underlying the discounted debt sustainability index (Table 2.9), the GVARc model has the highest accuracy rate in five countries—in other countries, the model is close to the highest with the exception of Germany and Italy[24]. For the event forecast underlying the augmented discounted debt sustainability index, the GVARc model has the highest accuracy rate in seven countries—in countries where it is not the highest, it is close to the highest (France and the US), but it is relatively low in Germany.

Based on the binary forecasts evaluation, the GVARc is the best or as good as other models across countries; the system is internally consistent in forecasting in comparison with the national starred systems therefore we use the GVARc system to generate our sustainability indexes.

2.6.3 Sustainability Measures

The debt sustainability index (Figure 2.2) flags up sustainability concern in 2009 across countries—the index falls to level below the 0.5 threshold in every country except Denmark. The timing of this fall corresponds with the European Sovereign Debt Crisis in 2009. In the US, the index falls sharply a year earlier, in 2008. In other years, the debt sustainability index flags up concern in Italy during the 1990s (has since improved in the early 2000) and France since the early 2000s.

The discounted debt sustainability index indicates different sustainability assessment from the debt sustainability index. For instance, in Germany, the discounted debt sustainability index flags up concerns since the early 2000s however the debt sustainability index does not in the same years, implying the stock dimension of fiscal risk remains low. During the years when the Global Financial Crisis and the Sovereign Debt Crisis occur,

[24]the accuracy rate is low across the models—based on the unconditional probability statistics—94%, Italy maintains its debt in the present value sense in all but one period during the sixteen forecast evaluation periods; the forecast model however predicts Italy would not manage to maintain its debt in the present value sense

whilst the discounted debt sustainability index, like the debt sustainability index falls sharply in Canada, Denmark, the Netherlands (in 2009) and the US (in 2008), it does not however fall sharply in other countries—the discounted debt sustainability index rises in Germany in 2009. Furthermore, in 2010, in comparison with the debt sustainability index, the discounted debt sustainability index does not rebound in every country as is the debt sustainability index, reflecting the stock and flow dimensions of fiscal sustainability are quite different.

Sustainability outlook changes substantially when we consider the stable case simultaneously. The augmented debt sustainability index is similar with the debt sustainability index in most countries except in France and Italy which provide interesting comparisons between the two indexes—the years when the debt sustainability index indicates a low probability of sustainability, the augmented sustainability indexes indicate a higher probability—the stable case forecasts drive up the probability of sustainability during these years.

Similarly, in the US, where the global financial crisis of 2008 originates, the debt sustainability index falls in 2008 and has since remained low however the augmented debt sustainability index has recovered. The stable case forecasts suffices sustainability of public debt, which has been borne out in recent years (2011 - 2015). Equally, concerning the flow dimension of the fiscal risk, where the discounted debt sustainability index flags up concern in early 2000s for both France and Germany, the augmented discounted debt sustainability index does not flag up such concerns during the same years—implying the stable case prevails during these years.

Table 2.5: Evaluation of the Five-Step-Ahead Point Forecasts

RMSFE for Five-Step-Ahead Public Debt Forecasts						
	RW	VAR	VARX	GVAR	VARXc	GVARc
Bel	*19.841*	0.768*	1.100	1.221	**0.558***	0.927
Can	*17.500*	0.949*	0.875*	0.927*	**0.689***	0.830*
Den	*38.559*	1.038	1.445	1.468	1.211	**0.634***
Fra	*12.370*	1.040	1.127	1.118	**0.882***	1.453
Ger	*6.239*	1.048	**0.781***	1.056	0.975	1.663
Ire	*25.061*	0.922*	1.259	1.057	1.231	**0.780***
Ita	***27.268***	1.113	1.101	1.068	1.026	**0.989**
Net	*13.245*	1.002	0.960*	1.001	**0.822***	0.997
UK	*17.596*	0.995*	1.000	**0.957***	1.019	1.080
US	***9.832***	1.004	1.231	1.156	1.418	1.659
RMSFE for Five-Step-Ahead Interest Rates Forecasts						
	RW	VAR	VARX	GVAR	VARXc	GVARc
Bel	***0.018***	1.324	1.339	1.513	1.163	1.153
Can	*0.021*	1.208	1.198	1.235	0.747*	**0.717***
Den	*0.023*	1.099	1.047	1.022	1.036	**0.998***
Fra	*0.017*	1.406	1.369	1.477	0.977	**0.724***
Ger	*0.017*	1.266	0.878*	0.737*	**0.684***	1.645
Ire	***0.033***	1.087	1.251	1.492	1.119	1.181
Ita	*0.023*	1.545	1.301	1.664	**0.634***	0.829
Net	*0.021*	1.091	0.949*	1.249	1.032	**0.917***
UK	*0.019*	0.999	1.528	1.242	**0.403***	0.842*
US	***0.013***	1.768	1.772	1.851	1.229	1.440
RMSFE for Five-Step-Ahead Output Growth Forecasts						
	RW	VAR	VARX	GVAR	VARXc	GVARc
Bel	*0.017*	1.033	**0.986***	1.004	**0.986***	1.287
Can	*0.019*	0.987*	0.955*	1.083	**0.926***	1.433
Den	*0.022*	1.002	1.013	1.000	1.013	**0.902***
Fra	*0.018*	0.971*	0.982*	**0.953***	0.979*	1.160
Ger	*0.023*	0.996*	**0.979***	0.991	0.986*	1.173
Ire	*0.049*	0.998*	1.000	1.015	0.996*	**0.922***
Ita	*0.026*	0.955*	0.927*	**0.898***	0.916*	0.890
Net	*0.019*	1.013	1.003	1.067	**0.990***	1.031
UK	***0.020***	1.005	1.016	1.062	1.011	1.051
US	*0.021*	1.020	0.987*	1.062	0.921*	**0.849***

Notes: The first column expresses the RMSFEs of the random walk (benchmark) forecasts (italic). The subsequent columns express the ratio of the models' forecasts relative to the benchmark's forecasts. The * denotes that the RMSE is significantly lower than that from the benchmark at 10% level of significance according to Giacomini and White (2006) test of equal forecast performance. The model with the lowest RMSFE and statistically significant better than the benchmark is highlighted in bold.

Table 2.6: Evaluation of the Five-Step-Ahead Density Forecasts

Average Log Scores for Five-Step-Ahead Debt Ratio Forecasts						
	RW	VAR	VARX	GVAR	VARXc	GVARc
Bel	*-0.988*	0.294*	0.062*	**0.502***	0.099*	0.480*
Can	*-1.252*	0.278*	0.221*	**0.590***	0.271*	0.410*
Den	*-0.810*	0.532*	0.333*	**0.823***	0.369*	0.718*
Fra	*-0.804*	0.238*	0.042*	0.426*	0.112*	**0.493***
Ger	*-0.899*	0.131*	0.088*	0.570*	0.114*	**0.671***
Ire	*-2.121*	0.337*	0.318*	0.542*	0.270*	**0.603***
Ita	*-1.437*	-0.196	-0.083	**0.420***	0.018	0.310*
Net	*-1.447*	0.297*	0.226*	**0.495***	0.106*	0.375*
UK	*-1.758*	0.006	-0.072	0.232	-0.048	**0.035***
US	*-1.186*	0.202*	-0.052	**0.645***	-0.178	0.388*
Average Log Scores for Five-Step-Ahead Interest Rates Forecasts						
	RW	VAR	VARX	GVAR	VARXc	GVARc
Bel	*-0.914*	0.022*	-0.163	**0.068***	0.013*	0.045*
Can	*-0.939*	-0.025	0.048*	0.089*	0.103*	**0.147***
Den	*-0.879*	-0.071	**0.029***	0.004*	-0.120	0.008*
Fra	*-0.860*	-0.015	-0.091	-0.015	-0.071	**0.045***
Ger	*-0.839*	-0.076	-0.017	0.044*	-0.013	**0.049***
Ire	*-0.911*	-0.010	-0.167	**0.006***	-0.152	-0.037
Ita	*-0.833*	-0.097	-0.128	**0.027***	0.019*	-0.008
Net	*-0.876*	-0.117	-0.077	-0.002	-0.162	**0.045***
UK	***-0.757***	-0.095	-0.133	-0.073	-0.081	-0.099
US	***-0.768***	-0.196	-0.145	-0.086	-0.150	-0.088
Average Log Scores for Five-Step-Ahead Output Growth Forecasts						
	RW	VAR	VARX	GVAR	VARXc	GVARc
Bel	*-0.995*	-0.006	-0.047	0.149*	-0.048	**0.174***
Can	*-0.878*	0.005*	-0.088	**0.052***	-0.063	0.041*
Den	*-1.095*	0.018*	-0.013	0.222*	-0.024	**0.240***
Fra	*-1.105*	0.022*	-0.114	0.232*	-0.143	**0.246***
Ger	*-1.147*	0.052*	-0.045	0.256*	-0.042	**0.263***
Ire	*-1.542*	0.057*	0.084*	0.192*	0.085*	**0.239***
Ita	*-1.134*	0.047*	-0.005	0.246*	-0.022	**0.247***
Net	*-1.066*	0.030*	-0.140	0.198*	-0.130	**0.220***
UK	*-1.057*	-0.010	0.017*	0.173*	0.048*	**0.182***
US	*-1.080*	0.095*	-0.157	0.219*	-0.088	**0.224***

Notes: The * denotes that the log predictive score is significantly larger than that from the random walk model, working at the 10% level of significance, and applying Giacomini and White (2006) test of equal forecast performance.

Table 2.7: The Debt Sustainability Index — Event Forecasts Evaluation, 1990-2005

	p	Accuracy Rates						Kuipers Score					
		RW	VAR	VARX	GVAR	VARXc	GVARc	RW	VAR	VARX	GVAR	VARXc	GVARc
Bel	88%	0.38	0.69	0.56	0.50	0.81	**0.88**	0.29	0.64	0.50	0.43	0.36	0.00
Can	75%	0.69	0.69	**0.75**	**0.75**	0.69	**0.75**	0.58	0.58	0.67	0.67	-0.08	0.00
Den	81%	0.38	0.69	0.63	**0.75**	0.63	**0.75**	0.23	0.62	0.54	0.69	0.54	0.44
Fra	50%	0.81	0.69	0.63	0.69	**0.88**	0.81	0.63	0.38	0.25	0.38	0.75	0.63
Ger	100%	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	NA	NA	NA	NA	NA	NA
Ire	100%	**1.00**	**1.00**	0.94	**1.00**	0.94	**1.00**	NA	NA	NA	NA	NA	NA
Ita	63%	0.38	0.50	**0.56**	**0.56**	0.50	0.44	0.00	0.20	0.30	0.30	0.20	0.03
Net	94%	0.69	0.75	0.75	0.75	**1.00**	0.94	-0.27	0.73	0.73	0.73	1.00	0.00
UK	100%	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	NA	NA	NA	NA	NA	NA
US	63%	0.50	0.63	0.63	**0.69**	0.31	0.63	0.13	0.40	0.33	0.50	-0.43	0.00
	p	PT Static						PT Dynamic					
		RW	VAR	VARX	GVAR	VARXc	GVARc	RW	VAR	VARX	GVAR	VARXc	GVARc
Bel		0.390	1.607	0.938	0.714	0.165	0.000	0.000	0.000	0.000	0.000	0.657	NA
Can		3.281*	3.281*	4.286**	4.286**	0.268	0.000	0.000	0.000	0.000	0.000	15.000**	NA
Den		0.577	2.637	2.019	3.462*	2.019	0.642	0.000	0.000	0.000	0.000	0.000	1.014
Fra		6.234**	2.637	0.603	1.759	8.750**	6.563**	0.000	0.000	0.092	0.692	0.000	0.000
Ger		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ire		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ita		NA	1.154	1.875	1.875	1.154	0.000	NA	2.098	0.542	0.542	2.098	0.477
Net		0.000	0.000	0.000	0.000	NA	15.000**	0.000	0.000	0.000	0.000	NA	NA
UK		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
US		1.875	2.727*	1.250	3.750*	2.143	0.000	2.581	0.161	0.005	0.625	2.662	NA

Notes: p is the unconditional probability of the event. 'NA' indicates the relevant statistics are not computable.
The 5 % and 10 % critical values for the PT tests are 3.841 and 2.706. '**' indicates significance at 5% level; '*' indicates significance at 10% level.

Table 2.8: The Augmented Debt Sustainability Index — Event Forecasts Evaluation, 1990-2005

	p	Accuracy Rates						Kuipers Score					
		RW	VAR	VARX	GVAR	VARXc	GVARc	RW	VAR	VARX	GVAR	VARXc	GVARc
Bel	88%	0.63	0.75	0.56	0.75	0.81	**0.88**	0.57	**0.71**	0.50	0.71	0.36	0.00
Can	75%	0.63	0.81	0.81	**0.88**	0.69	0.75	0.17	0.75	0.75	**0.83**	-0.08	0.00
Den	81%	0.69	**0.81**	**0.81**	**0.81**	0.63	0.75	0.62	**0.77**	**0.77**	**0.77**	0.54	0.44
Fra	63%	0.56	0.25	0.38	0.56	**0.63**	**0.63**	**0.10**	-0.60	-0.27	0.03	0.00	0.00
Ger	100%	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	NA	NA	NA	NA	NA	NA
Ire	100%	**1.00**	**1.00**	0.94	**1.00**	0.94	**1.00**	NA	NA	NA	NA	NA	NA
Ita	63%	0.63	0.44	0.50	**0.63**	0.44	0.56	0.27	-0.03	0.07	**0.27**	-0.03	0.17
Net	94%	0.88	0.75	0.94	0.81	**1.00**	0.94	-0.07	0.73	0.93	0.80	**1.00**	0.00
UK	100%	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	NA	NA	NA	NA	NA	NA
US	69%	0.69	0.63	0.63	**0.69**	0.44	**0.69**	0.00	-0.09	0.02	**0.11**	-0.25	0.00
	p	PT Static						PT Dynamic					
		RW	VAR	VARX	GVAR	VARXc	GVARc	RW	VAR	VARX	GVAR	VARXc	GVARc
Bel		1.224	2.143	0.938	2.143	0.165	0.000	0.000	0.000	0.000	0.000	0.657	NA
Can		1.111	5.625**	5.625**	7.500**	0.268	0.000	0.137	0.000	0.000	5.260**	15.000**	NA
Den		2.637	4.615**	4.615**	4.615**	2.019	0.642	0.000	0.000	0.000	0.000	0.000	1.014
Fra		0.045	6.667**	1.607	NA	0.000	0.000	0.721	6.903**	2.863*	NA	NA	NA
Ger		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ire		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ita		0.536	0.150	0.000	0.536	0.150	0.134	0.002	0.420	0.273	0.432	0.420	0.322
Net		NA	0.000	0.000	0.000	NA	15.000	NA	0.000	0.000	0.000	NA	NA
UK		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
US		0.000	0.390	0.085	0.642	0.511	0.000	NA	0.101	0.013	0.001	1.949	NA

Notes: p is the unconditional probability of the event. 'NA' indicates the relevant statistics are not computable.
The 5 % and 10 % critical values for the PT tests are 3.841 and 2.706. '**' indicates significance at 5% level; '*' indicates significance at 10% level.

Table 2.9: The Discounted Debt Sustainability Index — Event Forecasts Evaluation, 1990-2005

	p	Accuracy Rate						Kuipers Score					
		RW	VAR	VARX	GVAR	VARXc	GVARc	RW	VAR	VARX	GVAR	VARXc	GVARc
Bel	94%	0.38	0.88	0.63	0.56	**0.94**	**0.94**	0.33	0.87	0.60	0.53	**0.93**	0.00
Can	94%	0.50	0.69	0.69	0.69	**0.94**	**0.94**	0.47	**0.67**	**0.67**	**0.67**	0.00	0.00
Den	94%	0.06	0.19	0.13	0.38	0.44	**0.88**	-0.93	0.13	-0.87	-0.60	0.40	**0.87**
Fra	19%	0.63	**0.75**	0.56	0.56	0.69	0.56	-0.23	-0.08	-0.31	-0.05	**0.62**	0.46
Ger	13%	**0.88**	**0.88**	0.81	0.75	0.75	0.44	**0.00**	**0.00**	-0.07	-0.14	-0.14	-0.07
Ire	81%	0.69	**0.81**	0.75	0.75	0.69	0.75	**0.62**	0.51	0.44	0.44	0.36	0.18
Ita	94%	0.13	**0.19**	0.06	**0.19**	0.06	0.06	**0.07**	-0.80	-0.93	-0.80	-0.93	-0.93
Net	81%	0.75	**0.81**	0.75	0.75	**0.81**	**0.81**	0.69	**0.77**	0.69	0.69	0.00	0.00
UK	38%	**0.38**	**0.38**	**0.38**	**0.38**	**0.38**	**0.38**	0.00	0.00	0.00	0.00	0.00	0.00
US	38%	**0.69**	**0.69**	0.56	**0.69**	0.50	0.63	0.17	**0.30**	0.03	**0.30**	-0.07	0.40
	p	PT Static						PT Dynamic					
		RW	VAR	VARX	GVAR	VARXc	GVARc	RW	VAR	VARX	GVAR	VARXc	GVARc
Bel	94%	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Can	94%	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Den	94%	0.000	0.000	0.000	0.000	0.000	0.000	6.392**	0.000	0.000	0.000	0.000	0.000
Fra	19%	NA	0.000	0.938	0.000	4.286**	1.875	NA	0.000	0.081	0.505	1.911	0.306
Ger	13%	NA	NA	0.077	NA	NA	0.714	NA	NA	0.000	NA	NA	0.508
Ire	81%	3.281*	3.068*	1.875	1.875	1.111	1.298	0.000	2.845*	2.069	0.000	1.500	0.202
Ita	94%	0.077	4.286**	6.964**	2.946*	6.964**	6.964**	0.104	4.342**	0.000	3.511*	0.000	0.000
Net	81%	4.286**	5.625**	4.286**	4.286**	0.000	0.000	0.542	1.103	0.542	0.542	NA	NA
UK	38%	0.000	0.000	0.000	0.000	0.000	0.000	NA	NA	NA	NA	NA	NA
US	38%	1.607	1.250	0.000	1.250	NA	3.636*	0.444	0.324	0.004	0.324	NA	0.500

Notes: p is the unconditional probability of the event. 'NA' indicates the relevant statistics are not computable.
The 5 % and 10 % critical values for the PT tests are 3.841 and 2.706. '**' indicates significance at 5% level; '*' indicates significance at 10% level.

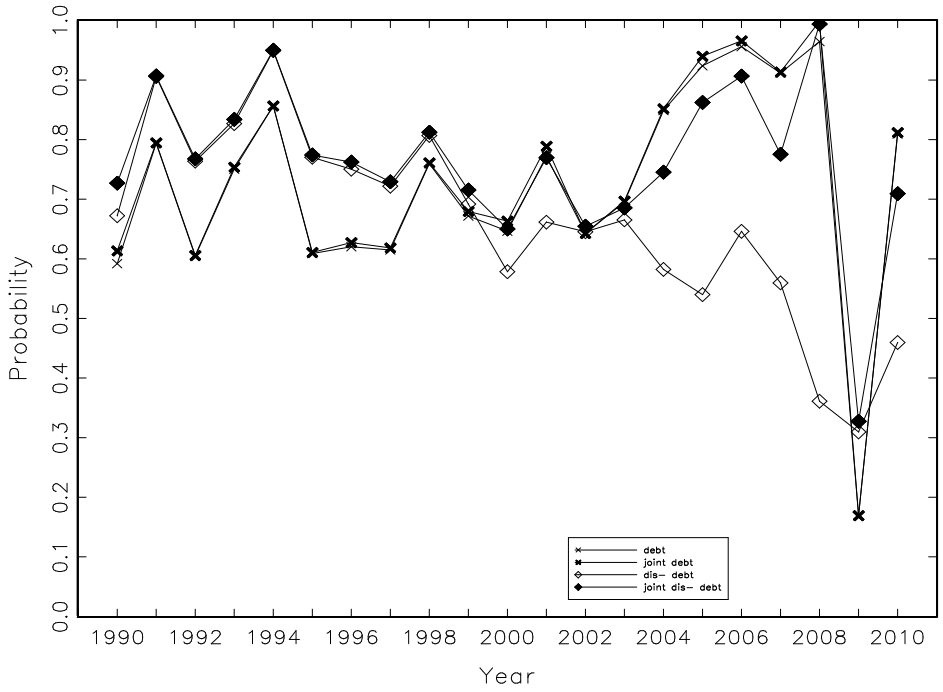
Table 2.10: The Augmented Discounted Debt Sustainability Index — Event Forecasts Evaluation, 1990-2005

	p	Accuracy Rates						Kuipers Score					
		RW	VAR	VARX	GVAR	VARXc	GVARc	RW	VAR	VARX	GVAR	VARXc	GVARc
Bel	94%	**0.94**	0.88	0.69	0.88	0.88	**0.94**	**0.00**	-0.07	-0.27	-0.07	-0.07	**0.00**
Can	94%	**0.94**	0.88	0.88	**0.94**	**0.94**	**0.94**	**0.00**	-0.07	-0.07	**0.00**	**0.00**	**0.00**
Den	94%	0.69	0.63	0.75	0.69	0.56	**0.88**	-0.27	0.60	-0.20	-0.27	0.53	**0.87**
Fra	31%	0.25	0.31	**0.38**	**0.38**	**0.38**	0.31	-0.31	-0.33	-0.24	**0.09**	**0.09**	0.00
Ger	19%	0.25	**0.81**	0.38	0.25	0.38	0.19	-0.18	**0.51**	-0.03	-0.18	-0.28	0.00
Ire	88%	**0.88**	**0.88**	0.81	**0.88**	0.81	**0.88**	**0.00**	**0.00**	-0.07	**0.00**	-0.07	**0.00**
Ita	94%	**0.94**	**0.94**	0.63	**0.94**	0.31	**0.94**	**0.00**	**0.00**	-0.33	**0.00**	-0.67	**0.00**
Net	100%	**1.00**	0.94	**1.00**	**1.00**	**1.00**	**1.00**	NA	NA	NA	NA	NA	NA
UK	38%	**0.38**	**0.38**	**0.38**	**0.38**	**0.38**	**0.38**	0.00	0.00	0.00	0.00	0.00	0.00
US	69%	0.69	0.69	**0.75**	0.69	**0.75**	0.69	0.00	0.00	**0.20**	0.00	**0.20**	0.00
	p	PT Static						PT Dynamic					
		RW	VAR	VARX	GVAR	VARXc	GVARc	RW	VAR	VARX	GVAR	VARXc	GVARc
Bel	94%	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Can	94%	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Den	94%	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fra	31%	1.875	1.250	0.536	0.536	0.536	0.000	1.939	2.790*	1.217	0.302	0.302	NA
Ger	19%	1.298	1.298	0.288	1.298	0.096	0.000	0.528	1.765	1.258	2.068	0.522	NA
Ire	88%	0.000	0.000	NA	0.000	NA	0.000	NA	NA	NA	NA	NA	NA
Ita	94%	0.000	0.000	0.390	0.000	1.607	0.000	NA	NA	0.302	NA	0.532	NA
Net	100%	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
UK	38%	0.000	0.000	0.000	0.000	0.000	0.000	NA	NA	NA	NA	NA	NA
US	69%	0.000	0.000	2.946*	0.000	2.946*	0.000	NA	NA	1.587	NA	1.587	NA

Notes: p is the unconditional probability of the event. 'NA' indicates the relevant statistics are not computable.
The 5 % and 10 % critical values for the PT tests are 3.841 and 2.706. '**' indicates significance at 5% level; '*' indicates significance at 10% level.

Figure 2.2: Sustainability Indexes

(a) Belgium



(b) Canada

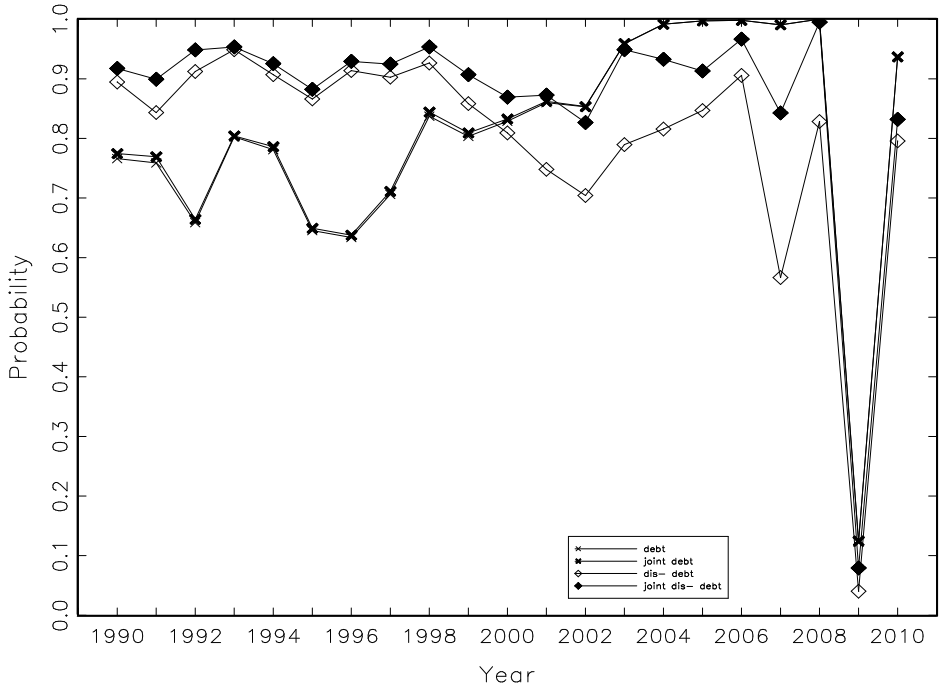
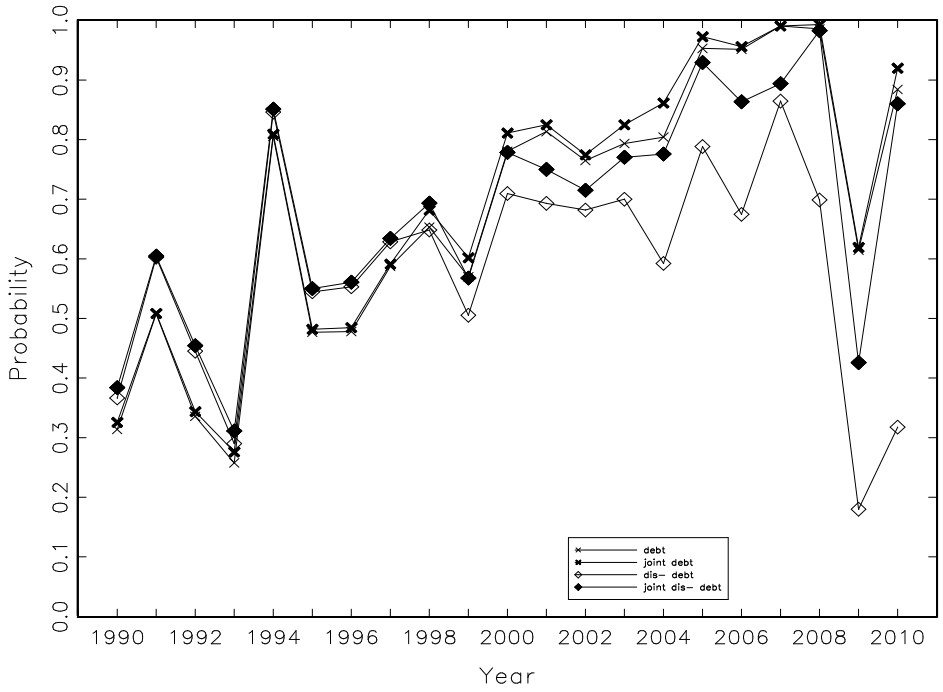


Figure 2.2: Continued

(c) Denmark



(d) France

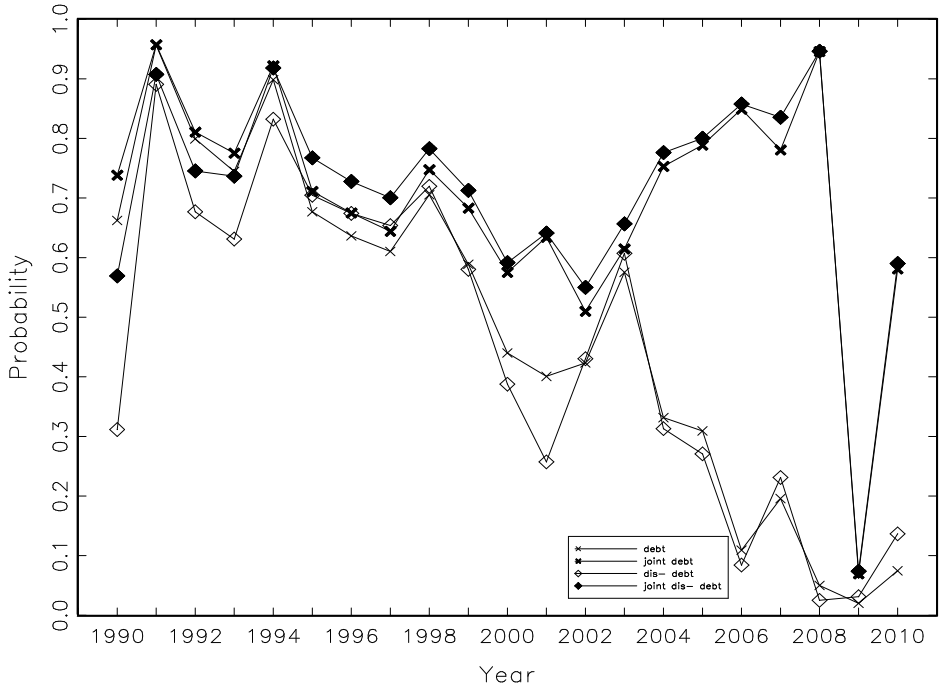
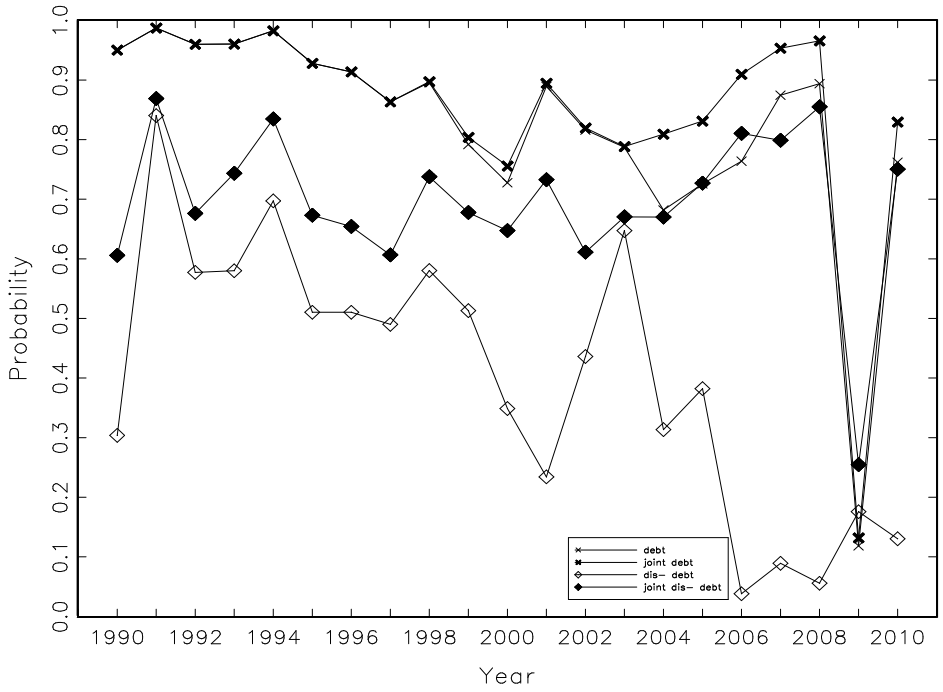


Figure 2.2: Continued

(e) Germany



(f) Ireland

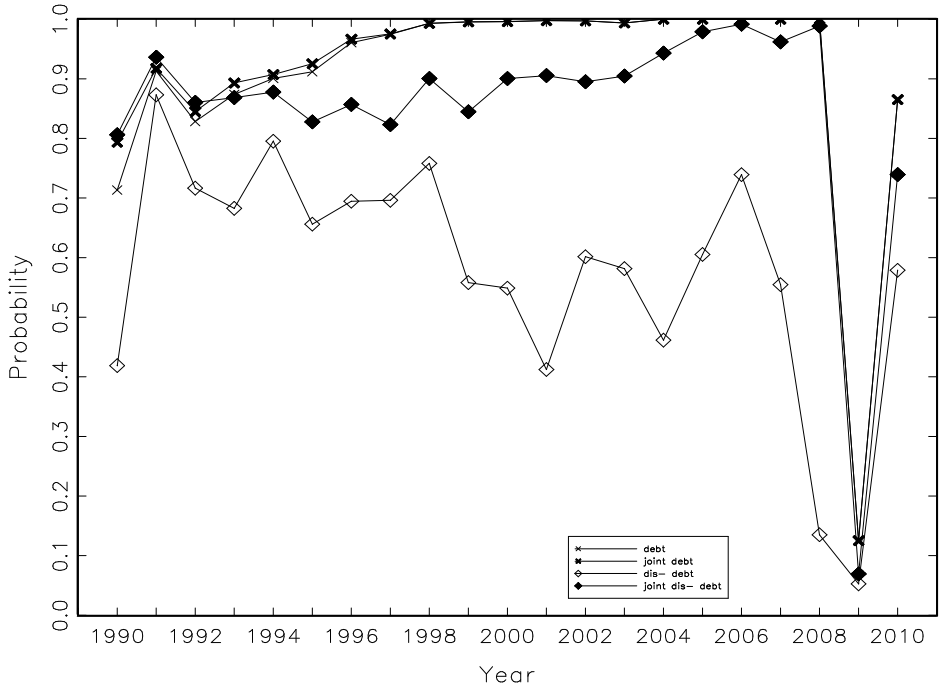
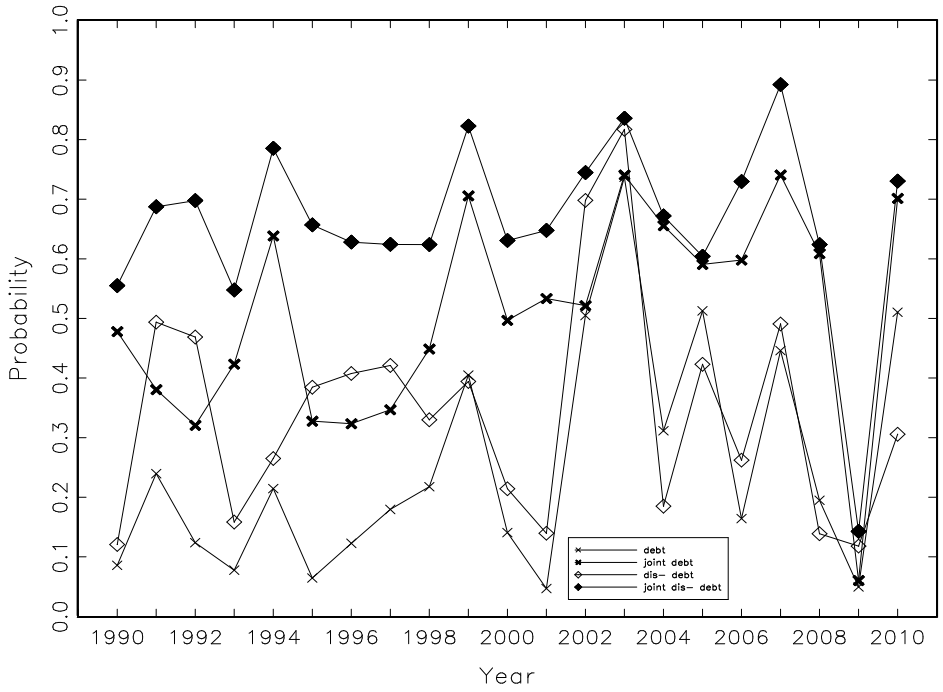


Figure 2.2: Continued

(g) Italy



(h) Netherlands

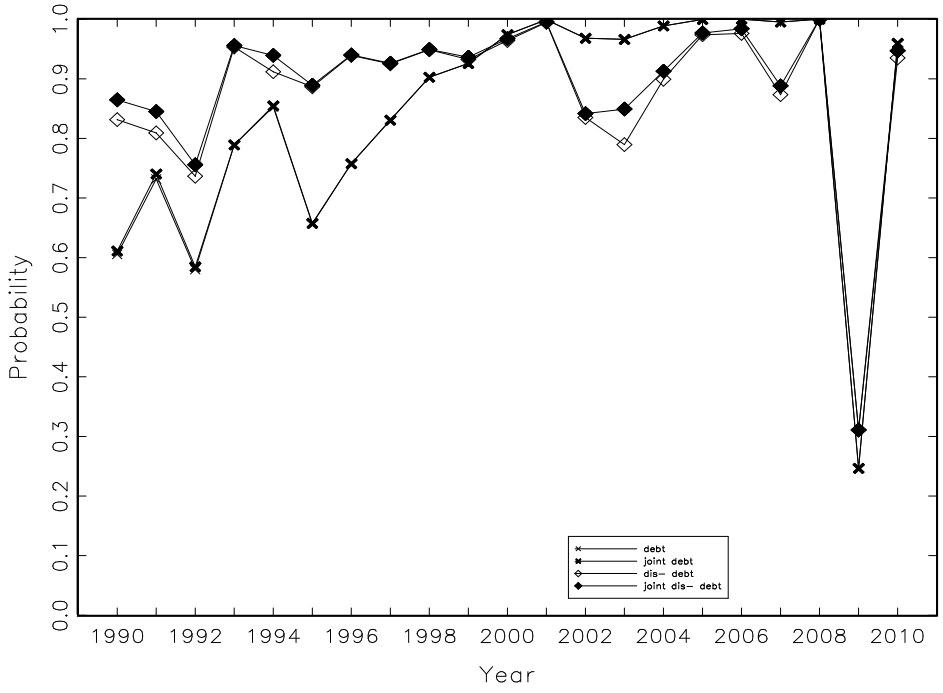
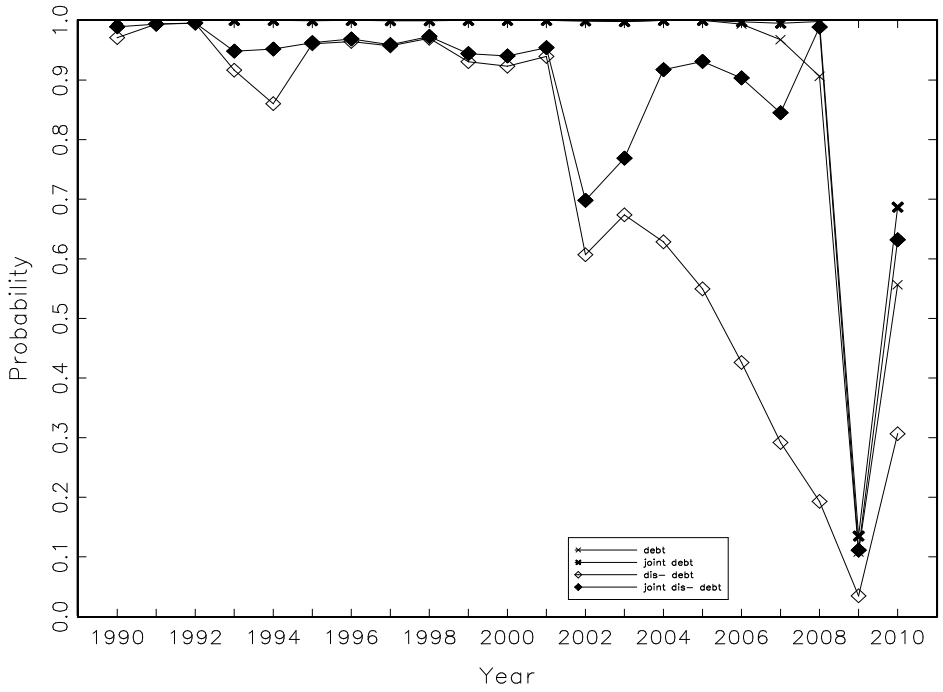
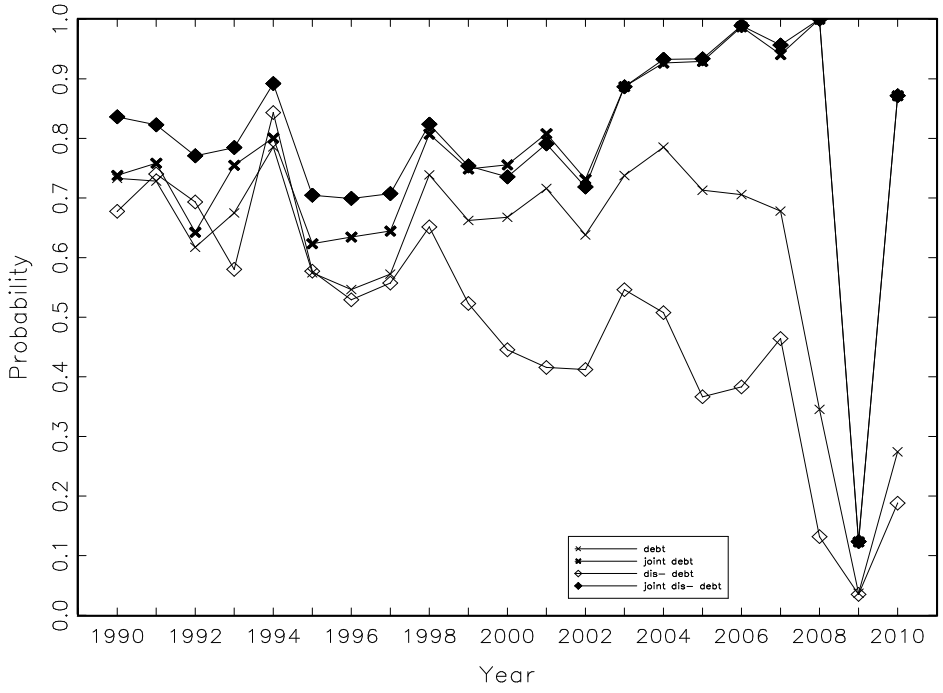


Figure 2.2: Continued

(i) UK



(j) US



2.7 Conclusion

We model cross-country interdependencies amongst debt ratios, real interest rates and output growths both in the long-run—via the long-run structural approach—and in the short-run. In the forecast evaluation exercise, this has shown to improve forecasting performances of the model—a model of sustainability of an economy—which underlie our sustainability indexes; this falls within the model-based fiscal indicator literature.

Our sustainability indexes with five year forecast horizon are probabilities of sustainability both in the stock dimension (debt sustainability index) and the flow dimension (discounted debt sustainability index). The approach, event probability forecasting has the advantage of accommodating multi-faceted definitions of sustainability, specifically, future movements of real interest rates and output growths—the stable case—we define the union of the stable case and the event underlying the debt and discounted debt sustainability indexes respectively.

Traditionally, fiscal sustainability is defined in terms of either stock or flow balances ignoring the developments of the real interest rate and output growth (Wyplosz, 2007). The augmented and non-augmented sustainability indexes highlight the differences between the two, as the probability is higher in the former than latter, therefore the importance of incorporating this definition of sustainability.

Our sustainability indexes are related to the literature in two substantive ways—first, like Polito and Wickens (2012), our measure of sustainability is a model-based fiscal indicator—we use a different model to capture cross-country interactions and long-run feature of the fiscal variables and we include the information on uncertainty surrounding the forecasts underlying the indicator via density forecasting; second, our measure is comparable with the literature by defining the events from the literature. We show the advantage of event probability forecasting in accommodat-

ing different sustainability events, and our results indicate including this multi-dimensional aspect is relevant in assessing sustainability.

As the model forecasts underpin the sustainability indexes, a future research direction would be to robustify the model forecasts via forecast combination, via either density forecast combination (see Hall and Mitchell (2007)) or Bayesian model averaging (see Raftery, Madigan, and Hoeting (1997) and Pesaran, Schuermann, and Smith (2009)). In addition, as the findings of the ADF and CADF tests at times conflict with one another, a further direction to robustify the findings of the unit root tests would be to consider the union of rejection testing strategies recommended in Harvey, Leybourne, and Taylor (2012). Furthermore, in illustrating the sustainability measures, we use a GVAR model and implement it in ten OECD countries. Two research avenues—the cross-country dimension[25] and relatedly, the choice of countries included in the analysis[26]—are worth exploring, their importance to the sustainability measures.

[25]To explore how allowing for cross-country linkages affects my results, we can compare the sustainability measures based on the VAR model (without cross-country interactions) against the GVAR model.

[26]To explore how the choice of countries affects the analysis, we can check the robustness of the results by either excluding certain countries in the illustration or alternating the weights used to construct the foreign variables.

Chapter 3

The Sources and Persistent Effects of Shocks to the Net Foreign Assets in the EU Countries

3.1 Introduction

The presence of current account imbalances has led to a considerable divergence in the economies of the EU (Lane, 2013a). Differences in wealth and liabilities—often termed the country's net foreign assets highlight competitiveness problems and, in economies with current account deficits and high external debt, accumulated liabilities raise the possibility of sudden stop in capital flows and the risk of macroeconomic crisis (Blanchard & Milesi-Ferretti, 2011). The flow imbalances amongst the EU economies peaked prior to the global financial crisis of 2008 and have narrowed since (Lane & Milesi-Ferretti, 2014). But considerable stock imbalances still remain, as noted by IMF's World Economic Outlook (IMF, 2014) and it is important to understand the causes of the imbalances and the extent to which they

are sustainable.

This chapter characterizes the drivers of the net foreign assets of the EU economies historically and investigates the drivers of these positions. Using measures developed by Lee et al. (1992), Pesaran, Pierse, and Lee (1993) and Lee and Pesaran (1993), the chapter first characterizes the persistent effects of shocks to a country's net foreign assets relative to GDP in a multi-country VAR model. We find, financial globalization in Europe is an important driver behind these economies' net foreign assets.

The net foreign assets of an economy is the net balance of countries' international balance sheet. The official terminology of a country's net foreign assets is the "Net International Investment Position". In the empirical analysis, the variable of interest is not the level of net foreign assets, but the level of net foreign assets scaled relative to GDP. It is a useful measure of a country's external wealth, expressed relative to the size of its economy and allows cross-country comparison. It is also the economic and policy variable of interest concerning the external sustainability of a country which is the primary subject of the next chapter.

The focus of our analysis is the net foreign assets of European economies. This is motivated by the considerable current account imbalances observed within the European economies and the fact that external balances are an important element of the European Commission's macroeconomic surveillance framework as described in the next chapter. Due to data limitations, twelve European countries, denoted as EU12[1] hereafter, are included in the analysis. The modelling framework is a multi-country model that describes the dynamics of net foreign assets in terms of shocks occuring in different countries; gravity factors such as distance and language are found to be the most important determinants of bilateral holdings which make up the net foreign assets (Lane & Milesi-Ferretti, 2008b).

[1]The EU12 countries include the United Kingdom, Austria, Belgium, Denmark, France, Germany, Italy, Netherlands, Sweden, Switzerland, Greece and Spain.

The chapter provides a time-series characterisation of the net foreign assets of the EU economies, particularly in the long-run. While there is no one-to-one correspondence between the presence of a unit root in debt and sustainability as discussed previously, it is nevertheless important to establish the extent to which the effects of shocks to debt persist over time. Having characterised the time-series properties of the net foreign assets, three economic questions are investigated. First, has the acceleration of cross-border financial flows within the EU contributed to the divergence of net foreign assets of the EU countries? Second, has the output performance underlying the European economies affected the long-run evolution of net foreign assets? Third, in light of the expansion of international balance sheets in these EU12 economies (therefore an increasing role of the valuation channel to drive the net foreign assets), how does the dollar (the world reserve currency) affect countries' net foreign assets directly via both the valuation changes and indirectly via the trade balance?

The net foreign assets of the countries of EU12 are empirically established as unit root processes. The persistence measure, quantifying the extent in which shocks persist in the long-run characterize countries' long-run evolution of net foreign assets. The persistent effects of shocks to countries' net foreign assets are considerably different across countries. The shocks to the three external factors—financial trade, aggregate output and the dollar are identified. We decompose the persistence measure by each of the identified shock to investigate the importance of these drivers of net foreign assets in the long-run. We find that each of the macroeconomic shocks matters heterogeneously in different countries. The shocks to the cross-border gross flows in these economies are found to be an important driver across the EU12 countries.

The empirical literature of the net foreign assets is relatively few—Lane and Milesi-Ferretti (2002) is the first comprehensive empirical study of the

determination of net foreign assets in a panel of developed and developing countries between 1970 and 2001. They explore cross-country variation of net foreign assets based on country-specific characteristics. In contrast, this chapter focuses on the long-term evolution of net foreign assets modelling the time series variation of net foreign assets in a multi-country restricted VAR model, allowing reduced form feedbacks between countries that are described in a two-country open economy model.

The layout of the chapter is as follows. Section 3.2 describes the economics of a country's net foreign assets and motivates three external factors that determine the net foreign assets. Section 3.3 discusses the modelling framework and motivates the persistence measures that are calculated. Section 3.4 describes the empirical sample and reports the analysis and the results.

3.2 The Determinants of a Country's Net Foreign Assets

First I will describe the balance of payments accounting as well as the the international balance sheet of a country, also known as the International Investment Position (IIP). Second, I will describe the economics of the flow balances and the stock balances. Finally, using the theories I will motivate the drivers of net foreign assets which are empirically investigated later.

3.2.1 Accounting Identities

External imbalances can be defined as either the flow imbalances or the stock imbalances. In international accounting, the balance of payments records the flow balances and the International Investment Position records the stock balances for a country.

Balance of Payments The balance of payments include the current account, the financial account and the capital account. The current account records real-side economic transactions, that is the flow of goods, services and investment income. The financial account is the counterpart of the current account that records the flow of funds which finances these real-side economic transactions. The capital account records one-off transaction; it is not economically interesting and therefore ignored in the analysis that follows. The balance of payments accounting identity implies a current account deficit, for instance is matched with a financial account surplus.:

$$\text{NETFLOW}_{\text{FA},t} + \text{NETFLOW}_{\text{CA},t} = 0 \tag{3.1}$$

where FA is the financial account and CA is the current account. Implied by the accounting identity, both accounts are balanced by one another, however, either the financial account or the current account could drive one another [2].

Current Account The current account has a special macroeconomic significance in the national accounting. The current account balance is the sum of the trade balance and investment income (or receipt) on its net foreign asset stock:

$$\text{CA} = \text{NX} + \text{r NFA} \tag{3.2}$$

[2]The causality of the financial account and the current account has been a subject of debate in the literature and the policy circle. The phenomenon of capital flowing uphill from developing to developed economies was first picked up by Lucas (1990). In the early 2000s, Bernanke et al. (2007) hypothesizes the savings glut explanation during the global imbalances, as well as the policy observer Wolf (2010), which espouses the view that, the accumulation of foreign assets which is recorded in the financial account drives the current account balance. More recently, Jin (2012) uses a general equilibrium economic model with two-sector trade and open-economy model to show the trade account drives the financial account. According to this paper, trade globalization leads to specialization of poor countries to labour intensive industries and rich countries to capital intensive industries; the disparity of the capital intensity of sectors in developing and developed countries lead to trade imbalances amongst the two groups of economies with different industrial structure.

where NX is trade balance and rB is investment income (or receipt). Substituting the current account and the investment income into the national macroeconomic identity via the trade balance

$$Y = C + I + G + NX$$

where Y is output, C is consumption, I is investment, G is government spending and NX is net exports; we can write

$$Y - C - G + rB - I = CA$$

Defining savings S as $S = Y - C - G + rB$, we have

$$S - I = CA \tag{3.3}$$

The current account balance is equivalent to the net lending and borrowing of an economy. An economy that runs a current account surplus (deficit) is lending (borrowing) to the rest of the world.

Net Foreign Assets The net foreign assets is the stock balance of a country's external position. The foreign assets and foreign liabilities are recorded on a country's international balance sheet (International Investment Position)—the difference between assets and liabilities on the balance sheet yields the Net International Investment Position, or Net External Position, shorthand as the net foreign assets hereafter. The assets and liabilities are owned and owed by the county's households, corporates and government—the net foreign assets is an aggregate measure of a country's indebtedness [3]. A country is either a creditor nation or a debtor

[3]The balance sheet is recorded with a residence principle. That is, the instruments on the balance sheet are recorded on the residence of the assets and liabilities and not on the ultimate nationality of the owners. This is particularly relevant for countries with foreign headquartered financial institutions which have substantial balance sheets. (Obstfeld, 2012) Whilst these external assets and liabilities may belong to foreign nationals, they

nation depending on the net foreign assets balance. Furthermore, the assets and liabilities on the balance sheet can be categorized by different instruments: portfolio equity, portfolio debt, foreign direct investment, international reserves and derivatives. The distinction between the portfolio and non-portfolio denomination is that the portfolio instruments are traded on the market and the non-portfolio instruments are not, borrowings between banks for instance.

There are two sources of change to the net foreign assets—the flow change (current account) and the non-flow change (net valuation changes and stock-flow residual):

$$\Delta \text{NFA}_t = \text{CA}_t + \text{NETVAL}_t + \text{OTH}_t \tag{3.4}$$

where ΔNFA is the change of net foreign assets, NETVAL is the net valuation effects and OTH_t is the stock-flow adjustment term. The foreign assets and liabilities are recorded based on market value, the portfolio instruments traded on market, for instance. The difference between the valuation changes on both the assets and liabilities sides yields the net valuation changes. The two sources of net valuation changes are either the valuation changes induced by market value movements ($\text{NETVAL}^{\text{MV}}$) or the valuation changes induced by exchange rate movements ($\text{NETVAL}^{\text{XR}}$):

$$\text{NETVAL}_t = \text{NETVAL}_t^{\text{MV}} + \text{NETVAL}_t^{\text{XR}} \tag{3.5}$$

The stock-flow adjustment term, OTH_t is the residual term which reconciles the mismatch between the change of net foreign assets, flow change and the net valuation effects. Typically, the residual terms are data revisions which may be due to previous uncovered errors or change in data collection methods [4].

are recorded on the domestic balance sheet, due to the residence of these assets.

[4]Lane and Milesi-Ferretti (2009) and Zucman (2013) are recent works that empha-

Net Foreign Assets-to-GDP Because the variable of interest is net foreign assets measured in terms of GDP, we can obtain the expression:

$$\mathrm{nfa}_t = (\frac{1}{1+\pi_t+\mathrm{g}_t})\mathrm{nfa}_{t-1} + \mathrm{ca}_t + \mathrm{netval}_t + \mathrm{oth}_t \tag{3.6}$$

The lower case denotes the previously defined variables measured relative to GDP, π_t is the inflation rate and g_t is the growth rate of real GDP. The growth rate of nominal GDP, π_t and g_t is the coefficient of difference equation of the dynamics of the net foreign assets-to-GDP. Assuming growth rate of nominal GDP, usually positive implies, the net foreign assets-to-GDP would be less persistent than the net foreign assets (with a less than unity coefficient in the difference equation).

3.2.2 The Dynamics of Current Account Balances and Net Foreign Assets

The dynamics of current account balance is described with the present value approach of the current account, represented with the fundamental current account equation (Sachs, 1982) and described succinctly as:

$$CA_t = [Y(t) - \tilde{Y}(t)] - [I(t) - \tilde{I}(t)] - [G(t) - \tilde{G}(t)] - [C(t) - \tilde{C}(t)] \tag{3.7}$$

where the permanent value, $\tilde{X}_r(t)$ is defined as:

$$\tilde{X}(t) \equiv \frac{r}{1+r}\sum_{s=t}^{\infty}(\frac{1}{1+r})^{s-t}X_s$$

The permanent value of the variable is the annuity value at the prevailing interest rate, i.e. the hypothetical constant level of the variable with the same present value as the variable itself. Therefore it involves the future

sized the importance of such measurement revisions in the dynamics of net foreign assets.

projection of output, investment, government spending and consumption. The permanent value is can be interpreted as the steady-state or long-run value. Expressed in this form, the current account can be thought of as the deviation of each current national income identity from its long-run value.

The balance on the current account is obtained in equation (3.7) when output, investment and government spending all equal their permanent values. The equation yields a number of predictions. For instance, if a supply shock unexpectedly boosts output, the current account balance moves towards greater surplus. Current account serves as efficient allocation of capital as a country could borrow to invest on projects that fetch returns repaying the interest payments in the future, meeting temporarily higher investment needs financed by foreign borrowing.

Conversely, if a consumption shock unexpectedly raises consumption, the current account balance moves towards greater deficit. Current account serves as consumption smoothing as households smooth their consumption as their consumption need is higher relative to the long-run average value. The permanent value of variable can change at time t too. For instance, $\tilde{Y}$ the permanent level of income can increase at time t - for instance, a belief that long-run productivity trend is stronger, or the unexpected discovery of natural resource wealth; the current account would move towards deficit.

The Determination of Net Foreign Assets The dynamics of the net foreign assets is related to the dynamics of the current account balances—the net foreign assets is a stock variable whilst the current account balance is a flow variable. There are two broad approaches to modelling the net foreign assets in the literature: the cyclical view and the trend view. The cyclical view posits the net foreign assets is an accumulation of random shocks; the trend view posits the net foreign assets are driven by demographic factors, the government debt and the economy's stage of development.

Cyclical View The cyclical view is represented by the two-country micro-founded open economy model (Obstfeld and Rogoff (1995), Corsetti and Pesenti (2001) and Betts and Devereux (2000)[5]). In these models, there are home and foreign representative individuals maximising intertemporal utility subject to the budget constraint and trading bonds with one another. Net foreign assets are modelled as a state variable—in each period when a shock occurs, the optimisation problem takes the net foreign assets as given; at the end of the period, if the shock affects net exports, net foreign assets change consequently. To illustrate, in Obstfeld and Rogoff (1996), a money shock originating in the home country depreciates the real effective exchange rate — home goods become relatively cheaper to foreign goods. This leads to higher purchases of foreign goods, an increase in net exports therefore an increase in net foreign assets — this is known as the expenditure switching effect.

Trend View The trend view is represented by Lane and Milesi-Ferretti (2002) where the net foreign assets is driven by demographic factors, the government debt, and the stage of a country's development. Demography explains persistent external imbalances via saving and investment behaviour. Countries with an ageing population accumulate foreign assets to supplement domestic income streams as it prepares for an increase in the ratio of retirees to workers; and curtails investment as the marginal product of capital diminishes with the reduction in the growth of the working-age population and of the labour force. Countries with a growing population reduce savings as households with children attempt to smooth consumption; and increases investment as the society with a high youth dependency ratio may require heavy investment in social infrastructure (education, housing).

The stage of a country's development affects a country's net foreign assets—a growing economy, at a relatively early stage of development could

[5]see Lane (2001) for a survey of the New Open Macroeconomics literature

run current account deficits as households smooth consumption in anticipation of higher output and corporations borrow to fund investments; in contrast, a developed economy, at a relatively later stage of development might run current account surplus as households smooth consumption in anticipation of lower output and corporations invest abroad in search of higher returns.

In both approaches, net foreign assets is a random walk. In the cyclical view, the net foreign assets is a random walk because a shock (money shock, government spending shock or productivity shocks) changes the current account which leads to either improvement or deterioration of net foreign assets; the net foreign assets would stay at the new level as the agent is infinitely-lived—there is no motive to reverse the change in net foreign assets. In the trend view, net foreign assets is a random walk because both the public debt and output per capita are random walks[6] whilst demography is a slow-moving variable.

3.2.3 Drivers of External Imbalances in Europe

In this section, I describe how financial integration, output movements and exchange rate movements could contribute to the divergence of external balances in Europe.

Financial Integration Financial integration in Europe—cross-border asset trade—has seen the most prominent increase in the world since the 1990s (Lane & Milesi-Ferretti, 2008a). The unprecedented increase has been underpinned by political integration within the EU. Cross-border finance flows are intra-temporal trade in nature, as home and foreign countries exchange assets in the same period, thus the term intra-, to insure

[6]Public debt is empirically found to be integrated of order one (Antonini, Lee, & Pires, 2013); output per capita is $I(1)$ because in the Cobb Douglas production function, the technology is the cumulation of productivity shocks (Garratt et al., 2012)

themselves against different 'states of nature'—the economic reason is risk diversification[7].

Financial integration could also facilitate the inter-temporal trade i.e. external imbalances across countries. In an environment where there is greater elasticity of capital flows, i.e. economies are more willing to tolerate flow imbalances, due to greater integration in the EU and the elimination of currency risk amongst the euro member countries, financial integration lowers the interest rates that encourages borrowing and lending across countries. In the dynamics of current account described by the fundamental current account equation, the lowering of interest rate, the convergence of government bond yields for instance, increases the permanent value of output in economies that experience a lower interest rate—then these economies would drive down the current account balance.

Prior to the global financial crisis, Lane (September 2015) describes the financial innovation and cross-border banking in Europe between 2003 and 2007 as "credit supply shock" (see also Shin (2012)). Hale and Obstfeld (2014) analyze international debt flows within EU that financed and potentially amplified the accumulation of these imbalances.

Output Movements The integration of EU economies through either trade or finance has facilitated the convergence of economic output amongst the EU economies—capitals flow to countries with higher economic growth and higher rates of returns. Blanchard and Giavazzi (2002) reason the current account imbalances are driven by the convergence mechanism between the EU core economies and the EU peripheral economies. The current account deficits countries were smoothing their consumption and borrowing to meet temporarily higher investment needs in anticipation of higher

[7]In a two-country open economy model, Home and Foreign countries exchange assets maintain their relative wealth with one another. The crucial ingredient of this risk diversification channel is the complete market assumption. This complete market assumption has been relaxed to explain the net imbalances across economies alongside the expansion in gross flows, see (Corsetti, Dedola, & Leduc, 2008) for instance.

permanent value of output. Lane and Pels (2012) investigates empirically the role of growth and expected growth in the determination of current account.

A positive productivity shock, assuming other components unchanged would raise the long-run productivity trend, $\tilde{Y}(t)$ that nudges an economy to run current account deficits. In the case of a permanent loss in output, $\tilde{Y}(t)$ goes up, the economy's current account balance would move towards surplus when the long-run value of output is permanently lower.

The Dollar Based on the accounting identities, the exchange rate movement can affect net foreign assets via two channels—first, directly via the net valuation changes (3.4); second, indirectly via the current account balance (3.2). Countries' international balance sheets have expanded as a consequence of financial integration; with the expanded size of international balance sheet, there is an increasing role of valuation channel to drive the net foreign assets[8]. Net valuation changes induced by exchange rate movement (3.5) matter to the extent there is a currency mismatch between foreign assets and foreign liabilities.

The trade balance and valuation effects induced by exchange rate movement could cancel out one another on its impact on countries' net foreign assets. Lane and Shambaugh (2010) compile currency exposures for a large number of countries between 1994 and 2004; they also compare trade-weighted effective exchange rate with net financial-weighted effective exchange rate that measures the impact of currency movements on that country's international balance sheet. They found tremendous heterogeneity between these two indexes. If the correlation between financial-weighted effective exchange rate and trade-weighted exchange rate is perfectly nega-

[8]In the decomposition of the dynamics of net foreign assets between 1996 and 2004, the valuation effects explain up to a third of variation in the dynamics of the net foreign assets (Lane & Milesi-Ferretti, 2007b); it is therefore an important feature of the net foreign assets data.

tive, it implies that, whilst the bilateral exchange rate movements are beneficial in direction to the country's current account (weighted by trade), the effect of the same bilateral exchange rate movement is detrimental to the country's net foreign assets.

The dollar are used to investigate the role of exchange rate movements in driving the net foreign assets. The dollar is the world reserve currency and the US is a major trading partner of European economies. The valuation effects induced by the movements in the dollar are the changes in the values of dollar-denominated financial assets and liabilities on countries' balance sheet. In Europe, Lane and Milesi-Ferretti (2007a) calculates the exposure of European economies to the dollar via the valuation channel and distinguishes three groups of countries: Austria, Finland, Greece, Italy and Portugal (low level); Belgium, France and Germany (moderate level); and the financial centres of Ireland, Luxembourg and the Netherlands (high level).

3.3 Characterising the Dynamics of A Unit Root Process

In this section, I describe the modelling framework, the persistence measure defined in Lee et al. (1992) and their approach to identifying the persistent effects of particular types of shock. The persistence measure shows the cumulated effects of shocks to a nonstationary process and it is useful to describe the model first with unspecified shocks and then in the presence of some explicitly-identified shocks.

Measuring the Persistent Effects of Shocks The modelling framework is a multi-country VAR. The vector of variables entering the VAR are countries' net foreign assets; assuming net foreign assets is a unit root

($I(1)$) variable, therefore the first difference of the net foreign assets is the dependent variable entering the VAR. Denoted as model M_0, the multi-country model is an unrestricted VAR of countries' net foreign assets:

$$\mathbf{\Delta y_t} = \mathbf{\Phi_0} + \sum_{\mathbf{k=1}}^{\mathbf{p}} \mathbf{\Phi_k \Delta y_{t-k}} + \varepsilon_{\mathbf{t}} \tag{3.8}$$

where $\mathbf{\Delta y_t}$ is $(\Delta \text{nfa}_{1,t}, \Delta \text{nfa}_{2,t}, \ldots, \Delta \text{nfa}_{m,t})'$, m is number of countries, $\mathbf{\Phi_0}$ is $m \times 1$ vector of intercepts, $\mathbf{\Phi_k}$ is $(m \times m)$ matrices of parameters, p is the number of lagged dependent variables and $\varepsilon_{\mathbf{t}}$ is $(\varepsilon_{1,t}, \varepsilon_{2,t}, \ldots, \varepsilon_{m,t})'$ with zero expectation and covariance Ω.

This multi-country VAR allows for a wide range of feedbacks between countries' net foreign assets. The feedbacks between countries' net foreign assets are described in the cyclical view of the net foreign assets' determination. Seen in the Wold representatation, the multi-country model could be interpreted as describing the dynamics of net foreign assets in terms of shocks to net foreign assets in many countries. Benchmarked against a univariate model, this enriches the description of dynamics of net foreign assets in the country dimension.

Inverting the VAR coefficients, we obtain

$$\mathbf{\Delta y_t} = \mathbf{\Psi_0} + \mathbf{C(L)}\varepsilon_{\mathbf{t}} \tag{3.9}$$

where $\mathbf{C(L)}$ is a matrix polynomial in the form of lag operator:

$$\mathbf{C(L)} = \sum_{\mathbf{i=0}}^{\infty} \mathbf{C_i L^i}$$

C_is are the impulse response coefficients associated with each point in history, which are themselves a function of Φ_k. The Wold representation in 3.9 describes the countries' net foreign assets as the sum of historical shocks of all the countries included in the VAR.

Lee et al. (1992)'s persistence measure is based on the spectral density of $\mathbf{\Delta y_t}$ scaled by its conditional variance:

$$\mathbf{P^2} = \frac{\mathbf{C(1)\Omega C(1)}'}{\mathbf{C(0)\Omega C(0)}'} \tag{3.10}$$

The persistence measure provides a variance-based measure of the permanent effect of a shock to the level of $\mathbf{y_t}$. The measure is based on the variance of the infinite horizon forecasts of the variables and involves the sum of impulse response coefficients, $\mathbf{C(1)}$ and contemporaneous correlation amongst shocks to countries' net foreign assets via $\mathbf{\Omega}$. For an $I(1)$ variable, the variance of the h-period ahead forecast grows at a constant rate while for an $I(0)$ variable it settles at a constant value. The growth of the variance is zero for a stationary series therefore and non-zero for $I(1)$ series, with the value taking larger values the more persistent are the effects of a shock of a given size. The persistence measure defined in Equation 3.10 has m dimension that corresponds with the number of countries entering the multi-country VAR. Corresponding with each country i, a country-specific persistence measure can be obtained with a selector matrix, $\mathbf{e_i}$, that is a vector of zeros except one on the i^{th} row:

$$P_{ii}^2 = \frac{\mathbf{e_i}'\mathbf{C(1)\Omega C(1)}'\mathbf{e_i}}{\mathbf{e_i}'\mathbf{C(0)\Omega C(0)}'\mathbf{e_i}} \tag{3.11}$$

The persistence measure defined above is the cumulated effects of shocks to the stationary process $\Delta niip_{i,t}$ scaled by the instantaneous effects of the shocks. The persistence measure can be interpreted as the permanent effects of a shock on the level, scaled by the instantaneous effects, to give the interpretation of "the percentage effect on $niip_{i,t}$ at the infinite horizon where $niip_{i,t}$ rises by 1% on impact".

Measuring the Persistent Effects of Identified Shocks The persistence measure can be extended to consider explicitly-identified sources of shocks to countries' external wealth.

Suppose $\mathbf{x_t}$ is a vector of external factors that will impact on net foreign assets in all countries. Assume that the innovations in these external aggregates are given by:

$$\mathbf{v_t} = \mathbf{x_t} - \sum_{\mathbf{i=1}}^{\mathbf{p}} \mathbf{\Gamma_i x_{t-i}} \tag{3.12}$$

with mean zero and variance $\mathbf{\Psi}$ where $\mathbf{\Gamma_i}$ is the matrix of VAR coefficients and p is the lag of the VAR. The external factors are assumed to be exogenous to the multi-country model, i.e. the modelling assumption is that there is no feedback from the multi-country model to the external factors. Then we can generalize equation (3.9) to write:

$$\mathbf{\Delta y_t} = \mu + \mathbf{D(L)}\nu_\mathbf{t} + \mathbf{C(L)}\varepsilon_\mathbf{t} \tag{3.13}$$

where $\mathbf{D(L)}$ is the matrix of lag polynomials describing the effects of the identified external shocks and the $\varepsilon_\mathbf{t}$ are now interpreted as 'unidentified' innovations to external wealth assumed to be uncorrelated with the $\mathbf{v_t}$.

The persistence measure of both the identified and unidentified shocks are:

$$P^2_{ii} = \frac{\mathbf{e_i'D(1)\Psi D(1)'e_i} + \mathbf{e_i'C(1)\Omega C(1)'e_i}}{\mathbf{e_i'D(0)\Psi D(0)'e_i} + \mathbf{e_i'C(0)\Omega C(0)'e_i}}$$

The $\mathbf{e_i}$ is a country selector matrix that picks out the corresponding country i persistence measure. Defined on the vector of either the identified shocks or the unidentified shocks, the persistence measure of the identified shocks, $P^2_{m,i}$ is:

$$P^2_{m,ii} = \frac{\mathbf{e_i'D(1)\Psi D(1)'e_i}}{\mathbf{e_i'D(0)\Psi D(0)'e_i}} \tag{3.14}$$

and the persistence of the unidentified shocks, $P^2_{o,i}$ is:

$$P^2_{o,ii} = \frac{\mathbf{e_i'C(1)\Omega C(1)'e_i}}{\mathbf{e_i'C(0)\Omega C(0)'e_i}} \tag{3.15}$$

Decomposing the Persistence of Identified Shocks The persistence measure of the identified shocks, P^2_{mi} is defined with respect to all the identified shocks. With v number of external factors, P^2_{mi} is the sum of each constituent shock:

$$P^2_{m,ii} = \sum_{j=1}^{v} \mu_{i,j} P^2_{m,ii,jj} + \sum_{j,k=1}^{v} \mu_{i,j} P^2_{m,ii,jk}$$

where

$$P^2_{m,ii,jj} = \frac{\mathbf{e_i}' d_{1j} \Psi_{jj} d_{1j}' \mathbf{e_i}}{\mathbf{e_i}' d_{0j} \Psi_{jj} d_{0j}' \mathbf{e_i}}, \qquad P_{m,ii,jk} = \frac{\sum_{k \neq j}^{v} \mathbf{e_i}' d_{1j} \Psi_{jk} d_{1k}' \mathbf{e_i}}{\mathbf{e_i}' d_{0j} \Psi_{jj} d_{0j}' \mathbf{e_i}} \tag{3.16}$$

and

$$\mu_{i,j} = \frac{\mathbf{e_i}' d_{0j} \Psi_{jj} d_{0j}' \mathbf{e_i}}{\mathbf{e_i}' D(0) \Psi D(0)' \mathbf{e_i}}$$

$P^2_{mi,jj}$ is the direct macro-shock specific persistence measure; it is the infinite horizon effects of macroeconomic shock j on the dependent variable, assuming other macroeconomic shocks are switched off. $P^2_{mi,jk}$ is the indirect macro-shock specific persistence measure; it arises from the co-movement between j^{th} macroeconomic shock and other macroeconomic shocks. μ_j faciliates the decomposition by weighing the contribution of each j macroeconomic shock relative to all macroeconomic shocks.

Contribution of Each Identified Shock To decompose the contribution of each identified shock to the persistence measure of the identified shocks, the following formula is used: the weight of each identified shock is multiplied with its specific persistence measure:

$$\mu_{i,j} P^2_{m,ii,jj} = \frac{\mathbf{e_i}' d_{1j} \Psi_{jj} d'_{1j} \mathbf{e_i}}{\mathbf{e_i'} \mathbf{D(0)} \mathbf{\Psi} \mathbf{D(0)}' \mathbf{e_i}} \tag{3.17}$$

Multiplying the two terms, in effect, the denominator becomes common to all identified shocks, it evaluates the infinite-horizon effect of each identified shock relative to a common denominator, as a measure of the relative importance of each identified shock.

3.4 Net Foreign Assets in Europe

We turn now to our empirical analysis of the net foreign assets of the EU12 countries based on data between 1970 and 2011.

Net Foreign Assets The net foreign assets dataset was made widely available following the publication of Lane and Milesi-Ferretti (2001, 2007b), and it is now maintained as the External Wealth of Nations (EWN) dataset[9]. Because this chapter focuses on the European countries, and for the purpose of applied time series analysis, I include only European countries with full sample availability, from 1970 to 2011, in the EWN dataset. The twelve Europe countries (EU12) included in the analysis are: the United Kingdom, Austria, Belgium, Denmark, France, Germany, Italy, Netherlands, Sweden, Switzerland, Greece and Spain [10].

The net foreign assets are measured in terms of the size of the economy (GDP). Figure 3.1 plots the net foreign assets of the EU12 countries between 1970 and 2011. For most countries, the net foreign assets have fluctuated (moved significantly or shifted significantly) during this period;

[9]Available on Prof. Lane's webpage. The maintained EWN dataset is a panel of countries over the period 1970-2011 and denominated in US dollar. The dataset is categorized by instruments on both sides of the balance sheet.

[10]Of the twelve countries, Belgium, the Netherlands, Austria, France, Germany, Italy, Greece and Spain are in the European Monetary Union (EMU). France and Germany are the euro core countries; Italy, Greece and Spain are the euro peripheral countries. The UK, Switzerland, Denmark and Sweden are the non-EMU countries.

the standard deviation of net foreign assets is high across countries—with the exception of Austria, Germany and Italy, the standard deviation of net foreign assets during this period is above 10% (see Table 3.1). In these economies—Belgium, France, Switzerland, Greece and Spain—the standard deviation of net foreign assets is above 20%. Switzerland is notably a large creditor with the average size of net foreign assets, almost 100% of GDP. Greece and Spain have relatively large average net foreign liabilities, -32% and -27% of GDP.

Unit Root Tests We test if the dynamics of net foreign assets is characterised as a unit root process with the ADF and CADF regressions, as described in the previous chapter. In this empirical analysis, we choose ADF(2) regression based on data availability and empirical result which is shown later, the problem of serial correlation is removed for augmentation of order two. Based on the ADF regressions and the IPS tests (Tables B.1 and B.2), the net foreign assets is I(1).

Net foreign assets could be correlated across countries, for instance if there is an unobserved common factor that affects all countries' net foreign assets. Based on the CADF regressions and the CIPS tests (Tables B.3 and B.4), the net foreign assets is I(1).

The characterization of net foreign assets as an $I(1)$ variable is consistent with either the international real business cycle approach or the political economy approach described earlier; both approaches model the net foreign assets as an $I(1)$ process.

Current Account Balances We investigate the components of the net foreign assets - current account balance, net valuation term and the other term (equation (3.6)). Figure 3.2 plots the current account balances of the EU12 countries. The average size of current account balances is single percent of GDP across countries, that is also the case for most years

in all countries with the exception of Greece and Spain (current account deficits) exceeding -10% of GDP in certain years; Netherlands, Sweden and Switzerland (current account surpluses) exceeding 10% of GDP in certain years. The current account balances are visually smooth in some countries particularly towards the end of the sample (Germany, Sweden, Greece and Spain).

We test if the dynamics of current account balance is either stationary or nonstationary with the ADF[11] and CADF regressions described earlier. The current account balance is an international economic variable, where accounting for common factors is relevant therefore the CADF test would be more suitable. Across countries and augmentation orders of the CADF regressions (see Tables B.7 and B.8), the current account balance is an $I(1)$ process—we do not reject the unit root null on the current account balances but reject the unit root null on the change of current account balances. This is also supported by the CIPS tests.

Net Other Terms The observed series are net foreign assets, current account balances and the growth rate of nominal GDP—according to the dynamic equation (3.6), we can compute the residual term which includes the net valuation term and the measurement error term, which we denote as the net other term. Figure 3.3 plots the net other terms of the EU12 countries. The net other terms visually seem to be mean-reverting, i.e. stationary. The magnitude of net other terms is mostly single percent of GDP; across countries however, there are outlier observations, reflecting in large standard deviation (Table 3.3). Switzerland is an outlier in this variable where the average net other term is -14% and the standard deviation is 20%—its average net foreign assets is 100% therefore subject to large movements in net valuation effects. (I did not mention about the net other

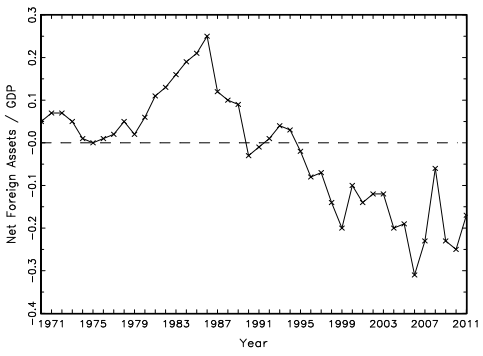
[11]The ADF regression results are mixed. Based on the IPS test, we reject the unit root hypothesis in the ADF(1) and ADF(2) regressions but do not reject the unit root hypothesis in the ADF(3) and ADF(4) regressions (Table B.5).

term moves significantly during the Global Financial Crisis.)

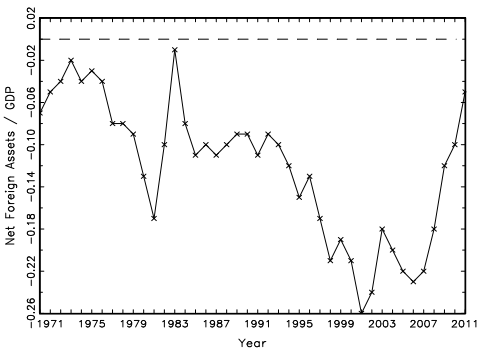
We test for unit root concerning the dynamics of net other terms. Based on the ADF regressions on the other terms (Table B.9), we reject the unit root null hypothesis across the four augmentation orders (the IPS test). Based on the CADF regressions (Table B.10), we reject the unit root null hypothesis across the four augmentation orders (the CIPS test). The tests therefore suggest net other terms are $I(0)$. The stationarity of the net other term can be justified by its two components—the measurement error and the net valuation effects. First, the nature of measurement error is irregular and its magnitude is random (could be positive or negative). Second, the net valuation effects are driven by asset prices and exchange rates, both of whom are known to be $I(1)$ process. The net valuation effect is however the difference between valuation changes on assets side and valuaton changes on liabilities side. The valuation change on either side of balance sheet is conceptually $I(1)$ but the difference between the two empirically is $I(0)$.

Figure 3.1: The Ratio of Net Foreign Assets to GDP of the EU12 countries over the period 1970–2011

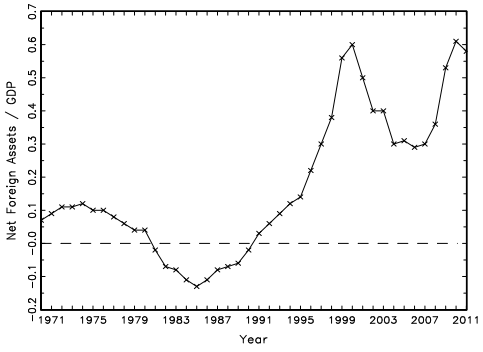
(a) UK



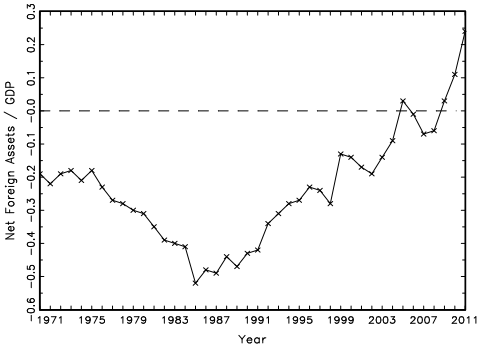
(b) Austria



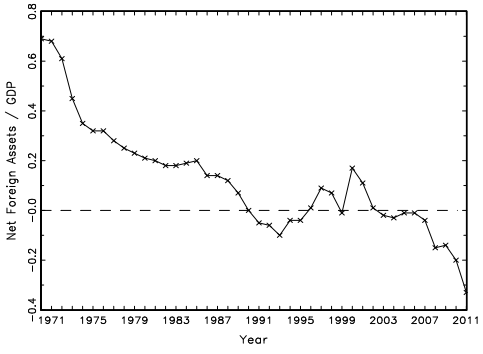
(c) Belgium



(d) Denmark



(e) France



(f) Germany

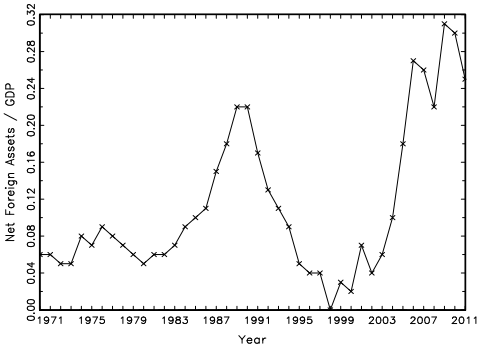
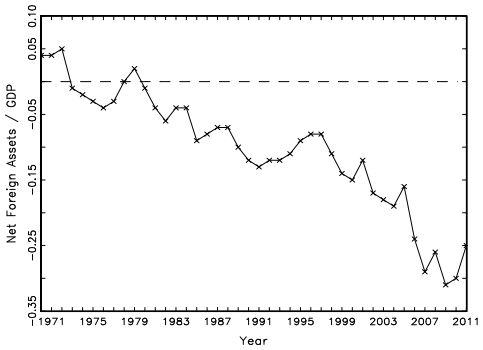
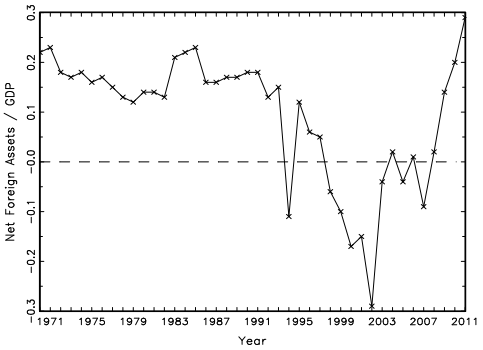


Figure 3.1: Continued

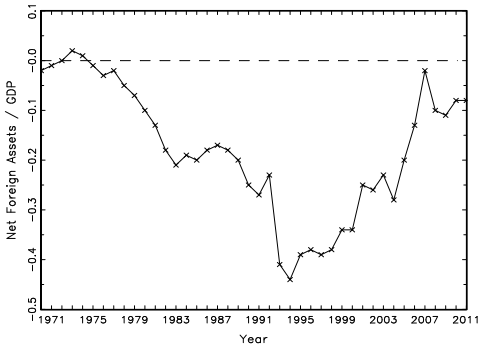
(g) Italy



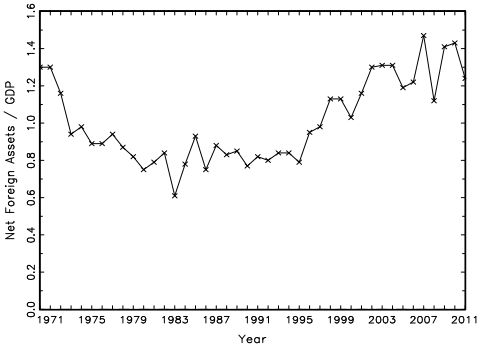
(h) Netherlands



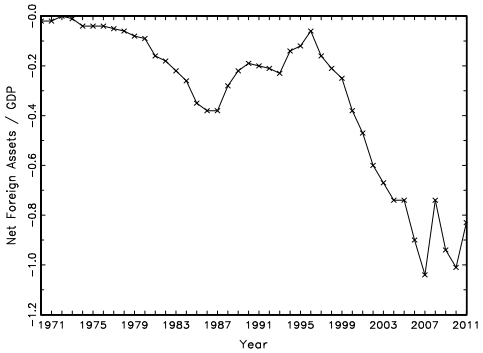
(i) Sweden



(j) Switzerland



(k) Greece



(l) Spain

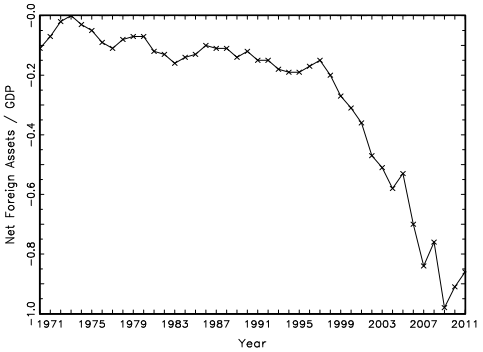
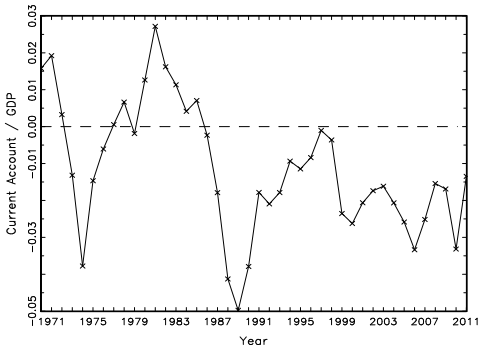
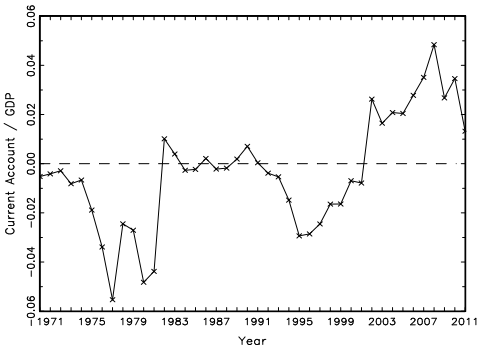


Figure 3.2: The Ratio of Current Account Balances to GDP of the EU12 countries over the period 1970–2011

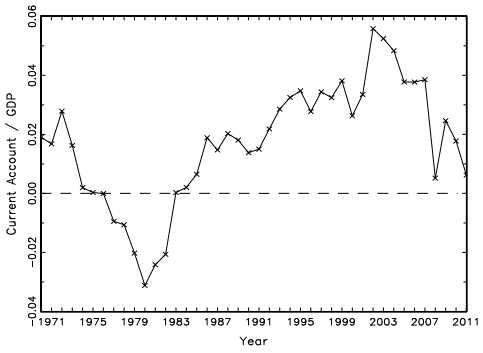
(a) UK



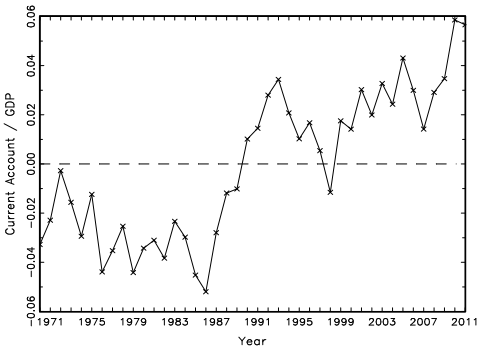
(b) Austria



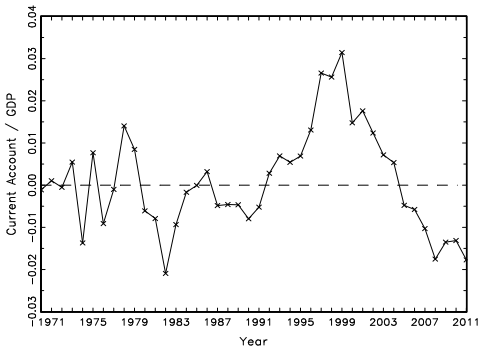
(c) Belgium



(d) Denmark



(e) France



(f) Germany

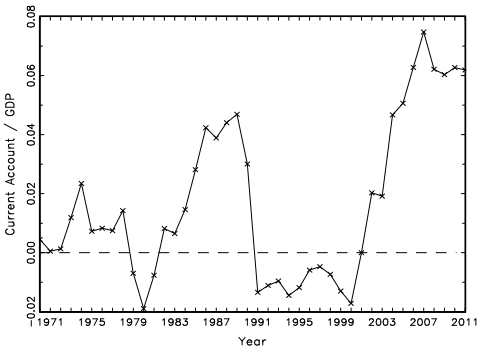
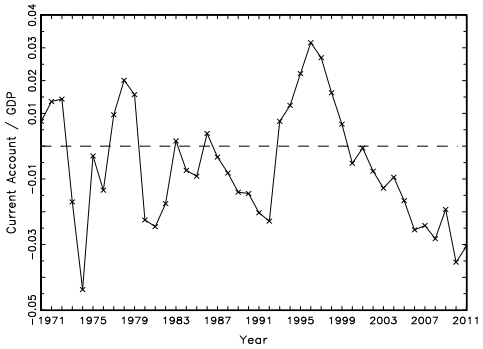
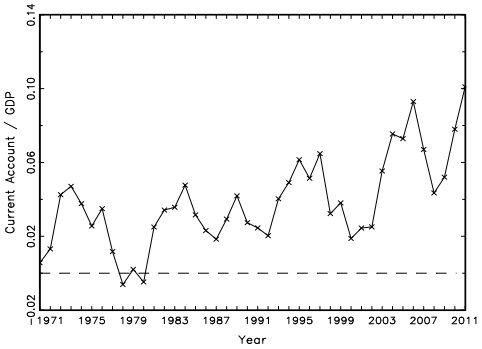


Figure 3.2: Continued

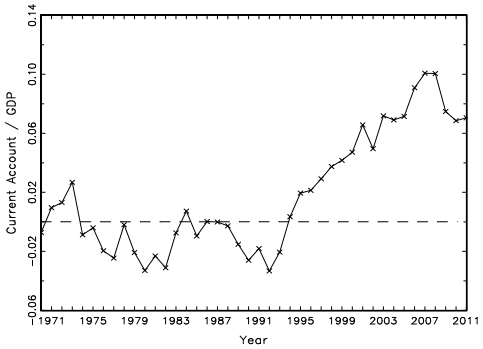
(g) Italy



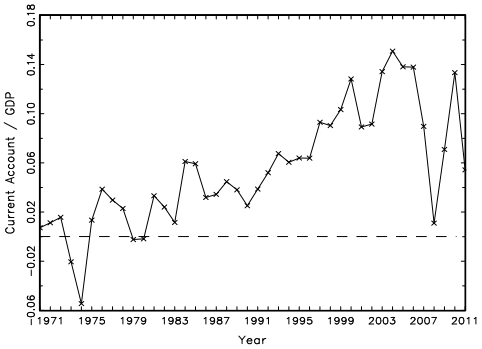
(h) Netherlands



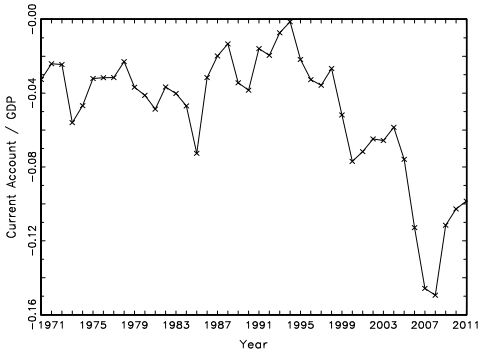
(i) Sweden



(j) Switzerland



(k) Greece



(l) Spain

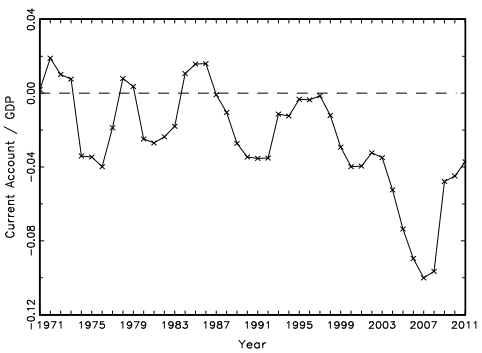
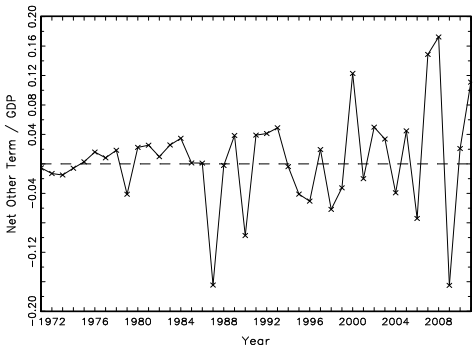
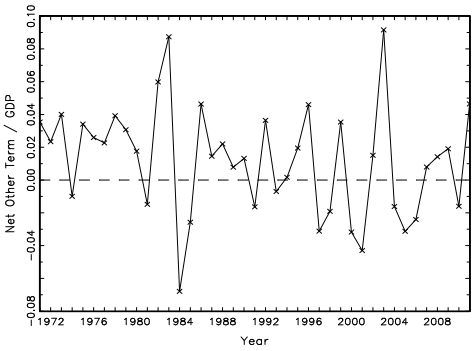


Figure 3.3: The Ratio of Net Other Terms to GDP of the EU12 countries over the period 1971 - 2011

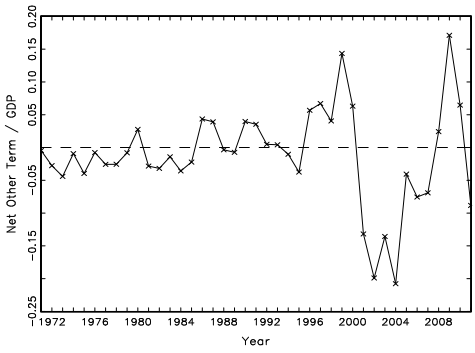
(a) UK



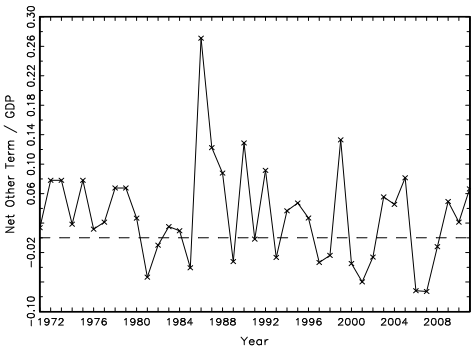
(b) Austria



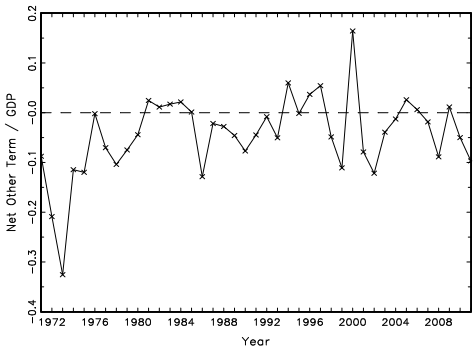
(c) Belgium



(d) Denmark



(e) France



(f) Germany

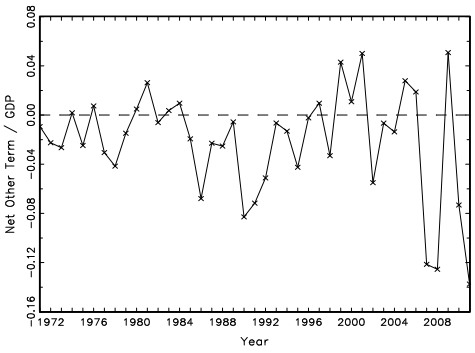
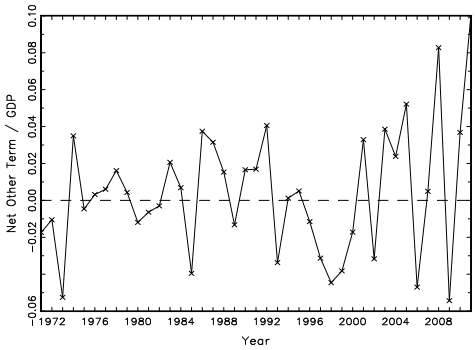
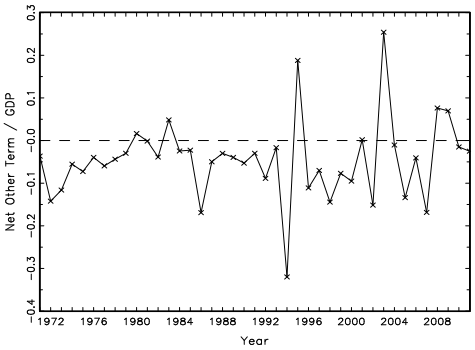


Figure 3.3: Continued

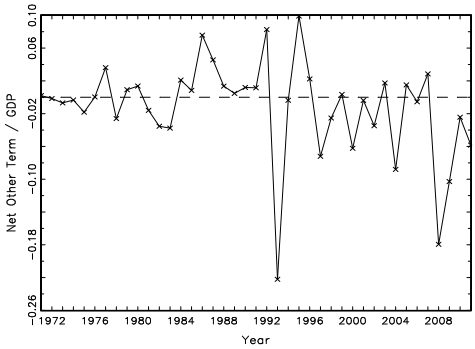
(g) Italy



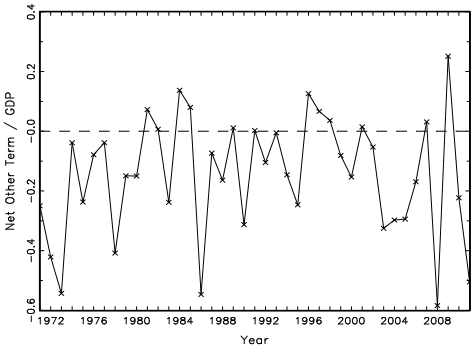
(h) Netherlands



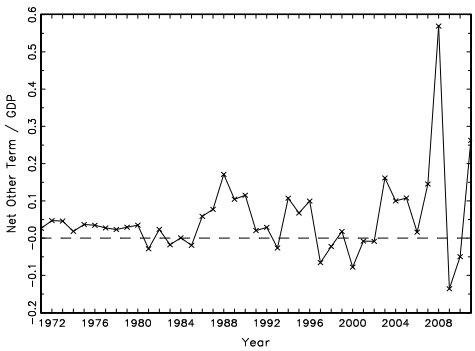
(i) Sweden



(j) Switzerland



(k) Greece



(l) Spain

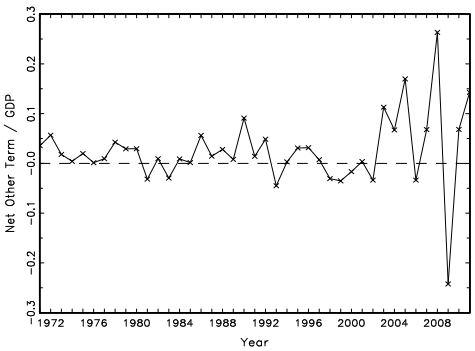


Table 3.1: Summary Statistics of The Net Foreign Assets to GDP, 1970 - 2011

	Mean (%)	St. Dev (%)	Min (%)	Max (%)
UK	-1.95	13.45	-31.00	25.00
Aus	-12.17	6.61	-26.00	-1.00
Bel	17.26	21.83	-13.00	61.00
Den	-23.57	16.87	-52.00	24.00
Fra	12.00	21.98	-33.00	69.00
Ger	11.24	8.20	0.00	31.00
Ita	-10.24	9.31	-31.00	5.00
Net	9.38	12.94	-29.00	29.00
Swe	-17.81	13.24	-44.00	2.00
Swit	100.81	22.34	61.00	147.00
Gre	-32.64	30.87	-104.00	0.00
Spa	-27.19	27.29	-98.00	0.00

Note: Source: (Lane & Milesi-Ferretti, 2007b).

Table 3.2: Summary Statistics of The Current Account Balances to GDP, 1970 - 2011

	Mean (%)	St. Dev (%)	Min (%)	Max (%)
UK	-1.14	1.76	-4.98	2.72
Aus	-0.35	2.29	-5.53	4.84
Bel	1.69	2.06	-3.12	5.58
Den	-0.08	3.04	-5.20	5.86
Fra	0.08	1.20	-2.09	3.15
Ger	1.71	2.72	-1.89	7.47
Ita	-0.59	1.79	-4.37	3.16
Net	3.84	2.43	-0.61	10.10
Swe	1.86	4.02	-3.33	10.07
Swit	5.44	4.72	-5.45	15.09
Gre	-5.02	3.49	-14.95	-0.13
Spa	-2.46	2.91	-10.01	1.90

Note: Source: (Lane & Milesi-Ferretti, 2007b).

Table 3.3: Summary Statistics of The Ratio of Net Other Terms to GDP, 1970 - 2011

	Mean (%)	St. Dev (%)	Min (%)	Max (%)
UK	0.55	6.67	-16.49	17.23
Aus	1.22	3.37	-6.79	9.16
Bel	-1.23	7.39	-20.76	17.11
Den	3.05	6.67	-7.29	27.11
Fra	-4.36	7.99	-32.55	16.43
Ger	-2.17	4.38	-13.75	5.08
Ita	0.39	3.45	-5.43	9.99
Net	-4.55	9.42	-31.99	25.41
Swe	-1.23	5.95	-22.21	9.92
Swit	-14.65	20.10	-58.38	25.12
Gre	5.16	11.06	-13.59	56.93
Spa	2.44	7.32	-24.24	26.35

Note: The net other term includes the net valuation gain and the measurement error. See text for details of the computation of the net other term.

Long-Run Movements of Net Foreign Assets The empirical finding—the net foreign assets and the current account balances are nonstationary, the net other terms are stationary—implies, over the long-run, the current account traces the net foreign assets. This is akin to Obstfeld (2012) puts it, "the valuation effects cannot be relied on as a channel for external adjustment" and "the current account still traces the net foreign assets in the long-run".

Unit Root and Debt Sustainability Unit root and cointegration have been used to analyze the sustainability of fiscal policy and net foreign assets, as described in the previous chapter. Unit root testing however do not have one-to-one correspondence with the sustainability of fiscal policy, as argued by Bohn (1995). This is because the unit root process does not amount to violating the transversality condition. If debt were to be a unit root process, the h-period-ahead forecast of debt increases as a polynomial in time of order h while the discount factor increases exponentially.

The dynamics of the fiscal variables is equivalent to the dynamics of the external variables therefore similar approaches could be adopted on the sustainability analysis of the public debt and on the net foreign assets. Our unit root tests suggest the net foreign assets is a unit root process. Akin to the public finance sustainability time series literature, the net foreign assets being an $I(1)$ process does not imply non-sustainability. Rather, modelling the net foreign assets as an $I(1)$ process is relevant in the estimation where the first difference is used and in measuring the degree in which the effects of shocks to net foreign assets persist. In the public finance literature, Antonini et al. (2013) measures the effects of shocks to public debt in ten European economies. Countries whose persistence measures are larger than unity are likely to not satisfy the sustainability events defined in the next chapter.

3.5 The Persistent Effects of Shocks to Net Foreign Assets

We first compute the persistent effects of the general shocks to net foreign assets. We then estimate the extended multi-country model, where we decompose the persistent effects of the identified shocks.

3.5.1 Persistent Effects of Shocks

The multi-country VAR model in equation (3.8) quickly runs into the curse of the dimensionality problem as the number of parameters increases with the number of countries entering the VAR. In our example, with twelve countries and two lags, the total number of parameters per country-equation is twenty five which would be difficult to estimate given samples that are typically observable. This curse of the dimensionality problem is addressed by imposing a homogeneity restriction on the coefficients on other countries in the multi-country VAR. The multi-country VAR is provided by the following simple regression models estimated for each country and stacked in each case to obtain a multi-country VAR:

$$M_1 : \Delta \text{nfa}_{i,t} = \mu_i + \sum_{s=1}^{r} \beta_{s,i} \Delta \text{nfa}_{i,t-s} + \sum_{s=1}^{r} \gamma_{s,i} \Delta \text{nfa}^*_{-i,t-s} + \varepsilon_{i,t} \qquad (3.18)$$

$$M_2 : \text{A restricted version of } M_1, \text{ where variables with coefficients with a t-statistic below unity (in absolute value) are excluded} \qquad (3.19)$$

Model M_1 is a VAR of order r which explains $\Delta \text{nfa}_{i,t}$ in terms of lagged net foreign assets growth in country i and the lags of debt growth in the rest of EU12 countries, that entails using the cross-section average of every other country's external wealth except country i, $\Delta \text{nfa}^*_{i,t} = \sum_{i=1}^{m-1} \Delta \text{nfa}_{-i,t}/m-1$.

M_2 imposes restrictions on M_1 where a specification search on individual country equations is carried out country by country therefore this search is based on the OLS estimates, where variables whose coefficients with a t-statistic less than unity were dropped. The purpose of the model specification is obtaining a more parsimonious specification; we follow the sequential hypothesis testing approach[12], or more specifically, the general-to-specific method (Campos, Ericsson, & Hendry, 2005; Hendry, 1995).

The models are estimated for the EU12 over the period 1970-2011 using Full Information Maximum Likelihood (FIML). Test of no serial correlation suggests two lags in Model M_1 are sufficient to capture the time series properties of the data. The specification search is sequential, where one variable is dropped each time: the variable with the smallest t-statistic gets eliminated; the trimmed model is re-estimated; the variable with the smallest t-statistic and less than the unity condition is dropped. This procedure is repeated until the t-statistics of all variables in the model exceed unity[13]. Individual countries' basic regressions with the regression diagnostics are reported in Table B.11. Having estimated the individual country regressions and stacked them into a VAR, the model can be inverted to obtain the model described in equation (3.9) and the associated persistence measures in equation (3.11).

There are considerable variations in the persistence measures of the European countries (see Table 3.4). We can distinguish two groups of countries: the persistence measure larger than unity—Belgium (2.25), Denmark (1.66), Germany (1.31), Sweden (1.44), and Spain (1.52)—and the persistence measure lower than unity—the UK (0.85), Greece (0.79), Italy (0.78), Switzerland (0.78), France (0.77), Austria (0.72) and the Netherlands (0.61).

[12]Alternatively, model selection can go via information criteria, cross validation, Lasso—least absolute shrinkage and selection operator—model selection and bagging; see Elliott and Timmermann (2016), Chapter 6.

[13]With the exception the short lag is not dropped if the long lag remains.

To illustrate, when the persistence measure is 2.25, as a consequence of a shock, a 1% increase to the net foreign assets on impact, increases the net foreign assets by 2.25% in the infinite horizon. In contrast, when the persistence measure is 0.61, a 1% increase to the net foreign assets on impact would result in 0.61% increase to the net foreign assets in the infinite horizon. One group of these economies is more responsive to accumulation of wealth or liabilities than the other.

Table 3.4: Persistence Measures (Model M_2)

Countries		Total P_{ii}
1	Bel	2.25
		(0.54)
2	Den	1.66
		(0.26)
3	Spa	1.52
		(0.09)
4	Swe	1.44
		(0.12)
5	Ger	1.31
		(0.05)
6	UK	0.85
		(0.04)
7	Aus	0.72
		(0.02)
8	Gre	0.79
		(0.01)
9	Swit	0.78
		(0.04)
10	Ita	0.78
		(0.02)
11	Fra	0.77
		(0.03)
12	Net	0.61
		(0.01)

Note: The persistence measure (P_{ii}) is estimated based on Model M_1 (3.19). The persistence measure is defined in (3.11).

3.5.2 Persistent Effects of Identified Shocks

The above results focusing on the effects of general shocks, is interesting but cannot provide insights on the nature of the shocks affecting countries' net foreign assets. We turn now to the extended multi-country model described in section 3.3.

External Drivers As motivated earlier in section 3.2, we want to investigate empirically the effects of financial integration, output movements and the dollar on the net foreign assets. Financial integration is measured by the International Financial Integration (IFI) index—the average size of a country's international balance sheet measured in terms of GDP (Lane & Milesi-Ferretti, 2007b). More specifically, it is the cross-section mean of countries' balance sheet:

$$\text{IFI}_t = \frac{1}{m} \sum_{i=1}^{m} \frac{A_{it} + L_{it}}{Y_{it}}$$

In the twelve European countries, the average size of a country's international balance sheet is less than 100% of a country's GDP; since the mid-1990s, cross-border financial flows accelerated throughout the 2000s, halted in the Global Financial Crisis of 2008; by the end of the sample, the average size of a country's balance sheet is more than 600% of a country's GDP (see Figure 3.4). We define the aggregate output with the sum of GDP across the twelve countries:

$$\text{EU12}Y_t = \sum_{i=1}^{12} Y_{it}$$

There are four world's major currencies of these twelve European countries: the euro, the British pound, the Swiss franc and the Swedish krona; prior to the introduction of the euro in 1999, there are the old legacy currencies of the European economies. We measure the dollar fluctuation with the

dollar effective exchange rate index maintained by the Bank of International Settlements. It is the time-varying trade weighted bilateral nominal exchange rates between the US and its trading partners. The dollar appreciates before depreciates in 1980s. The dollar depreciates in the early 2000s, in the global financial crisis however, there is a rush into the dollar instead of a run (see Figure 3.4).

The individual country regressions augmented with these macroeconomic shocks are stacked together in a multi-country VAR; the individual country regression is:

$$M_3 : \Delta \text{nfa}_{i,t} = \tilde{\mu}_i + \sum_{s=1}^{r} \tilde{\beta}_{s,i} \Delta \text{nfa}_{i,t-s} + \sum_{s=1}^{r} \tilde{\gamma}_{s,i} \Delta \text{nfa}^*_{-i,t-s} + \sum_{j=1}^{v} \sum_{s=0}^{r} \delta_{i,js} v_{j,t-s} + \tilde{\varepsilon}_{i,t} \tag{3.20}$$

where $v = 3$ as there are three external drivers. Simultaneously, akin to the equation (3.12) described in section 3.3, we identify the shocks in a VAR. Prior to that, we test the time series properties of the hypothesized drivers. We do not reject the unit root null hypothesis for the level of the IFI index and the aggregate output[14] (Tables B.12, B.13); we therefore model the hypothesized drivers in first difference—the shocks represent permanent shift in the level of the hypothesized drivers. The VAR is therefore:

$$\Delta x_t = \sum_{s=1}^{p} \Gamma_s \Delta x_{t-s} + v_t \tag{3.21}$$

where Δx_t is 3×1 vector of external drivers, x_t is the logarithm of IFI_t, $\text{EU12}Y_t$ and dollar index; Γ_s is 3×3 matrix of lagged coefficients and p is the lag of the VAR. Lag lengths r and r are decided based on the test of no serial correlation. Model M_3 consists of equations (3.20) and (3.21) can be estimated jointly via FIML.

A specification search procedure is carried out country-by-country, based

[14]Despite the unit root test suggests the effective dollar index is stationary, we follow the conventional economic literature in modelling exchange rate as a unit root process (Kilian & Taylor, 2003).

on individual countries' estimates, coefficients whose absolute value of the t-ratio are less than unity are dropped. The procedure drops one variable at a time and is based on the principle of dropping the longest lags first on the lagged dependent variables before the lagged macro shocks; moreover, short lags are not dropped if the long lags remain.

The contemporaneous coefficients of all the identified shocks are dropped in Belgium and Sweden; the persistence measure of identified shocks are not computable. The lagged coefficients of all the identified shocks are dropped in Germany. The financial shocks are included in every country. The output shocks are included in all countries except Germany and Greece. The dollar shocks are included in every country (see Table B.14).

Moreover, the empirical shocks obtained from the VAR are plotted between 1973 and 2011. For the financial shocks (see Figure 3.5), we see a sequence of positive financial shocks—1985, 1989, the mid-1990s and throughout the 2000s— implying the prominent rise in cross-border finance flows reflected in the expanded size of country's international balance sheet. The timing of these shocks correspond with economic events such as—the abolition of capital controls in the 1980s and early 1990s, the harmonisation of financial regulations and the introduction of single currency (Lane, 2013a). The negative financial shock corresponds in 2008 the freezing of the credit markets.

For the output shocks, we see a good run of positive output shocks in Europe during the 70s and negative output shocks during the 90s and 2000s, notably the dot com bubble in 2001 and the global financial crisis in 2008 (see Figure 3.5). For the dollar shocks, we see the Plaza Accord appreciation shocks in early 80s, the Nixon shock in 1992; moreover, in both recent financial crises in 2001 and 2008, the dollar surges as capitals flight to safety.

Persistent Effects of Identified Shocks The persistence measures of the identified and unidentified shocks are similar to those estimated in estimated model M_1 (Table 3.5). The degree in which the shocks persist differs across countries; where the persistence measure of the identified shocks is less than unity in one group of countries: the UK, France and the Netherlands; and the persistence measure of the identified shocks is either unity or larger than unity in other countries: Austria, Denmark, Switzerland, Germany, Italy, Greece and Spain. In these countries, the net foreign assets are vulnerable to increase or decrease induced by the identified shocks.

When the persistence measure of identified shocks is decomposed by each of the identified shocks (Table 3.6), a few summary observations can be made. The financial shocks are important drivers of the net foreign assets—in seven countries: Austria, Denmark, Germany, Italy, the Netherlands, Greece and Spain, the shocks are either the most persistent or equally persistent. The financial shocks are notably most persistent in Spain. Aa described earlier, the effects of the financial shocks on the external balances occur via the lowering of interest rate, that encourage borrowing and lending amongst countries.

The output shocks are less important in the long-run evolution of net foreign assets across countries, with the exception of Austria and Denmark. The dollar shocks are important in several countries: Austria, Denmark, France, and Switzerland but less important in other countries including the UK, the Netherlands and Greece. Because the net valuation changes mean-reverts, the dollar shocks on the long-term evolution of net foreign assets occur via the current account, i.e. either the trade balance or the investment income.

Table 3.5: Persistence Measures of Identified and Unidentified Shocks (Model M_3)

Countries		Macro $P_{m,ii}$	Other $P_{o,ii}$	Total P_{ii}
12	Spa	1.69	1.10	1.29
		(0.43)	(0.09)	(0.18)
2	Aus	1.12	0.68	0.82
		(0.29)	(0.09)	(0.12)
10	Swit	1.11	0.54	0.65
		(0.50)	(0.09)	(0.11)
4	Den	1.08	1.06	1.07
		(0.13)	(0.12)	(0.12)
7	Ita	1.03	1.18	1.11
		(0.23)	(0.19)	(0.16)
11	Gre	1.01	1.00	1.00
		(0.40)	(0.00)	(0.10)
6	Ger	1.00	1.00	1.00
		(0.00)	(0.00)	(0.00)
5	Fra	0.98	0.57	0.76
		(0.24)	(0.08)	(0.12)
8	Net	0.67	0.74	0.72
		(0.22)	(0.10)	(0.12)
1	UK	0.42	0.73	0.70
		(0.23)	(0.10)	(0.09)
9	Swe	-	1.08	1.08
		-	(0.08)	(0.08)
3	Bel	-	2.19	2.19
		-	(0.53)	(0.53)

Note: The persistence measure is estimated based on Model M_2 (3.20). Individual countries' persistence measures (P_{ii}) are estimated using equation (3.14) in the text. The decomposition of total persistence into $P_{m,ii}$ and $P_{o,ii}$, i.e. persistence due to identified and unidentified shocks, is described by equation 3.14 and equation 3.15 in the text.

Table 3.6: Further Decomposition of Countries' Persistence Measures of Identified Shocks (Model M_2)

Country		DLIFI	DLY	DLEX	Interaction	Total
		$\sqrt{\mu_{i,1}P^2_{m,ii,11}}$	$\sqrt{\mu_{i,2}P^2_{m,ii,22}}$	$\sqrt{\mu_{i,3}P^2_{m,ii,33}}$	$\sum_{j,k=1}^{3}\mu_j P^2_{m,ii,jk}$	$P_{m,ii}$
12	Spa	1.62	0.57	0.57	-0.40	1.69
		(0.45)	(0.34)	(0.31)		(0.43)
6	Ger	0.97	0.00	0.50	-0.20	1.00
		(0.12)	(0.00)	(0.36)		(0.00)
7	Ita	0.84	0.54	0.67	-0.39	1.03
		(0.26)	(0.22)	(0.26)		(0.23)
2	Aus	0.81	0.78	0.88	-0.80	1.12
		(0.23)	(0.37)	(0.43)		(0.29)
11	Gre	0.80	0.00	0.48	0.16	1.01
		(0.34)	(0.00)	(0.48)		(0.40)
8	Net	0.64	0.26	0.23	-0.08	0.67
		(0.25)	(0.30)	(0.35)		(0.22)
4	Den	0.76	0.84	0.88	-0.88	1.08
		(0.24)	(0.15)	(0.25)		(0.13)
5	Fra	0.46	0.31	0.95	-0.24	0.98
		(0.12)	(0.29)	(0.35)		(0.24)
1	UK	0.22	0.43	0.07	-0.07	0.42
		(0.39)	(0.21)	(0.12)		(0.23)
10	Swit	0.11	0.10	1.02	0.17	1.11
		(0.37)	(0.12)	(0.53)		(0.50)
3	Bel	-	-	-	-	-
		-	-	-		-
9	Swe	-	-	-	-	-
		-	-	-		-

Note: The table shows for each type of macroeconomic shock, the contribution of the direct and overall measures of persistence of shocks to $P_{m,ii}$ as described by equation (3.16) in the text. The individual countries' persistence measures are obtained using the selection vector e_i. DLIFI refers to the first difference of the logarithmic International Financial Integration index, DLY refers to the growth rate of aggregate output and DLEX refers to the growth rate of the dollar effective exchange rate index (see text for details).

3.6 Conclusion

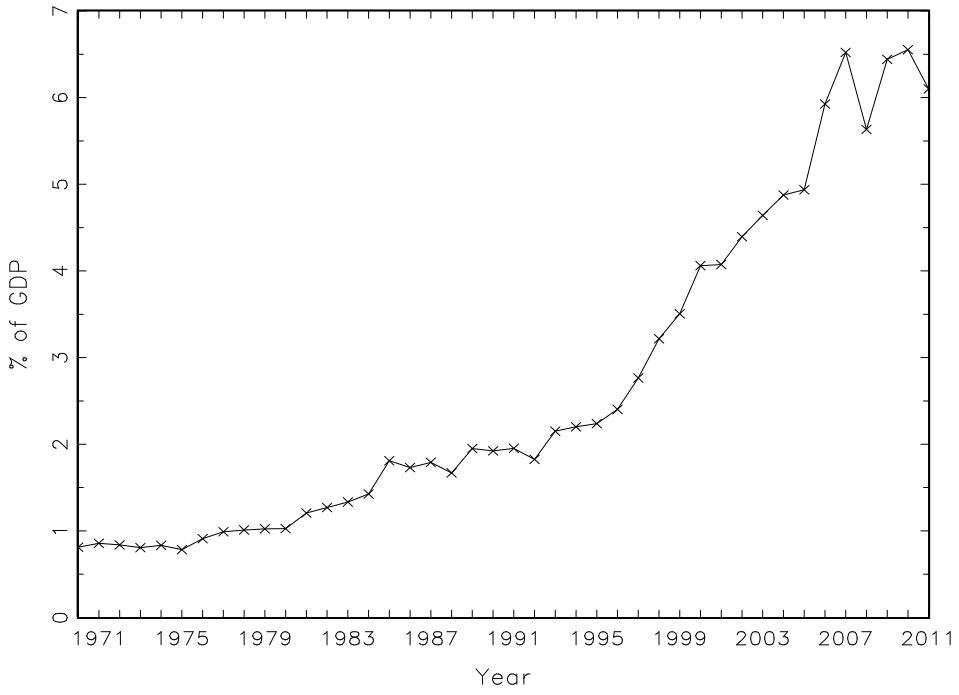
The net foreign assets of the EU countries have grown divergent in recent years. This chapter characterizes the long-run evolution of net foreign assets; by performing unit root tests on the components of net foreign assets—current account and net valuation changes, we find the current account matters for the long-run evolution of net foreign assets whilst the net valuation change does not, which is in line with Obstfeld (2012).

The persistence measure picks out debtor and creditor countries that are vulnerable to increase and decrease in their net foreign assets-to-GDP — Germany and Spain, for example. In the first instance, these shocks are general and any shocks that occur to the net foreign assets-to-GDP. In the second instance, measuring and decomposing the persistent effects by financial shocks, output shocks and dollar exchange rate shocks — the financial shocks are persistent in more countries than the output shocks and the dollar shocks. Therefore we find financial integration is an important driver behind these economies' net foreign assets.

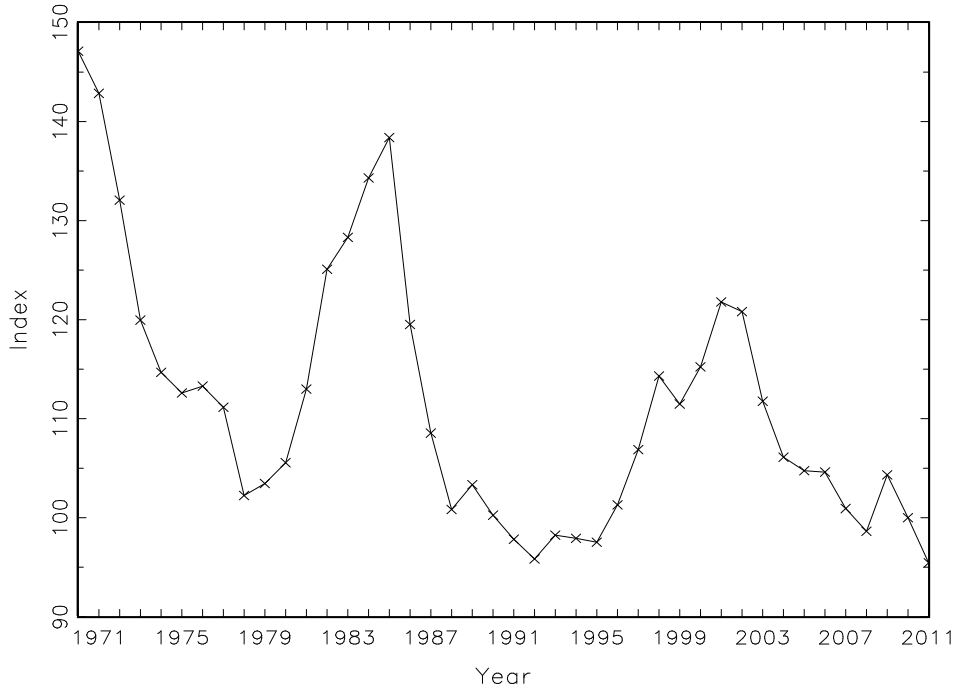
These empirical findings seem to highlight the expansion of gross flows contributed to persistence of net flows, resulting in the divergence of net foreign assets. Prior to the European Sovereign Debt crisis, most of the flow imbalances have been financed by debt flows (Lane, 2013a); the sudden drying up of the credit markets trigger the crisis as debt is riskier with its repayment obligations and therefore subjected to sustainability reassessment. Whilst there are advantages to financial integration, notably risk-sharing, it also carries the cost of exacerbating external imbalances especially when putting countries at the risk of debt crises. There is a case for policy makers to monitor the level of external indebtedness, the subject of the next chapter, as well as the debt-equity composition of a country's balance sheet.

Figure 3.4: Drivers of Net Foreign Assets in the EU12 countries over the period 1970–2011

IFI Index



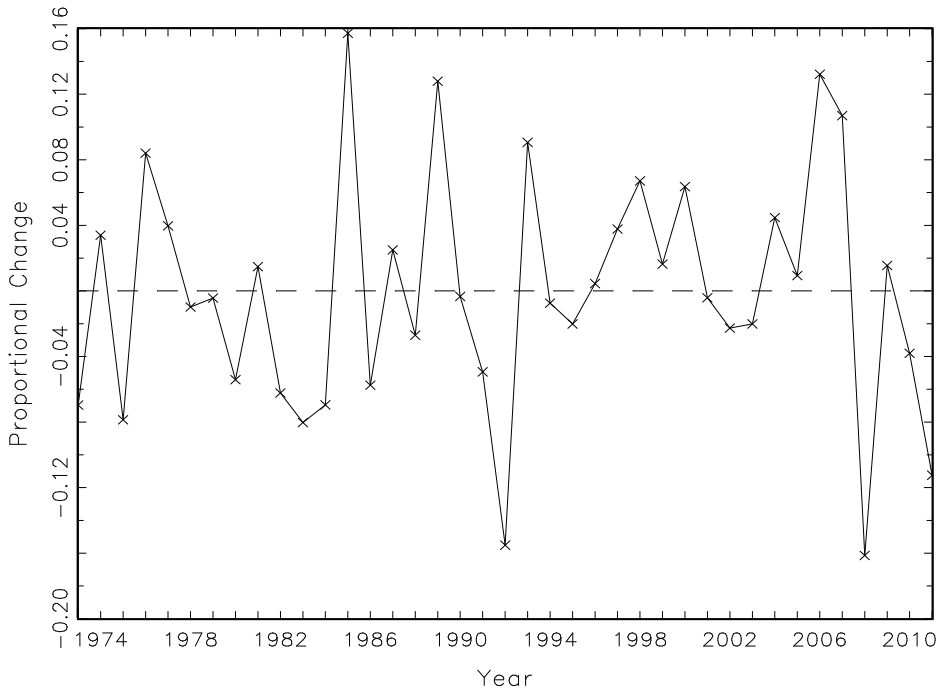
Dollar Effective Exchange Rate Index



Note: The International Financial Integration (IFI) Index is the (cross-section) average of international balance sheet, measured in terms of a country's GDP across the twelve European countries. The EU12 output is the sum of output across the twelve European countries. The exchange rate is defined in terms of currencies per US dollar. Source: Klau and Fung (2006).

Figure 3.5: Identified Shocks over the period 1973–2011

Shocks to IFI Index



Shocks to EU12 Output

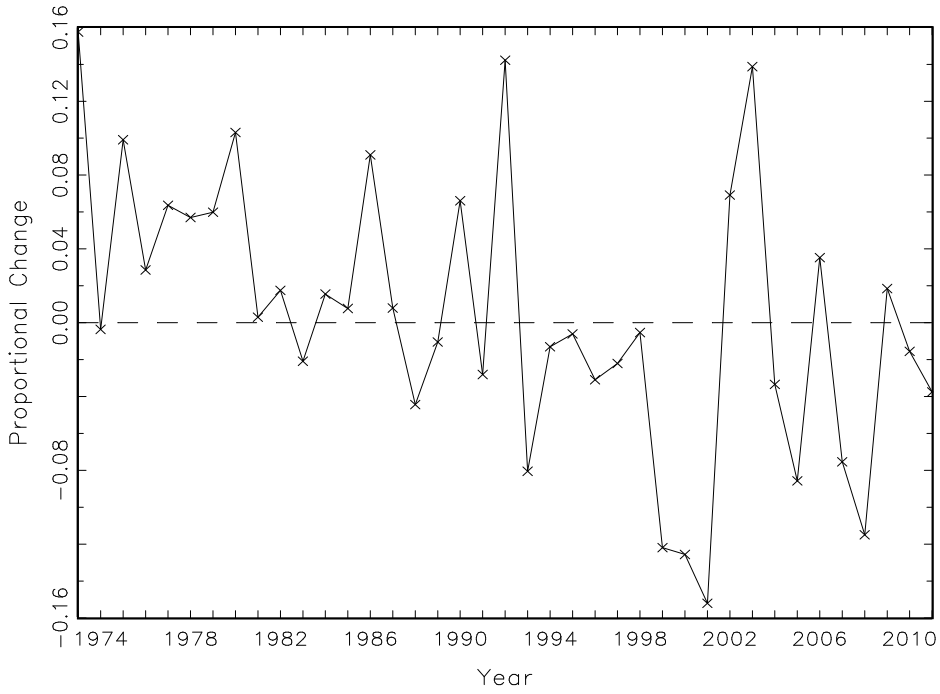
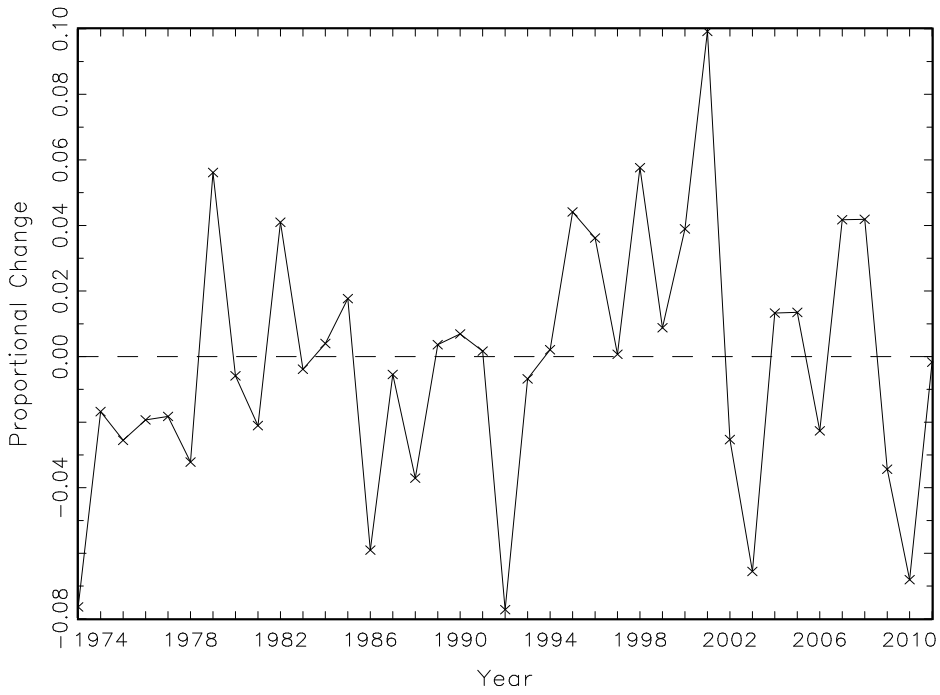


Figure 3.5: Continued

Shocks to Dollar Effective Exchange Rate Index



Chapter 4

Maintaining External Balances — Implementing the EU Surveillance Programme Using Event Probability Forecasts

> Importantly, the euro zone crisis should not be thought of as a sovereign debt crisis. ... The key was foreign borrowing. Many of the nations that ran current account deficits—and thus were relying of foreign lending—suffered; none of those running current account surpluses were hit (Baldwin & Giavazzi, 2015).

4.1 Introduction

The divergence of the external balances in Europe, discussed in Chapter 1, is the underlying cause of the European Sovereign Debt crisis, as captured succinctly in the beginning quote. During the crisis, the crisis-hit economies—Ireland, Portugal, Spain and Greece—experienced sudden stop and underwent painful external adjustment cost, in the form of output losses and unemployment (Lane & Milesi-Ferretti, 2014). The role of the

pre-crisis external imbalances leading up to the crisis and the painful external adjustment cost were the basis in which the "Macroeconomic Imbalance Procedure" was introduced by the European Commission in December 2011 (Commission, 2012; Lane, 2013a). The procedure acknowledges one type of risk is fiscal—measured by public sector debt-to-GDP, which is stipulated in the Maastricht Treaty, the other type of risk is country risk, in other words, the sustainability of external balances, measured by the stock imbalances—the net foreign assets-to-GDP and the flow imbalances—the current accounts-to-GDP.

This chapter proposes measures of the sustainability of the external balances, by providing the likelihood of sustainability that is based on a formal model of the stock and flow imbalances, as well as output growths. We illustrate and measure the likelihood of external sustainability according to the Macroeconomic Imbalance Procedure which defines sustainable indicative thresholds for the net foreign assets-to-GDP and the current accounts-to-GDP. The procedure has been implemented on EU countries since 2012, we therefore measure external sustainability based on the empirical sample used in the previous chapter (having investigated the drivers of net foreign assets in the context of European countries).

There are three contributions: first, we propose a new approach, in the literature of external sustainability, to measuring external sustainability i.e. probabilistic statements of the likely occurrence of future sustainability events, in our illustration, event forecasts relating to the Macroeconomic Imbalance Procedure. Second, in our empirical illustration, we evaluate the forecasting performance of the model which generates our measures, investigating the role of behavioural feedbacks and the role of cross-country interactions. Third, our measures are useful description of external sustainability and policy tools to the European Commission, as our measures shows forecasting value.

The Macroeconomic Imbalance Procedure is a new surveillance framework introduced subsequent to the sovereign debt crisis, as part of the annual European semester of macroeconomic surveillance. Under the procedure, the two headline external balances, the net foreign assets-to-GDP and current accounts-to-GDP are included in the monitoring framework, as the crisis highlights the importance of external sustainability. As part of monitoring both the stock and flow imbalances, the surveillance indicates respective thresholds: for the net foreign assets-to-GDP, the threshold of sustainability is -35% of GDP; for the three-year moving average of current accounts-to-GDP, the thresholds of sustainability are specified both the current account deficits and surpluses— -4% and 6% of GDP. We will describe later the macroeconomic reasons of the two-sided sustainable thresholds, i.e. both surpluses and deficits for the current accounts.

We implement the procedure with our proposed sustainability measures by providing the likelihoods, measuring the external balances against the thresholds. More specifically, we propose the **net foreign assets sustainability index**, which is the probability forecast of the net foreign assets in three years' time staying within -35% of GDP, thereby less vulnerable to episodes of sudden stop i.e. shun from the bond market. We also propose the **smoothed net foreign assets sustainability index**[1], which is the probability forecast of the average of the one-year-before, contemporaneous observations and the three-year-ahead net foreign assets forecast staying within -35% of GDP. Subsequently, we propose the **current accounts sustainability index**, which is the probability forecast of the five-year average of two-year-before, one-year-before, contemporaneous current accounts observations, one-year-ahead and two-year-ahead current accounts forecasts staying within -4% and 6% of GDP, thereby less susceptible to the accumulation of net foreign asset or liability position; not undergoing

[1]for reasons discussed later in the text.

painful external adjustment cost during crisis times; and not distorting the structure of the economy during normal times.

Using our empirical sample of twelve EU countries between 1970-2011, we measure the net foreign assets sustainability index and the current accounts sustainability index between 1995 and 2011[2], with a rolling forecasting exercise. In developing our indexes, we pay attention to developing the model which generates the indexes. Within the rolling forecasting exercise, we evaluate the forecasting performance of the Global Vector Auto Regression (GVAR) model against two simpler variants of the GVAR model, a national VAR model and a Global Auto Regression (GAR) model (without macroeconomic feedbacks) as well as the random walk as the benchmark. We first compare the three-year-ahead forecasts with the realizations followed by the event forecasts evaluation, where the event forecasts underlie the sustainability indexes, to evaluate the models in decision-making. We use the GVAR model to generate the sustainability indexes.

Subsequent to generating the indexes, we compare the indexes with the Macroeconomic Imbalance Procedure put in place between 1995 and 2011. The net foreign assets of Greece and Spain, both crisis-hit countries breach -35% threshold in the early 2000s. Our indexes describe usefully the external sustainability defined according, indicating low external sustainability in Greece and Spain. Furthermore, before Greece and Spain breach the 'safe' threshold of country risk (-35%), the net foreign assets sustainability index ascribe low likelihood of staying within the safe threshold earlier on to the decision makers, thereby demonstrating the relevance of the measure, in this illustration, enhancing the preventive role of the procedure in addressing external sustainability.

The chapter is organized as follows: first, we describe the Macroeconomic Imbalance Procedure, highlighting the monitoring of the variables of

[2]This coincides with the period before the crisis when the external balances in Europe began to diverge.

interest—net foreign assets-to-GDP and current account-to-GDP—in the policy framework; we also discuss the theoretical foundations of the proposals. Section 4.3 describes our measure to implement the Macroeconomic Imbalance Procedure. Underpinning our measure is a forecast model, the section also motivates the GVAR modelling framework, commenting its relevance in the context of external balances. Section 4.4 illustrates our measure in our empirical sample and discusses the results.

Relation to Other Chapters This chapter relates to the sustainability of external balances; whereas chapter 2 relates to the sustainability of public sector debt. As we shall see, the sustainability discussion of the external dynamics is similar with the fiscal dynamics.

The similarity also carries on to the literature on assessing the sustainability of a country's external position. For instance, the IMF's debt sustainability assessment described in chapter 2 was used to conduct the sustainability assessment based on foreign debt which is more relevant in debt crises in developing countries (Reinhart & Rogoff, 2011). The only difference in the framework or tool is, instead of looking at the public debt-to-GDP, the foreign debt-to-GDP is used. In addition, Wickens and Uctum (1993) test the sustainability of current account deficits with a VAR of net foreign assets and current accounts, which is a backward-looking approach in the characterization of fiscal indicator literature, which is not dissimilar in this literature; however, the literature is applied less in the context of external balances. Not until recently with the role of external imbalances played in the European crisis, the sustainability of external balances becomes more prominent.

The sustainability thresholds are specific in this chapter as we are interested in characterising our measure in implementing the procedure. But, akin to chapter 2, our approach can accommodate concepts of external sustainability, such as maintaining the same level of net foreign assets-to-

GDP. We also want to promote our measure by drawing direct parallel to the procedure.

4.2 Theoretical Framework: The Sustainability of the External Balances

In this section, we discuss the theoretical framework of external sustainability—we begin with a sustainability analysis which describes debt dynamics in general with its implication on external sustainability. We then move on to the Macroeconomic Imbalance Procedure as an illustration of a policy framework designed to address external sustainability.

4.2.1 Sustainability of Net Foreign Liability Position

The sustainability analysis of net foreign liability position is conditioned on trade surpluses. This can be seen by expressing the net foreign assets as the present discounted value of future trade balances (Obstfeld & Rogoff, 1995):

$$\begin{aligned} \mathrm{NFA_t} &= (\frac{1}{1+\mathrm{r}})\sum_{\mathrm{s=t}}^{\mathrm{s=\infty}}(\frac{1}{1+\mathrm{r}})^{\mathrm{s\text{-}t}}(\mathrm{G_s}+\mathrm{I_s}+\mathrm{C_s}-\mathrm{Y_s}) \\ &= -(\frac{1}{1+\mathrm{r}})\sum_{\mathrm{s=t}}^{\mathrm{s=\infty}}(\frac{1}{1+\mathrm{r}})^{\mathrm{s\text{-}t}}(\mathrm{NX_s}) \end{aligned} \tag{4.1}$$

where $\mathrm{NFA_t}$ is the net foreign assets, r is the interest rate earned on the net foreign assets, G, I, C, Y and NX are government spending, investment, consumption, output and trade balance respectively. There is a negative sign in front of the trade balance, implying that, a net foreign liability position is sustainable depending on the future stream of trade surpluses. Similar to the fiscal dynamics in chapter 2, the sustainability of public sector debt is conditioned on the future stream of primary surpluses.

Net foreign liabilities-to-GDP is the variable of interest in external sustainability. To illustrate the general framework of sustainability analysis, we use the debt stabilizing criterion, discussed in chapter 2, as a starting point of sustainability. That is, the minimal condition would be to prevent net foreign liabilities from getting bigger as a percentage of GDP. Assuming that the economic output (Y), GDP grows at a constant rate g:

$$\mathrm{Y_{t+1}} = (1+\mathrm{g})\mathrm{Y_t}$$

Assuming the growth rate is positive, the change of the net foreign assets—to maintain a constant net foreign liabilities-to-GDP—is equal to the growth rate of the GDP multiply with the current net foreign liabilities:

$$\mathrm{NFA_{t+1}} - \mathrm{NFA_t} = \mathrm{gNFA_t}$$

Assuming zero valuation effects, the change of the net foreign assets is given by the current account, replacing the left-hand-side of the previous equation with the current account:

$$\begin{aligned} \mathrm{rNFA_t} + \mathrm{NX_t} &= \mathrm{gNFA_t} \\ \mathrm{NX_t} &= -(\mathrm{r}-\mathrm{g})\mathrm{NFA_t} \end{aligned} \tag{4.2}$$

It follows from equation 4.2 that if $\mathrm{r} > \mathrm{g}$, the unstable case named in chapter 2, a debtor country must run a trade surplus ($-(\mathrm{r}-\mathrm{g})\mathrm{NFA_t}$) in order to stabilize the ratio of net foreign liabilities to GDP. If $\mathrm{r} < \mathrm{g}$, the stable case named in chapter 2, a debtor country can run a trade deficit equal to $-(\mathrm{r}-\mathrm{g})\mathrm{NFA_t}$ in order to stabilize the ratio of net foreign liabilities to GDP. The stable case or the unstable case plays a key role in sustainability analysis—the sustainability assessment of net foreign liabilities conditioned on the trade balances, which is the non-interest component of the current

account, differ markedly depending on either the stable case or the unstable case.

This general discussion of the dynamics of net foreign liabilities, trade balance, stable and unstable cases is a simple yet powerful description of the debt crises in recent histories and the European Sovereign debt crisis. When the real interest rate and growth rate switches from the stable case to the unstable case, trade balance has to change from deficits to surpluses to maintain a stable debt. In order to achieve this change in trade balance quickly, countries experience sudden stop in capital markets, reduce spending on imports, both of which are associated with recessions.

To illustrate the usefulness of this framework, in the 1970s, emerging market such as Brazil and Mexico were growing quickly; in real term, the world interest rate is low because of high inflation. With a low world interest rate and high growth rate, the stable case, despite running current account deficits, their debt dynamics were sustainable. At the beginning of the 1980s however, there were global recession and big increase in world interest rate—real interest rate and growth rate change sign, in particular, switches from stable to unstable case; debt dynamics which looked sustainable previously was no longer the case, sudden stop occurred and a debt crisis followed (Sachs, 1985). Similarly, in the early 1990s, emerging Asia was enjoying high growth rates; despite borrowing from abroad, their debt dynamics were sustainable. In the late 90s however, growth rates came down, due to the over-accumulation of capital and the mis-allocation of capital into non-traded relative to traded sectors. The fall in growth rate changes the sustainability outlook of the net foreign liability position, sudden stop occurred (Corsetti, Pesenti, & Roubini, 1999; Sachs, Tornell, & Velasco, 1996).

In the European Sovereign Debt crisis, prior to the crisis, countries such as Ireland, Spain, Greece and Portugal were experiencing a combination of

both low world interest rate (for reasons discussed in chapter 3) and good run of economic growth, despite running current account deficits, the external sustainability of these countries appears healthy. However, subsequent to the global financial crisis originating in the US, these countries went into recessions; and the financial crisis saw more scrutiny in the financial markets. Because of the high stock of net foreign liabilities and a downgraded prospects of growth in these economies, financial markets demand higher interest rates on further borrowings which countries rely on: the stable case switches to the unstable case, net foreign liabilities of the crisis-hit economies no longer looks sustainable where countries are required to run trade surpluses to be sustainable, as implied by our sustainability analysis.

To summarize, international lending and borrowings can be fickle (Bluedorn, Duttagupta, Guajardo, & Topalova, 2013); when the stable case switches to the unstable case, there is a crisis risk associated with a large net foreign liability position; furthermore, large trade deficits have to change towards surpluses; as shown by empirical studies (Lane & Milesi-Ferretti, 2012, 2014), this often entails recessions, justifying the case for reduction of external imbalances during normal times. The Macroeconomic Imbalance Procedure is introduced to monitor the sustainability of external balances in EU countries.

4.2.2 Macroeconomic Imbalance Procedure

Under the Macroeconomic Imbalance Procedure, there are the preventive arm—the Alert Mechanism Report—the annual feast of summary statistics produced by Eurostat, designed to be an early warning indicator and the corrective arm—the Excessive Imbalance Procedure—which can fine a country up to 0.1% of GDP if the country is under Country Specific Recommendation and does not comply with the recommendation. As we are implementing our sustainability measures in the context of the Macroeco-

nomic Imbalance Procedure, we first describe briefly the operation of the procedure, followed by a review of theoretical foundations on the proposals of the procedure, particularly on the net foreign assets and the current accounts.

Background The European Commission, subsequent to the European Sovereign Debt crisis, adopts the view that the crisis originates from a loss of competitiveness for the euro area, notably the divergence between the core and periphery countries. The EU institutions adopted a package of legal acts, the 'six pack' that, amongst other things, created the Macroeconomic Imbalance Procedure. The macroeconomic imbalance procedure is a new surveillance procedure designed to prevent and correct macroeconomic imbalances.

Under the macroeconomic imbalance procedure, ten indicators[3] are monitored against their indicative thresholds (Commission, 2012). The Commission conducts annual surveillance based on these indicators, when countries are pointed out for deeper analysis, Country Specific Recommendations are issued to countries in autumn each year. The Commission monitors the progress in the countries receiving the Country Specific Recommendations. In effect, the macroeconomic imbalance procedure integrates into the annual surveillance cycle, called the European semester.

External Imbalances and Growth Performance As pointed out in section 4.1, the sustainability thresholds for the current account balances are two-sided, -4% and 6% of GDP. Earlier in the sustainability analysis, we discuss how large external imbalances are associated with crisis risk. Here

[3]three-year backward moving average current account balance, net foreign assets, five-year percentage change of export market shares, three-year percentage change in nominal unit labour cost, three-year percentage change of the real effective exchange rates, private sector debt, private sector credit flow, changes in the house price index, general government debt and three-year backward moving average of the unemployment rate

we discuss why running persistent and large current account surpluses and deficits distort the structure of the economy, hence unsustainable.

Large and persistent imbalances syptomizes significant inter-sectoral shifts in economic activity between domestic-oriented and export-oriented activities (Blanchard & Milesi-Ferretti, 2010, 2011). Equally, high current account deficits squeezes the export sector, the non-traded sector expands in relative term. Summers (1988) argues the temporary squeezing of the exporting sector may have adverse long-term consequences as traditional traded sectors would require learning-by-doing.

The long-run sustainability constraint implies that, in steady state, creditors would run trade deficits; and debtors would run trade surpluses. This implies, countries which have had persistently large surplus, must at some point switch from export-oriented activities to domestic-oriented activities. This presents reallocation challenge; as persistent current account surpluses countries run the risk of structural under-development of its nontraded sector. In addition, such reallocation poses a challenge for the labour market, because it requries considerable mobility of workers across sectors (Lane, 2013b).

Therefore, large and persistent current account surpluses and deficits distort the structure of economy in terms of traded vs. non-traded sectors during normal economic times. Sustainability implies the current accounts to narrow over time which can pose macroeconomic adjustment challenges; therefore neither persistent current account deficits nor persistent current account surplus is sustainable.

4.3 Measuring the Sustainability of External Balances

We now introduce our approach to measuring the sustainability of external balances—event probability forecasting. As our measure involves model-generated forecasts, we first motivate a formal model of the net foreign assets, the current accounts and the output growths. We illustrate our measures by implementing the Macroeconomic imbalance Procedure.

The Global VAR Modelling Framework We employ the Global VAR modelling framework described in section 2.3.1. The vector of endogenous variables includes the net foreign assets, the current account balance and the output growth. The present value budget constraint in equation (4.1) implies a feedback between the net foreign assets and the trade balance, which is part of the current account. This feedback would be captured by the VAR. The VAR would also capture the feedbacks between output growth and the external balances, as described earlier.

Furthermore, common factors potentially drive the evolution of net foreign assets, current account balances and output growths. As the external balances are bilateral variables, common correlations are expected. In chapter 3, we elaborate how common shocks: the financial shocks, the regional output shocks and the dollar shock can affect the external balances of an economy.

We use the Global VAR modelling framework to accommodate cross-country interdependencies amongst these economic variables of interest. The variables entering the VAR, $\mathbf{x}_{it} = (\mathrm{nfa}_{it}, \mathrm{ca}_{it}, \mathrm{y}_{it})'$ are net foreign assets, current account balance and output. The vector of foreign variables, $\mathbf{x}^*_{it}$ is a cross-section average of the variables in other countries—$\mathbf{x}^*_{it} = \sum_{j \neq i} \frac{x_{jt}}{n-1} (j = 1, \ldots, n)$ where n is the number of countries. The GVAR not only describes the national feedbacks between the macroeco-

nomic variables but also describes the cross-country feedbacks between the variables.

Implementing the Macroeconomic Imbalance Procedure We use the GVAR model to generate density forecasts, discussed earlier in section 2.4. The measures of external sustainability are the density forecasts represented in terms of probability forecasts by defining the events of interest—the event probability forecasts are simply the proportion of density forecasts satisfying the defined events of interest.

We illustrate our measure by implementing the Macroeconomic Imbalance Procedure. Our approach is straightforward to implement the procedure as we compare the density forecasts with the threshold defined in the procedure. We work with the following three indexes:

- the net foreign assets sustainability index—the probability forecasts of the net foreign assets in three years' time staying within the procedure threshold, $\Pr[\text{nfa}_{t+3} \leq -35\%]$;
- the smoothed net foreign assets sustainability index—the probability forecasts of the moving average of the net foreign assets: the previous period, the contemporaneous and the three-year-ahead forecast staying within the procedure threshold, $\Pr[\frac{\text{nfa}_{t-1}+\text{nfa}_t+\text{nfa}_{t+3}}{3} \leq -35\%]$; and
- the current accounts sustainability index—the probability forecasts of the five-year moving average of current accounts: the previous two periods, the previous period, the contemporaneous, the one-year and two-year-ahead forecasts staying within the thresholds, $\Pr[-4\% \leq \frac{\text{ca}_{t-2}+\text{ca}_{t-1}+\text{ca}_t+\text{ca}_{t+1}+\text{ca}_{t+2}}{5} \leq 6\%]$.

Both the net foreign assets sustainability indexes measure the sustainability of a country's net foreign asset position, with the likelihood of staying within -35% of GDP. In relation to the sustainability analysis, staying

within the threshold is less likely to suffer from sudden stop when the stable case switches to the unstable case.

The smoothed net foreign assets sustainability index is defined relative to the first net foreign assets sustainability index as the net foreign assets under consideration is an average of observations and forecasts. This is motivated by the volatile nature of net foreign assets empirics due to the net valuation changes, which is discussed in chapter 3 and has implication on our indexes, as we shall see later.

The current account sustainability index employs the five-year moving average of current account observations and forecasts; in comparison with the procedure which looks at the three-year moving average of current accounts. Implementing the procedure, the current accounts sustainability index has the deficit and the surplus bounds. The index is the likelihood of the average of current accounts observations and forecasts staying within the bounds that are 'healthy'; in relation to the previous discussion, staying within the sustainable bounds imply that during normal times, the traded vs. non-traded sectors of the economy are not distorted, and during crisis times, countries are less likely to suffer from sudden stop; if external adjustment is required, it would be not be as painful as a large external deficits.

4.4 Empirical Illustration: EU12 Countries

The macroeconomic imbalance procedure is implemented in EU countries; therefore I use the same empirical sample in the previous chapter, the EU12 countries between 1970 and 2011. The net foreign assets and the current accounts; and their time series properties are described and investigated in chapter 3. The other variable of the VAR, output growth is sourced from the Total Economy Database (TED), maintained by The Conference

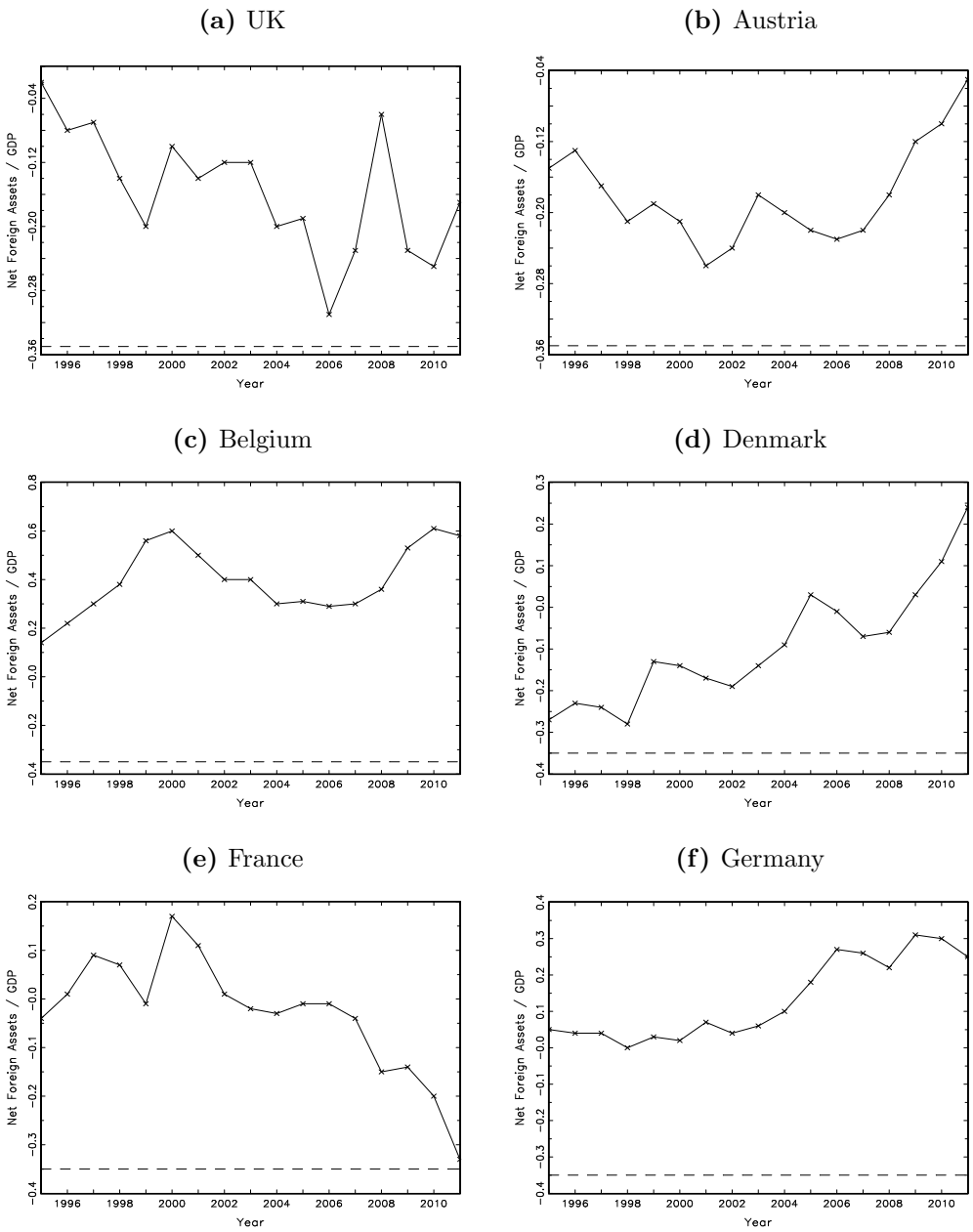
Board[4]. The net foreign assets and the current account balances are unit root process across countries. The unit root tests suggest output growths are stationary in all countries except in Greece and Spain. The variables entering the VAR are therefore net foreign assets in first difference, current accounts in first difference and output growth.

As we are illustrating our sustainability indexes between 1995 and 2011, we can first look at the macroeconomic imbalance procedure applied in our empirical sample. Figure 4.1 plots the EU12 countries' net foreign assets against the -35% of GDP threshold between 1995 and 2011. Greece and Spain breach the -35% threshold in 2000 and 2001 respectively; their net foreign assets have since been deteriorating and remain beyond the bound. Sweden is beyond the threshold at the beginning; but its net foreign assets has been improving and staying within the threshold since 1999.

Figure 4.2 plots the three-year moving average of current account balances against 6% and -4% of GDP between 1995 and 2011. There are six countries, both current account surpluses and current account deficits countries, that breach the bounds. Switzerland has always been beyond the beyond during this period. Germany, Netherlands and Sweden breach the 6% threshold in 2007, 2005 and 2003 respectively and have persisted beyond the threshold. On the deficits side, Greece and Spain breach the -4% threshold and persisted during this period. During the financial and sovereign debt crisis, their current account balances narrowed sharply as a consequence of sudden stop episodes. The other six countries: the UK, Austria, Belgium, Denmark, France and Italy have stayed within the sustainable thresholds during this period.

[4]previously the Groningen Growth and Development Centre

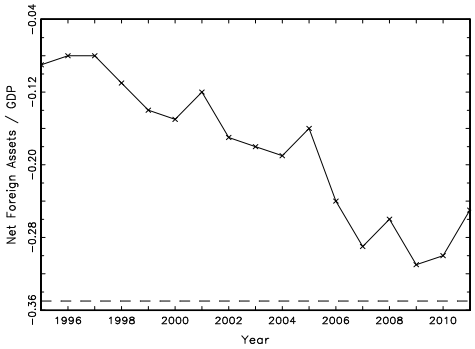
Figure 4.1: The Ratio of Net Foreign Assets to GDP Against The MIP Threshold in the EU12 countries over the period 1995-2011



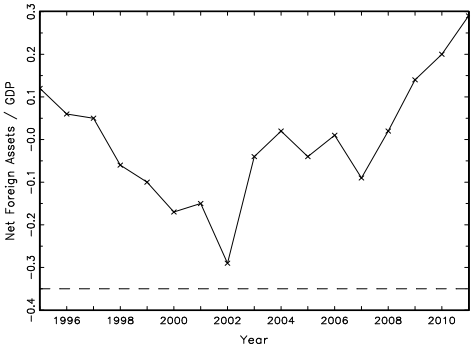
The net foreign assets are measured in terms of the economy's GDP. The dotted line is the zero line; the dashed line is the threshold indicated in the Macroeconomic Imbalance Procedure. Source: Lane and Milesi-Ferretti (2007b).

Figure 4.1: Continued

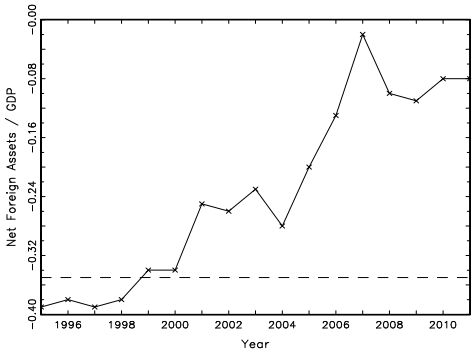
(g) Italy



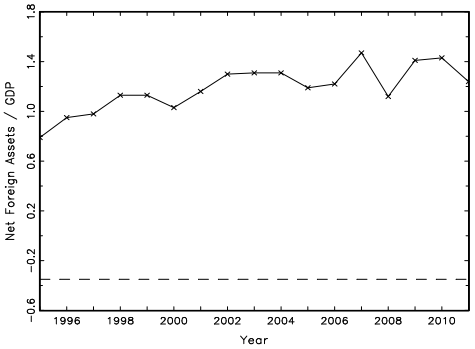
(h) Netherlands



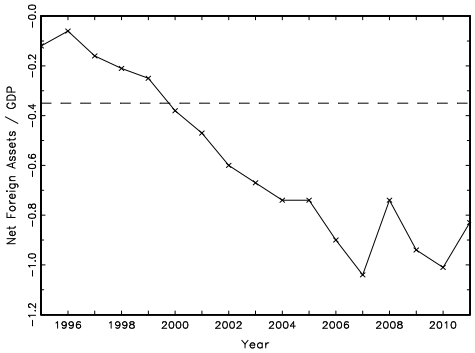
(i) Sweden



(j) Switzerland



(k) Greece



(l) Spain

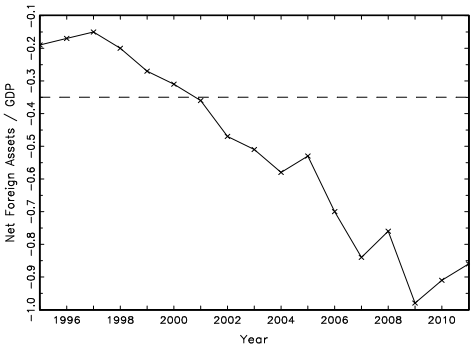
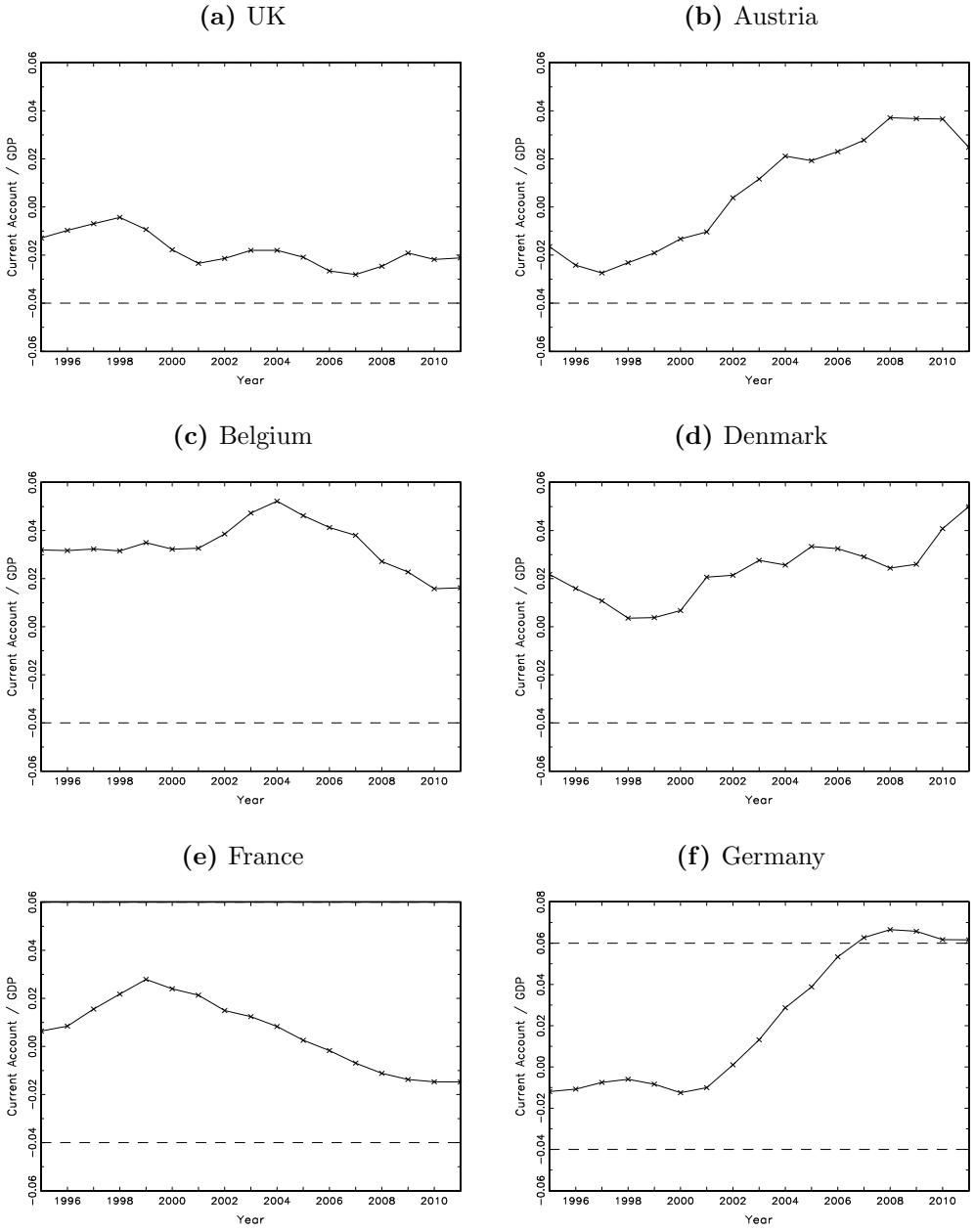


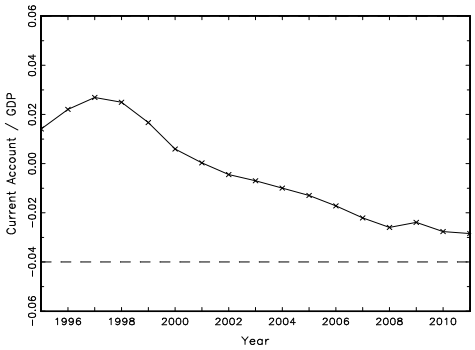
Figure 4.2: The Ratio of Current Account Balances to GDP Against The MIP Thresholds in the EU12 countries over the period 1995-2011



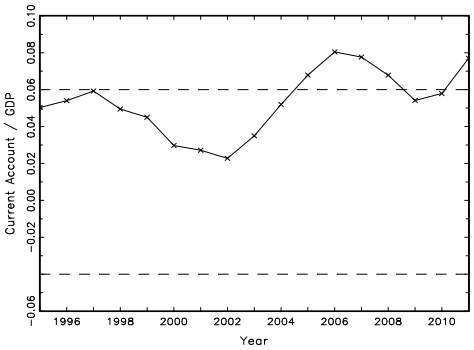
The current account balances are measured in terms of the economy's GDP. The dotted line is the zero line; the dashed lines are the thresholds stipulated in the Macroeconomic Imbalance Procedure. Source: Lane and Milesi-Ferretti (2007b).

Figure 4.2: Continued

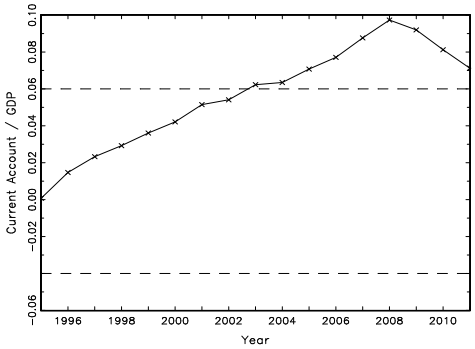
(g) Italy



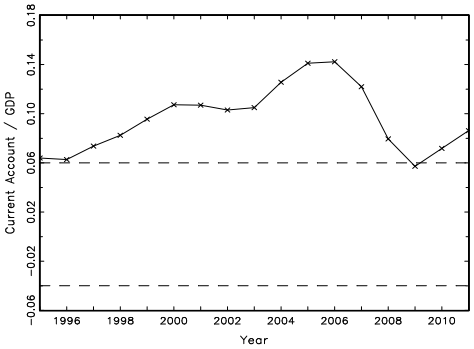
(h) Netherlands



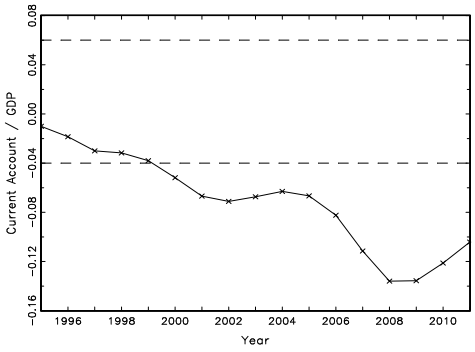
(i) Sweden



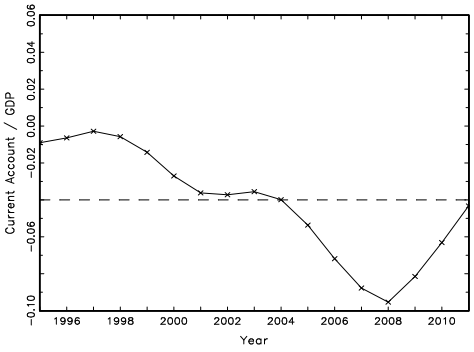
(j) Switzerland



(k) Greece



(l) Spain



4.4.1 Results: Sustainability Measures of External Balances

We illustrate the net foreign assets sustainability indexes and the current accounts sustainability index in a rolling forecasting exercise between 1995 and 2011. Before we provide these measures, we first evaluate the forecasting performance of the GVAR model against the realizations. We also carry out event forecasts evaluation, where the events underlie the sustainability indexes. The forecast evaluation methods are described in section 2.4.

The regression exercise was conducted on a rolling window starting with the estimation window, 1970-1995 and ending with the estimation window, 1983-2008. These sample sizes are relatively arbitrary but made to maximize the estimation period while maintaining a reasonably long period for forecast evaluation. The effective sample in each rolling window is 26 years, modelled in first difference, this becomes 25 years, with leg length equal to one[5], the sample further reduces to 24 years. The suggested maximum coefficients from the literature (Smith & Fuertes, 2010), conventionally is a third of the effective sample i.e. 8. With one lag, four variables including an intercept amount to five coefficients per equation.

In section 4.3, we describe how the present value budget constraint implies feedbacks between the net foreign assets and the current accounts. We also describe how common factors might affect the evolution of net foreign assets and current account balances. Therefore we propose three forecasting models:

- the GVAR model, accounting for both macroeconomic feedbacks and cross-section dependence. The country-by-country estimated model is:

$$\mathbf{\Delta x_{it}} = \mu_{\mathbf{i}} + \mathbf{\Gamma_{1i}} \mathbf{\Delta x_{i,t-1}} + \sum_{j=0}^{1} \mathbf{\Psi_{ji}} \mathbf{\Delta x^{*}_{it-j}} + \varepsilon_{\mathbf{it}}$$

[5]This is with the data constraint in mind. I test the serial correlation based on a lag; it does not violate the no serial correlation assumption.

where the vector of domestic variables, $\mathbf{x_{it}} = (\mathbf{nfa_{it}}, \mathbf{ca_{it}}, \mathbf{ly_{it}})'$, $\mathbf{nfa_{it}}$ is the ratio of net foreign assets to GDP, $\mathbf{ca_{it}}$ is the ratio of current account balances to GDP, $\mathbf{ly_{it}}$ is the logarithmic output; $\mathbf{x^*_{it}}$ is vector of foreign variables; $\mathbf{\Gamma_{1i}}$ is 3×3 matrix and $\mathbf{\Psi_{ji}}$s are diagonal 3×3 matrices. The global system is solved following section 2.3.1.

- the Global Autoregressive (GAR) model, allowing cross-section dependence amongst the dependent variables respectively and excluding excluding feedbacks between the domestic variables. The country-by-country estimated model is same as the GVAR but the coefficient matrix $\mathbf{\Gamma_{1i}}$ is restricted to be diagonal.

- the VAR model, allowing the feedbacks between the variables and excluding feedbacks from the foreign variables. The country-by-country estimated model is restricted version of the GVAR where $\mathbf{\Psi_{ji}}$s are dropped:

$$\mathbf{\Delta x_{it}} = \mu_\mathbf{i} + \mathbf{\Gamma_{1i}} \mathbf{\Delta x_{i,t-1}} + \varepsilon_\mathbf{it}$$

- the random walk with drift, benchmarking against every forecast model:

$$\mathbf{\Delta x_{it}} = \mu_\mathbf{i} + \varepsilon_\mathbf{it}$$

Because of the small sample in each rolling window, in both the GAR and the GVAR models, the feedbacks from foreign variables, $\mathbf{\Psi_{ji}}$s in both the estimated models of GVAR and GAR are restricted to be diagonal. For instance, in the regression of the current account, only the foreign current account is included, neither the foreign net foreign assets nor the foreign output growth is included in the regression.

Specification search is conducted sequentially as described in chapter 3 on the three forecast models, where estimated coefficients whose absolute value of T-ratios are less than one are dropped. In the VAR, the specifica-

tion search is conducted on the lagged dependent variables and not on the drift term. In both the GAR and the GVAR, specification search is conducted on the lagged dependent variable as well as the contemporaneous and lagged cross-section average variable.

Point and Density Forecasts Evaluation As the forecast horizon is three years ahead, the forecast evaluation period starts in 1995 and ends in 2008. There are therefore, fourteen evaluation periods.

For the point forecasts of net foreign assets (Table 4.1), 5/12 countries with the lowest RMSE are the VAR; 2/12 countries with the lowest RMSE are the GVAR; 1/12 country with the lowest RMSE is the GAR. In short, 8/12 countries models with either macroeconomic feedbacks or cross-country interactions or both outperform the random walk. For the point forecasts of output growths, 9/12 countries with the lowest RMSE is the GAR, 1/12 country with the lowest RMSE is the VAR, 1/2 country with the lowest RMSE is the GVAR. In short, cross-section dependence improves the forecasting performance of model across countries. For the point forecasts of current accounts, 3/12 countries with the lowest RMSE are the GVAR, 2/12 countries with the lowest RMSE are the GAR and 1/12 country with the lowest RMSE is the VAR.

In the density forecasts evaluation exercise (Table 4.2), across net foreign assets, output growths and current account balances, modelling cross-country interactions improves models' forecasting performance over the benchmark.

Binary Forecasts Evaluation We evaluate event forecasts which underlie the net foreign assets sustainability index (Table 4.3) and the current accounts sustainability index (Table 4.4). Across countries, the models score fairly similar accuracy rates. The accuracy rates are fairly high in both event forecasts.

Table 4.1: Evaluation of the Three-Step-Ahead Point Forecasts

RMSE for Net Foreign Assets Forecasts				
	RW	VAR	GAR	GVAR
UK	*0.093*	1.046	1.225	1.159
Aus	*0.075*	**0.951***	1.005	0.991
Bel	*0.207*	1.335	1.269	1.291
Den	*0.121*	0.867*	1.023	**0.842***
Fra	*0.112*	**0.921***	0.973	0.968
Ger	*0.086*	0.977*	1.118	**0.972***
Ita	*0.046*	1.127	1.049	1.012
Net	*0.193*	1.016	1.013	1.004
Swe	*0.123*	**0.856***	1.015	0.892*
Swit	*0.176*	1.063	**0.873***	1.005
Gre	*0.180*	**0.953***	1.004	0.984
Spa	*0.140*	**0.964***	1.058	1.046
RMSE for Output Growth Forecasts				
	RW	VAR	GAR	GVAR
UK	*0.023*	**0.981***	1.014	1.047
Aus	*0.019*	1.014	**0.971***	1.032
Bel	*0.016*	1.129	**0.954***	1.018
Den	*0.024*	1.007	0.926*	**0.913***
Fra	*0.017*	1.010	**0.946***	1.030
Ger	*0.025*	1.096	1.007	1.056
Ita	*0.024*	0.978*	**0.901***	0.963*
Net	*0.023*	1.074	**0.955***	1.004
Swe	*0.029*	1.018	**0.951***	0.954*
Swit	*0.019*	1.013	**0.927***	0.931*
Gre	*0.047*	0.988*	**0.964***	0.998
Spa	*0.026*	1.024	**0.909***	1.031
RMSE for Current Account Balances				
	RW	VAR	GAR	GVAR
UK	*0.014*	1.105	1.114	1.128
Aus	*0.021*	0.998	1.008	1.130
Bel	*0.020*	1.234	1.038	1.345
Den	*0.021*	**0.893***	0.967	1.016
Fra	*0.014*	1.129	1.020	1.265
Ger	*0.025*	1.005	0.967*	**0.932***
Ita	*0.017*	1.303	1.009	1.251
Net	*0.036*	0.790*	0.983*	**0.763***
Swe	*0.023*	1.073	1.002	1.094
Swit	*0.056*	0.910*	1.031	**0.908***
Gre	*0.044*	1.090	**0.991***	1.048
Spa	*0.039*	1.053	**0.930***	1.100

Note: The * denotes that the RMSE is significantly lower than that from the random walk model, working at the 10% level of significance, and applying the Giacomini and White (2006) test of equal forecast performance.

Table 4.2: Evaluation of the Three-Step-Ahead Density Forecasts

Average Log Scores for Net Foreign Assets Forecasts				
	RW	VAR	GAR	GVAR
UK	*-1.720*	-0.012	-0.065	-0.029
Aus	*-2.023*	-0.016	-0.004	0.002
Bel	*-2.285*	0.000	0.056*	**0.087***
Den	*-1.918*	0.017*	0.017*	**0.054***
Fra	*-1.872*	0.040*	0.044*	**0.071***
Ger	*-2.067*	0.099*	0.060*	**0.121***
Ita	*-1.845*	0.012	0.020*	**0.052***
Net	*-1.817*	-0.181	-0.188	-0.134
Swe	*-1.974*	-0.037	0.019*	**0.059***
Swit	*-1.661*	-0.090	-0.028	-0.089
Gre	*-2.323*	0.161*	0.141*	**0.183***
Spa	*-2.884*	0.069*	0.077*	**0.099***
Average Log Scores for Output Growth Forecasts				
	RW	VAR	GAR	GVAR
UK	*-1.791*	-0.010	**0.040***	0.035*
Aus	*-1.766*	0.006*	**0.060***	0.019*
Bel	*-1.763*	-0.013	**0.114***	0.077*
Den	*-1.845*	0.015*	**0.113***	0.090*
Fra	*-1.794*	0.003*	**0.126***	0.094*
Ger	*-1.892*	-0.024	**0.132***	0.050*
Ita	*-1.898*	0.034*	**0.148***	0.087*
Net	*-1.947*	-0.008	**0.166***	0.109*
Swe	*-1.978*	0.004	**0.179***	0.145*
Swit	*-1.795*	0.018*	**0.123***	0.112*
Gre	*-2.234*	0.005	**0.149***	0.120*
Spa	*-1.954*	0.032*	**0.168***	0.129*
Average Log Scores for Current Accounts Forecasts				
	RW	VAR	GAR	GVAR
UK	*-1.593*	-0.007	-0.003	-0.018
Aus	*-1.666*	0.000	**0.017***	0.001
Bel	*-1.998*	-0.104	**0.052***	-0.054
Den	*-1.614*	-0.009	-0.033	-0.027
Fra	*-1.665*	-0.050	-0.002	-0.040
Ger	*-1.826*	0.057*	0.080*	**0.089***
Ita	*-1.611*	-0.067	**0.023***	-0.008
Net	*-1.982*	0.046*	0.072*	**0.125***
Swe	*-1.751*	-0.006	**0.020***	0.014*
Swit	*-2.007*	0.052*	0.040*	**0.065***
Gre	*-2.072*	-0.063	**0.058***	-0.020
Spa	*-2.121*	0.044	**0.138***	0.111*

Note: The * denotes that the log predictive score is significantly larger than that from the random walk model, working at the 10% level of significance, and applying Giacomini and White (2006) test of equal forecast performance.

Table 4.3: The Net Foreign Assets Sustainability Index—Event Forecasts Evaluation, 1995-2008

	p	Accuracy Rates				Kuipers Score			
		RW	VAR	GAR	GVAR	RW	VAR	GAR	GVAR
UK	100%	0.93	0.93	**1.00**	**1.00**	NA	NA	NA	NA
Aus	100%	1.00	1.00	1.00	1.00	NA	NA	NA	NA
Bel	100%	1.00	1.00	1.00	1.00	NA	NA	NA	NA
Den	100%	1.00	1.00	1.00	1.00	NA	NA	NA	NA
Fra	100%	1.00	1.00	1.00	1.00	NA	NA	NA	NA
Ger	100%	1.00	1.00	1.00	1.00	NA	NA	NA	NA
Ita	100%	1.00	1.00	1.00	1.00	NA	NA	NA	NA
Net	100%	1.00	1.00	1.00	1.00	NA	NA	NA	NA
Swe	93%	0.64	**0.71**	0.64	**0.71**	0.62	**0.69**	0.62	**0.69**
Swit	100%	1.00	1.00	1.00	1.00	NA	NA	NA	NA
Gre	14%	0.79	0.79	0.79	0.79	0.75	0.75	0.75	0.75
Spa	21%	0.79	0.79	0.79	0.79	0.73	0.73	0.73	0.73

Note: p is the unconditional probability of the event 1995-2010. 'NA' indicates the relevant statistics are not computable.

Table 4.4: The Current Accounts Sustainability Index—Event Forecasts Evaluation, 1995-2008

	p	Accuracy Rates				Kuipers Score			
		RW	VAR	GAR	GVAR	RW	VAR	GAR	GVAR
UK	100%	1.00	1.00	1.00	1.00	NA	NA	NA	NA
Aus	100%	1.00	1.00	1.00	1.00	NA	NA	NA	NA
Bel	100%	1.00	1.00	1.00	1.00	NA	NA	NA	NA
Den	100%	1.00	1.00	1.00	1.00	NA	NA	NA	NA
Fra	100%	1.00	1.00	1.00	1.00	NA	NA	NA	NA
Ger	86%	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Ita	100%	1.00	1.00	1.00	1.00	NA	NA	NA	NA
Net	64%	0.86	**1.00**	0.86	**1.00**	0.69	1.00	0.69	1.00
Swe	50%	0.93	0.93	0.86	**1.00**	0.86	0.86	0.71	**1.00**
Swit	0%	**0.93**	**0.93**	**0.93**	0.86	NA	NA	NA	NA
Gre	21%	0.93	0.93	0.93	0.93	0.91	0.91	0.91	0.91
Spa	57%	0.93	0.93	0.93	0.93	0.83	0.83	0.83	0.83

Note: p is the unconditional probability of the event 1995-2010. 'NA' indicates the relevant statistics are not computable.

Net Foreign Assets Sustainabilty Index Figure 4.3 plots the net foreign assets sustainability index and the smoothed net foreign assets sustainability index in the EU12 countries. The net foreign assets sustainability index is based on the three-year-ahead forecasts; the smoothed net foreign assets sustainability index is based on the three-year moving average of the observations and the forecasts.

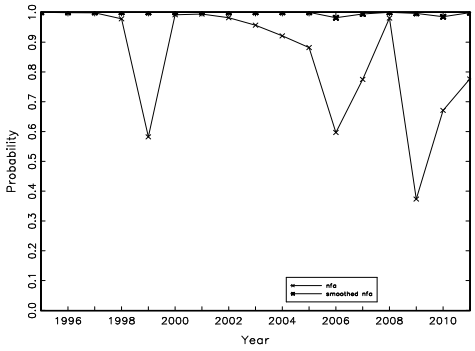
In our empirical sample, as pointed out earlier, Greece and Spain breach the -35% threshold in 2000 and 2001 respectively. In Greece, the net foreign assets sustainability index starts deteriorating in 1997; in Spain, the net foreign assets sustainability index starts deteriorating in 1999—our model-based likelihood of future events could serve as early warning indicator. Inspecting the net foreign assets sustainability indexes in other countries however, the index fluctuates, that is due to the volatile component of the net foreign assets—the net other term, discussed in chapter 3 which includes net valuation changes and measurement error[6].

In response to that, we propose the smoothed net foreign assets sustainability index. The smoothed net foreign assets sustainability index becomes stable; however due to averaging, for instance, the net foreign assets index loses its forecast informational advantage—the index fell in 2000 (Greece) and 2001 (Spain) respectively. Due to the volatile nature of the net foreign assets, the procedure, as it compares the contemporaneous net foreign assets with the threshold, should ascertain the source of the change of net foreign assets in a given year. If the change of net foreign assets is attributed to the current account, the net foreign asset sustainability index can serve as a useful measure.

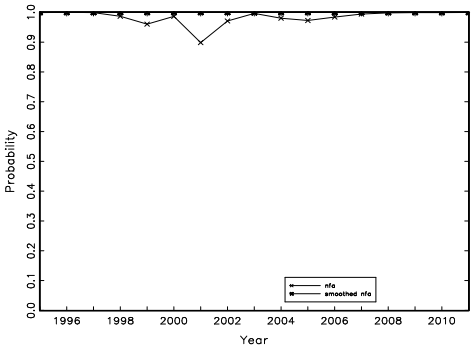
[6]The point at which the index fluctuates can be traced to fluctuation of net foreign assets in Figure 4.1. The historical net other term including net valuation changes and measurement errors can be as high as 56% of GDP, for instance in Greece (Table 3.3).

Figure 4.3: Net Foreign Assets Sustainability Index of the EU12 countries over the period 1995-2011

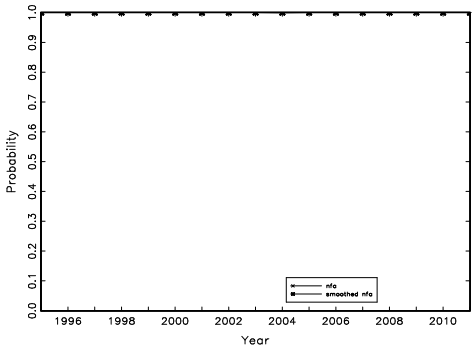
(a) UK



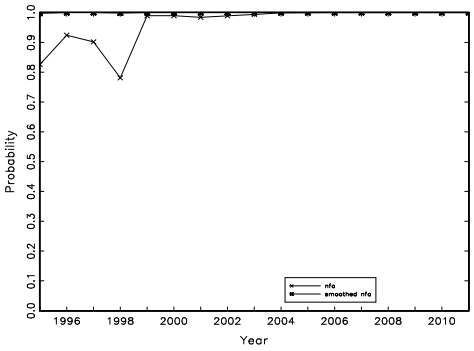
(b) Austria



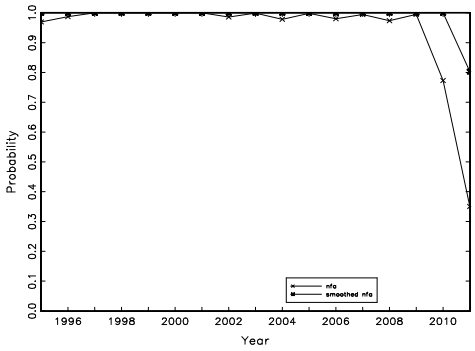
(c) Belgium



(d) Denmark



(e) France



(f) Germany

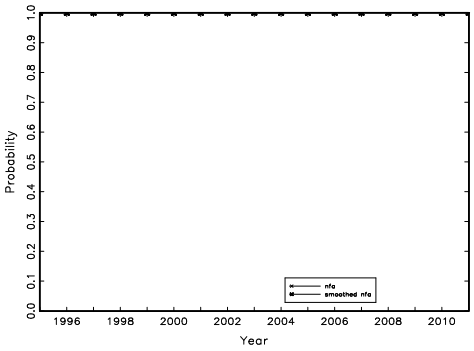
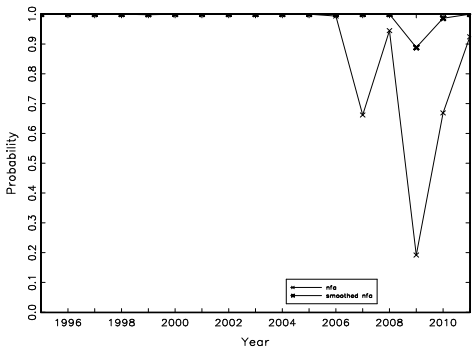
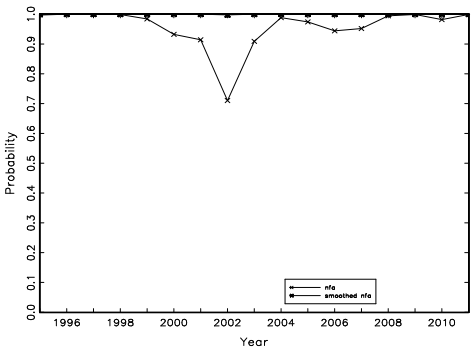


Figure 4.3: Continued

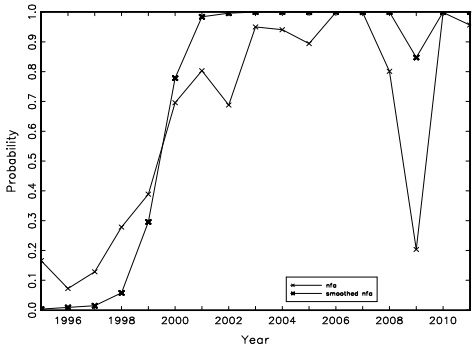
(g) Italy



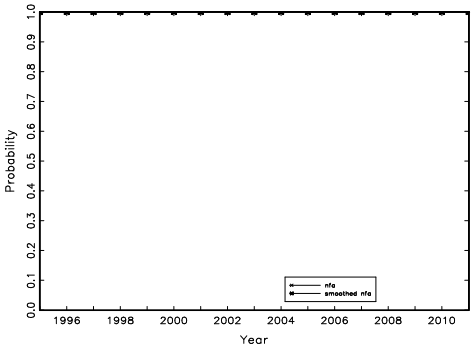
(h) Netherlands



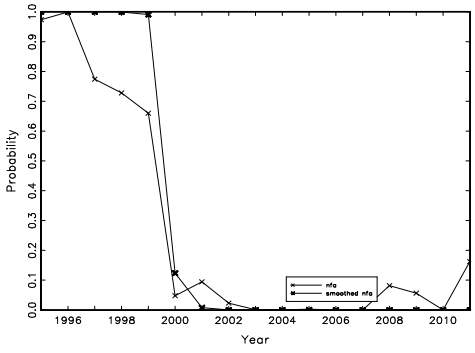
(i) Sweden



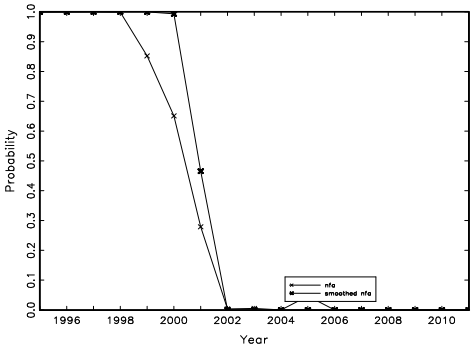
(j) Switzerland



(k) Greece



(l) Spain



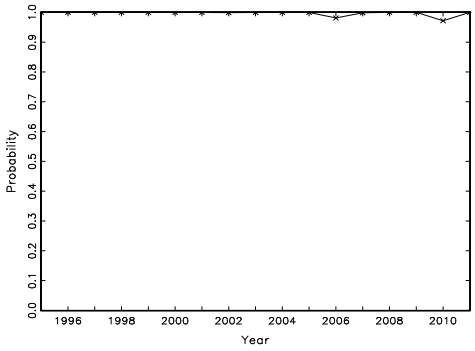
Current Accounts Sustainability Index Figure 4.4 plots the current accounts sustainability index in the EU12 countries. The current accounts sustainability index is based on five-year average of the three-year current accounts observations and one- to two-year current accounts forecasts. There are two points: first, our sustainability measures correspond with the earlier description of comparing countries' three-year moving average current accounts with the thresholds. For countries which stay within the sustainable thresholds (the UK, Austria, Belgium, Denmark, France and Italy) during this period, the index is close to unity in these countries. Second, in other countries (Germany, the Netherlands, Sweden, Switzerland, Greece and Spain), the index not only falls to low likelihood of sustainability but also the movement of the likelihood precedes these countries breaching the threshold, which is the earlier point on the early warning indicator our measures of sustainability can serve[7].

Switzerland's low probability of current accounts sustainability throughout the period highlights the point of maintaining external balances discussed earlier in section 4.2.2: running high and persistent current account surpluses risks distorting the structure of the economy between traded and non-traded sectors of its economy, which poses long-term allocation challenges such as labour in the economy.

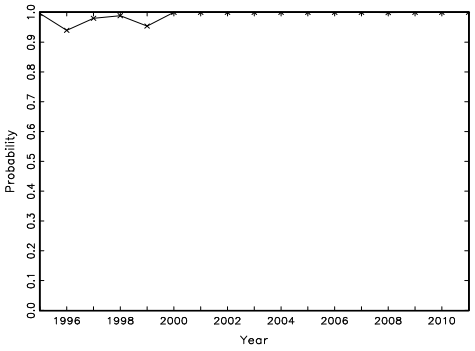
[7]In Germany, the three-year moving average of current account balances breaches the threshold in 2007; the index falls sharply in 2006. The Netherlands breaches the threshold in 2005, the index falls sharply in 2004. Sweden breaches the threshold in 2003, the index has been falling since 2000. Of the current account deficit countries, Greece's breaches the threshold in 2000, the index falls sharply in 1999; Spain breaches the threshold in 2005, the index falls sharply in 2003

Figure 4.4: Current Accounts Sustainability Index of the EU12 countries over the period 1995-2011

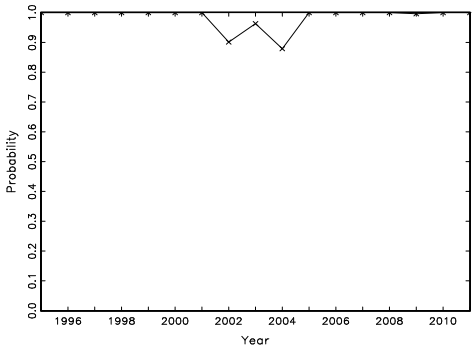
(a) UK



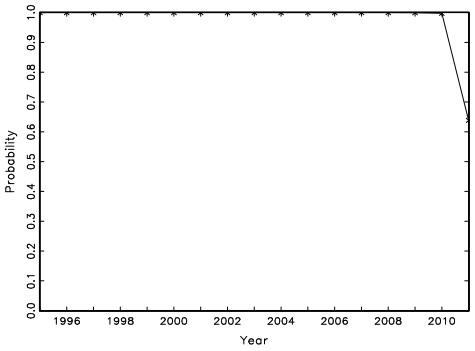
(b) Austria



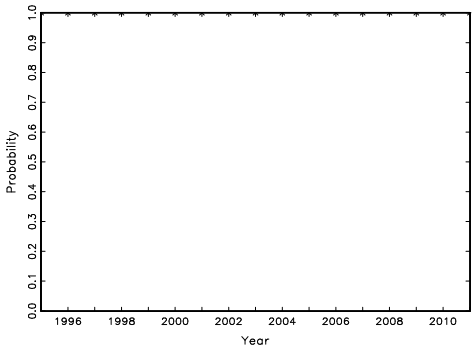
(c) Belgium



(d) Denmark



(e) France



(f) Germany

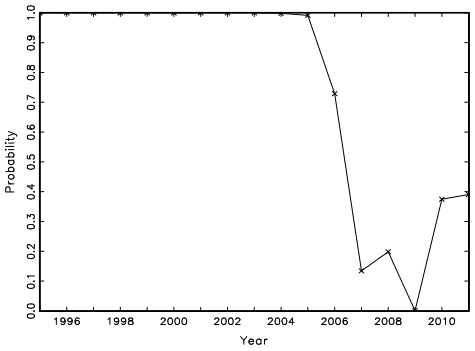
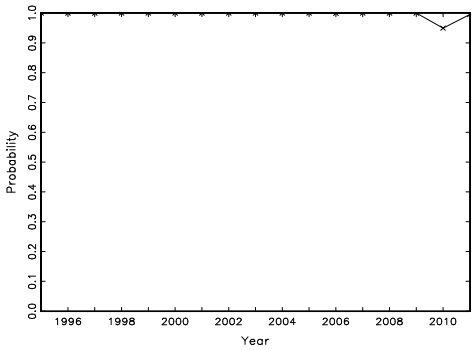
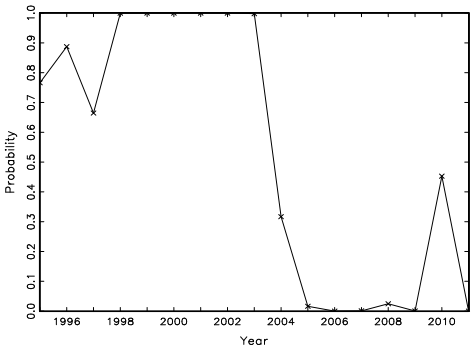


Figure 4.4: Continued

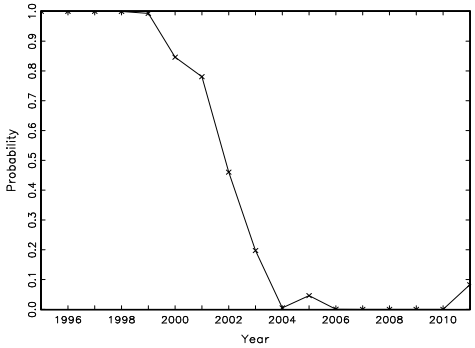
(g) Italy



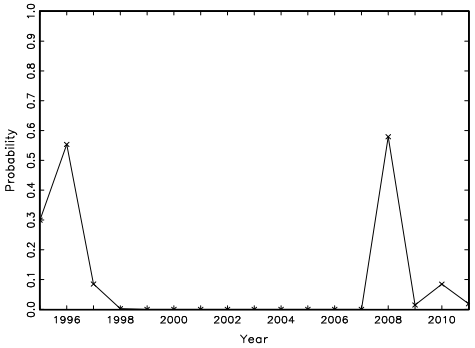
(h) Netherlands



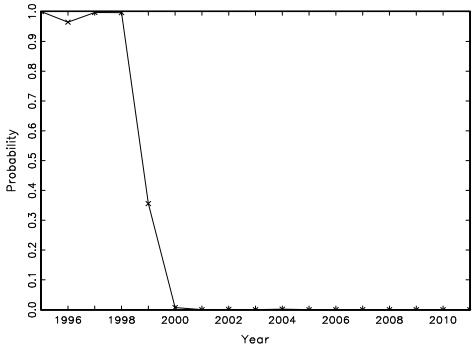
(i) Sweden



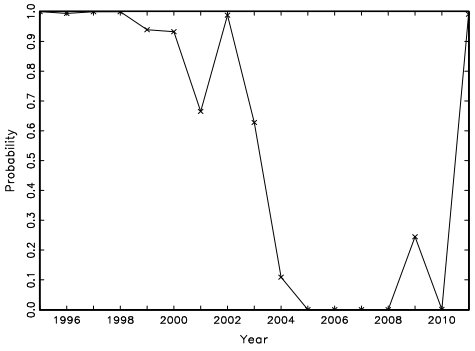
(j) Switzerland



(k) Greece



(l) Spain



4.5 Conclusion

The European Sovereign Debt crisis highlights the sustainability of external balances in the crisis-hit economies. The policy response, the Macroeconomic Imbalance Procedure addresses external sustainability by including the net foreign assets and the current accounts under the surveillance framework.

We propose measuring the likelihood of the sustainability of both the stock and flow imbalances; we implement our measures to the procedure. We develop our measure based on a model which allows for cross-country interactions and macroeconomic feedbacks between net foreign assets, current accounts and output growths. Applying our measure in twelve EU countries between 1970 and 2011, demonstrates its usefulness in measuring sustainability and in serving as early earning indicators, which enhances the preventive aim of the Macroeconomic Imbalance Procedure.

One obvious extension would be to consider debt and equity component separately in the net foreign assets sustainability index. Debt, with its fixed payment obligation is more risky than equity.

Chapter 5

Conclusion

The European Sovereign Debt crisis has brought the sustainability of public finance into prominence; the underlying cause however is the persistent current account imbalances before the crisis, which lead to vulnerably high net foreign liability position in the crisis-hit countries. The policy response, rightly, is that of addressing the sustainability of external balances. This thesis has studied the sustainability of both fiscal and external balances.

Chapter 2 contributes to the literature by proposing a new measure of fiscal sustainability. Sustainability is multi-dimensional—the event probability forecasting approach can accommodate various dimensions of sustainability. Applying our approach on an empirical sample including eight EU countries, shows that our approach offers a rich and complete description of fiscal sustainability.

Chapter 3 investigates the divergence of net foreign assets-to-GDP, which is the variable that measures country risk. As this period coincides with the prominent rise in financial globalization and the expansion of countries' international balance sheets, the chapter characterizes the long-term movement, distinguishing itself from the literature, of net foreign assets in twelve EU countries and investigate the effects of financial integration, the regional economic output and the movements of the dollar on the net

foreign assets. Whilst each of the factors drive net foreign assets in various countries, financial integration is a prominent contributor across countries.

Chapter 4 measures the likelihood of sustainability of net foreign assets and current accounts. In response to the sovereign debt crisis, the European Commission includes both the external balances under its surveillance. We illustrate our measure by implementing the introduced policy. Illustrating on the EU countries, our measures are not only describe countries' sustainability of external balances but also serve as early warning indicators.

Looking ahead, since the crisis, "flow imbalances have narrowed, but considerable stock imbalances remain", as noted by the IMF's World Economic Outlook (IMF, 2014). Our results indicate current account is the driver of net foreign assets in the long-run historically. Despite the larger international balance sheet and growing importance of the net valuation effects, based on the empirics, the valuation channel is not a mechanism to rely on as external adjustment to achieve the long-run budget constraint between debtors and creditors. The Macroeconomic Imbalance Procedure is therefore a right approach to address sustainability of external position in the long-run; only by narrowing surpluses and deficits amongst EU economies, countries' net foreign liabilities could be brought down and countries would be less vulnerable to sudden stop episodes such as the sovereign debt crisis.

Two of the thesis chapters propose sustainability measures of both fiscal balance and external balances. We learn a few things: analysis of fiscal sustainability in practice, in the form of fiscal indicators, the definitions of sustainability underlying the fiscal indicators are various. Policy discussion should consider the various dimensions of fiscal sustainability, importantly the stability condition which has not been considered in the fiscal indicators but grown in relevance in the ongoing macroeconomic discussion on the debt overhang hypothesis (Reinhart & Rogoff, 2010) and the secular

stagnation hypothesis (Teulings & Baldwin, 2014). Our approach to measuring fiscal sustainability are useful in this respect, when it can consider the simultaneous occurrence of different events relating to fiscal sustainability.

We also illustrate our approach to measuring the sustainability of external imbalances by implementing the Macroeconomic Imbalance Procedure. Our measures are forward-looking and model-based: forward-looking makes it useful to decision makers; model-based requires a good description of the economic behaviour of the fiscal and external variables. Our model-based forecasts can be used to serve not only as early warning indicators but also as indexes judging the feasibility of policy measures or announcements. Our model-based, forward-looking and likelihood approach, we hope, would enriches and robustify sustainability analysis in both policy and academic discussions.

Appendix A

Sustainability of Public Sector Debt — Measurement Using Event Probability Forecasts in OECD Countries

Table A.1: ADF Test on the Public Debts

	Country	ADF(1)	ADF(2)	ADF(3)	ADF(4)
1	Bel	-2.43	-2.89	-3.35*	-3.25*
2	Can	-1.49	-2.08	-2.16	-2.14
3	Den	-2.09	-2.47	-2.07	-2.36
4	Fra	-3.22*	-3.00	-2.82	-3.66**
5	Ger	-3.05	-2.97	-3.35*	-2.76
6	Ire	-2.23	-1.82	-1.83	-1.80
7	Ita	-0.96	-1.13	-1.68	-1.44
8	Net	-2.14	-2.35	-2.75	-2.90
9	UK	-0.31	-0.38	-0.10	-0.16
10	US	-2.39	-2.32	-2.31	-2.33
	IPS	0.53	-0.17	-0.52	-0.93

Note: ADF(p) statistics are computed using ADF regressions with **an intercept, a linear trend** and p lagged differences of the dependent variable. The IPS test statistic is the normalised value of the mean of ADF statistics and is compared to the standard normal distribution (Im et al., 2003).

The 1%, 5% and 10% critical values for the ADF tests are -4.154, -3.502 and -3.180.

The 1%, 5% and 10% critical values for the IPS tests are -2.58, -1.96 and -1.64.

'*' denotes significance at the 10%, '**' at the 5% and '***' at the 1% level.

Table A.2: ADF Test on the Growth of Public Debts

	Country	DF	ADF(1)	ADF(2)	ADF(3)
1	Bel	-2.42	-2.00	-1.83	-1.82
2	Can	-5.18***	-3.01	-2.73*	-2.69*
3	Den	-2.83*	-2.38	-2.70*	-2.46
4	Fra	-4.65***	-4.72***	-4.81***	-4.27***
5	Ger	-5.32***	-4.44***	-3.20**	-3.59***
6	Ire	-3.17**	-3.49**	-2.75*	-2.71*
7	Ita	-5.51***	-4.19***	-2.97**	-3.12**
8	Net	-3.78***	-2.79*	-1.65	-1.63
9	UK	-3.85***	-2.57	-2.43	-2.42
10	US	-2.81*	-2.63*	-1.73	-1.80
	IPS	-6.57***	-4.10***	-2.07**	-2.21**

Note: ADF(p) statistics are computed using ADF regressions with **an intercept** and p lagged differences of the dependent variable.

The 1%, 5% and 10% critical values for the ADF tests are -3.568, -2.921 and -2.598.

The 1%, 5% and 10% critical values for the IPS tests are -2.58, -1.96 and -1.64.

Table A.3: CADF Test on the Public Debts

	Country	CADF(1)	CADF(2)	CADF(3)	CADF(4)
1	Bel	-3.58*	-3.97**	-3.47*	-3.90**
2	Can	-1.44	-2.37	-2.25	-2.02
3	Den	-1.64	-2.45	-1.51	-1.94
4	Fra	-3.37	-2.81	-2.74	-3.15
5	Ger	-2.85	-2.86	-3.23	-2.53
6	Ire	-2.89	-2.95	-2.90	-2.80
7	Ita	-0.51	-0.86	-1.05	-1.02
8	Net	-2.37	-2.59	-2.48	-2.49
9	UK	1.02	0.26	-0.23	-0.05
10	US	-1.74	-2.31	-2.52	-1.92
	CIPS	-1.94	-2.29	-2.24	-2.18

Note: CADF(p) statistics are computed using ADF regressions with **an intercept, a linear trend** and p lagged differences of the dependent variable, plus the lagged level and contemporaneous and p lagged differences of the cross-section average. The CIPS test statistic is the cross-section mean of the CADF tests. The critical values are tabulated in Pesaran (2007).

The 1%, 5% and 10% critical values for the CADF tests are -4.49, -3.78 and -3.44.

The 1 %, 5% and 10% critical values for the CIPS tests are -3.06, -2.84 and -2.73.

Table A.4: CADF Test on the Growth of Public Debts

	Country	CDF	CADF(1)	CADF(2)	CADF(3)
1	Bel	-3.57**	-2.87	-3.42**	-3.22*
2	Can	-6.18***	-3.11*	-2.82	-2.85
3	Den	-3.29**	-2.96	-3.52**	-2.81
4	Fra	-4.77***	-4.96***	-5.05***	-4.40***
5	Ger	-5.09***	-4.02***	-3.08*	-3.36**
6	Ire	-3.83**	-3.56**	-2.20	-1.49
7	Ita	-6.05***	-4.21***	-3.01*	-2.85
8	Net	-6.00***	-3.59**	-3.01*	-2.84
9	UK	-4.47***	-2.86	-2.32	-2.16
10	US	-3.48**	-2.80	-2.04	-2.42
	CIPS	-4.67***	-3.49***	-3.05***	-2.84***

Note: CADF(p) statistics are computed using ADF regressions with **an intercept**, p lagged differences of the dependent variable, plus the lagged level and contemporaneous and p lagged differences of the cross-section average. The CIPS test statistic is the cross-section mean of the CADF tests. The critical values are tabulated in Pesaran (2007).

The 1%, 5% and 10% critical values for the CADF tests are -3.94, -3.29 and -2.94.

The 1 %, 5% and 10% critical values for the CIPS tests are -2.55, -2.33 and -2.21.

Table A.5: ADF Test on the Real Interest Rates

	Country	ADF(1)	ADF(2)	ADF(3)	ADF(4)
1	Bel	-2.18	-2.72	-2.54	-1.86
2	Can	-1.90	-2.32	-1.74	-1.86
3	Den	-1.80	-1.21	-1.47	-0.96
4	Fra	-1.73	-1.54	-1.17	-1.28
5	Ger	-2.09	-1.97	-2.06	-2.55
6	Ire	-2.59	-2.63	-1.94	-1.94
7	Ita	-2.47	-2.06	-2.61	-1.77
8	Net	-1.55	-1.37	-1.31	-1.47
9	UK	-2.52	-2.35	-1.66	-1.65
10	US	-2.90	-2.39	-2.29	-1.73
	IPS	-0.01	0.14	0.75	1.03

Note: ADF(p) statistics are computed using ADF regressions with **an intercept, a linear trend** and p lagged differences of the dependent variable. The IPS test statistic is the normalised value of the mean of ADF statistics and is compared to the standard normal distribution (Im et al., 2003).

The 1%, 5% and 10% critical values for the ADF tests are -4.154, -3.502 and -3.180.

The 1%, 5% and 10% critical values for the IPS tests are -2.58, -1.96 and -1.64.

'*' denotes significance at the 10%, '**' at the 5% and '***' at the 1% level.

Table A.6: ADF Test on the Change of Real Interest Rates

	Country	DF	ADF(1)	ADF(2)	ADF(3)
1	Bel	-7.00***	-4.27***	-4.05***	-4.71***
2	Can	-7.87***	-4.49***	-4.89***	-3.91***
3	Den	-8.44***	-6.97***	-4.34***	-4.62***
4	Fra	-8.04***	-5.95***	-6.46***	-4.44***
5	Ger	-10.35***	-6.23***	-4.50***	-3.24**
6	Ire	-7.17***	-4.90***	-5.50***	-4.29***
7	Ita	-6.49***	-5.85***	-3.64***	-4.67***
8	Net	-9.37***	-6.08***	-4.70***	-3.63***
9	UK	-9.71***	-6.27***	-6.39***	-4.74***
10	US	-6.43***	-5.83***	-4.83***	-5.10***
	IPS	-21.83***	-13.06***	-9.98***	-8.00***

Note: ADF(p) statistics are computed using ADF regressions with **an intercept** and p lagged differences of the dependent variable.

The 1%, 5% and 10% critical values for the ADF tests are -3.568, -2.921 and -2.598.

The 1%, 5% and 10% critical values for the IPS tests are -2.58, -1.96 and -1.64.

Table A.7: CADF Test on the Real Interest Rates

	Country	CADF(1)	CADF(2)	CADF(3)	CADF(4)
1	Bel	-3.95**	-4.96***	-4.88***	-6.06***
2	Can	-5.31***	-5.23***	-3.72*	-3.99**
3	Den	-2.11	-1.26	-1.27	-0.84
4	Fra	-3.59*	-3.91**	-5.10***	-4.97***
5	Ger	-4.36**	-3.47*	-3.03	-3.70*
6	Ire	-2.79	-1.88	-1.28	-1.40
7	Ita	-2.24	-1.07	-1.33	-2.88
8	Net	-2.49	-2.00	-1.22	-1.34
9	UK	-3.77*	-2.91	-1.33	-1.06
10	US	-4.47**	-3.67*	-3.95**	-3.41
	CIPS	-3.51***	-3.03**	-2.71	-2.96**

Note: CADF(p) statistics are computed using ADF regressions with **an intercept, a linear trend** and p lagged differences of the dependent variable, plus the lagged level and contemporaneous and p lagged differences of the cross-section average. The CIPS test statistic is the cross-section mean of the CADF tests. The critical values are tabulated in Pesaran (2007).

The 1%, 5% and 10% critical values for the CADF tests are -4.49, -3.78 and -3.44.

The 1 %, 5% and 10% critical values for the CIPS tests are -3.06, -2.84 and -2.73.

Table A.8: CADF Test on the Change of Real Interest Rates

	Country	CDF	CADF(1)	CADF(2)	CADF(3)
1	Bel	-6.76***	-4.92***	-4.92***	-4.34***
2	Can	-8.03***	-6.01***	-7.04***	-4.71***
3	Den	-8.43***	-7.06***	-4.59***	-4.48***
4	Fra	-9.20***	-7.09***	-7.79***	-5.39***
5	Ger	-9.43***	-7.37***	-5.68***	-3.93***
6	Ire	-6.20***	-5.54***	-4.65***	-3.44***
7	Ita	-8.58***	-8.08***	-4.44***	-3.40***
8	Net	-9.63***	-6.48***	-6.23***	-4.02***
9	UK	-9.04***	-7.11***	-8.75***	-5.78***
10	US	-5.46***	-5.73***	-4.51***	-4.70***
	CIPS	-8.08***	-6.54***	-5.86***	-4.42***

Note: CADF(p) statistics are computed using ADF regressions with **an intercept**, p lagged differences of the dependent variable, plus the lagged level and contemporaneous and p lagged differences of the cross-section average. The CIPS test statistic is the cross-section mean of the CADF tests. The critical values are tabulated in Pesaran (2007).

The 1%, 5% and 10% critical values for the CADF tests are -3.94, -3.29 and -2.94.

The 1 %, 5% and 10% critical values for the CIPS tests are -2.55, -2.33 and -2.21.

Table A.9: ADF Test on the Output Growths

	Country	ADF(1)	ADF(2)	ADF(3)	ADF(4)
1	Bel	-3.93**	-3.38*	-2.68	-3.12
2	Can	-4.22***	-3.99**	-3.55**	-3.03
3	Den	-5.41***	-3.65**	-3.59**	-2.95
4	Fra	-4.01**	-3.19*	-3.00	-2.86
5	Ger	-6.21***	-4.79***	-3.85**	-3.52**
6	Ire	-3.05	-1.90	-1.92	-1.16
7	Ita	-5.97***	-5.25***	-5.01***	-4.09***
8	Net	-3.60**	-3.55**	-2.75	-2.10
9	UK	-4.98***	-3.70**	-3.42*	-3.01
10	US	-5.17***	-4.48***	-4.26***	-3.27*
	IPS	-9.16***	-6.16***	-4.61***	-3.10***

Note: ADF(p) statistics are computed using ADF regressions with **an intercept, a linear trend** and p lagged differences of the dependent variable. The IPS test statistic is the normalised value of the mean of ADF statistics and is compared to the standard normal distribution (Im et al., 2003).

The 1%, 5% and 10% critical values for the ADF tests are -4.158, -3.504 and -3.181.

The 1%, 5% and 10% critical values for the IPS tests are -2.58, -1.96 and -1.64.

'*' denotes significance at the 10%, '**' at the 5% and '***' at the 1% level.

Table A.10: CADF Test on the Output Growths

	Country	CADF(1)	CADF(2)	CADF(3)	CADF(4)
1	Bel	-3.01	-3.19	-2.70	-2.90
2	Can	-4.36**	-3.97**	-3.43	-3.63*
3	Den	-5.53***	-3.49*	-4.36**	-3.64*
4	Fra	-3.98**	-3.67*	-3.55*	-3.52*
5	Ger	-3.44*	-2.93	-2.39	-2.11
6	Ire	-3.05	-1.46	-1.49	-1.31
7	Ita	-5.31***	-6.03***	-5.00***	-3.78**
8	Net	-3.64*	-3.22	-2.92	-2.16
9	UK	-4.32**	-3.78**	-3.21	-3.06
10	US	-4.82***	-4.26**	-3.95**	-3.69*
	CIPS	-4.15***	-3.60***	-3.30***	-2.98**

Note: CADF(p) statistics are computed using ADF regressions with **an intercept, a linear trend** and p lagged differences of the dependent variable, plus the lagged level and contemporaneous and p lagged differences of the cross-section average. The CIPS test statistic is the cross-section mean of the CADF tests. The critical values are tabulated in Pesaran (2007).

The 1%, 5% and 10% critical values for the CADF tests are -4.49, -3.78 and -3.44.

The 1 %, 5% and 10% critical values for the CIPS tests are -3.06, -2.84 and -2.73.

Table A.11: Preferred Specification of the Cointegrated VAR

Country	Endo	Exo	D	k	Rank	Modulus of Roots
Bel	d, r	d^*, r^*		2	2	0.78, 0.78, 0.11, 0.11
Can	d, r	d^*, r^*		2	2	0.85, 0.31, 0.09
Den	d, r	d^*, r^*		2	1	1, 0.72, 0.31, 0.31
Fra	d, r	d^*, r^*		3	2	0.84, 0.69, 0.45
Ger	r, r^*		D^b_{67}	2	1	1,0.44,0.44,0.39
Ire	r, r^*		D^b_{78}	2	1	1, 0.36, 0.36, 0.20
Ita	r, r^*			2	1	1, 0.49, 0.43
Net	d, r	d^*, r^*	D^b_{08}	2	2	0.85, 0.66, 0.23, 0.22
UK	r, r^*		D^b_{75}	2	1	1, 0.39, 0.29, 0.29
US	d, r	d^*, r^*	D^b_{08}	2	2	0.85, 0.61, 0.61, 0.36

D is dummy of the model, k is the lag length of the model, rank refers to that of the $\mathbf{\Pi}$ matrix.

Table A.12: Model Misspecification (cont'd), 1958-2010

Country	$\chi^2_{SC}(4)$	$\chi^2_H(9)$	$\chi^2_N(4)$
Bel	3.496	13.564	0.506
Can	4.116	19.679*	2.723
Den	3.263	9.179	12.429*
Fra	4.418	10.408*	11.115
Ger	1.220	6.705	1.407
Ire	3.834	20.024*	5.119
Ita	13.489*	15.314*	10.270*
Net	7.764	16.483	1.760
UK	6.337	19.584*	8.727
US	1.071	2.324	2.716

"*" indicates significance at the 5% level. The diagnostics test statistics of serial correlation (SC), heteroscedasticity (H) and normality (N) can be compared with the χ^2 distribution. The 5% critical values of $\chi^2(4)$, $\chi^2(9)$ and $\chi^2(4)$ are ...

Table A.13: Cointegration Rank Statistics

Country	H_0	H_1	Test Statistic	95% C.V.	90% C.V.
Bel	$r = 0$	$r = 1$	51.46**	31.66	29.13
	$r \leq 1$	$\mathbf{r = 2}$	20.35**	16.49	13.85
Can	$r = 0$	$r = 1$	36.86**	32.23	29.07
	$r \leq 1$	$\mathbf{r = 2}$	16.39**	15.73	13.53
Den	$r = 0$	$r = 1$	34.30**	31.21	28.59
	$\mathbf{r \leq 1}$	$r = 2$	13.11	16.19	13.60
Fra	$r = 0$	$r = 1$	46.58**	32.07	29.22
	$r \leq 1$	$\mathbf{r = 2}$	19.15**	16.09	14.16
Ger	$r = 0$	$r = 1$	25.79**	21.30	18.81
	$\mathbf{r \leq 1}$	$r = 2$	4.44	10.09	8.47
Ire	$r = 0$	$r = 1$	22.28**	22.02	19.58
	$\mathbf{r \leq 1}$	$r = 2$	2.67*	10.31	8.45
Ita	$r = 0$	$r = 1$	19.76*	21.99	19.44
	$\mathbf{r \leq 1}$	$r = 2$	2.80	10.36	8.73
Net	$r = 0$	$r = 1$	39.33**	32.28	29.20
	$\mathbf{r \leq 1}$	$r = 2$	13.08	16.64	14.14
UK	$r = 0$	$r = 1$	38.18**	20.90	18.65
	$\mathbf{r \leq 1}$	$r = 2$	3.41	9.84	8.33
US	$r = 0$	$r = 1$	63.19**	31.77	28.40
	$r \leq 1$	$\mathbf{r = 2}$	21.00**	15.76	13.61

Notes: The test statistic is the trace test statistic. '**' indicates statitical significance at 5%, '*' at 10%

Table A.14: Test of the Identifying Restrictions on Cointegrating Vectors

Country	Rank	Cointegrating vector β					$\chi^2(v)$	p-value
		d	r	d^*	r^*	μ		
Bel	2	1	-9.67	-0.55	0	-2.27	0.015 (1)	0.90
		0	1	0	-0.88	-0.01		
Can	2	1	-16.51	0	0	-3.36	0.861 (3)	0.83
		0	1	0	-1	-0.02		
Den	1	1	-50.51	-3.02	27.31	8.46	-(0)	-
Fra	2	1	0	-1.90	6.71	3.25	1.43 (1)	0.49
		0	1	0	-1	0.002		
Ger	1	-	1	-	-1.19	0.01	-	-
Ire	1	-	1	-	-1	-0.02	0.242 (1)	0.62
Ita	1	-	1	-	-1	-0.01	0.521 (1)	0.47
Net	2	1	-25.19	0.65	0	-6.58	0.01 (1)	0.92
		0	1	0	-0.65	0.01		
UK	1	-	1	-	-0.88	-0.002	- (0)	-
US	2	1	0	-1	0	-0.67	1.96 (3)	0.58
		0	1	0	-0.67	0.01		

Table A.15: Determination of the Cointegration Rank

Country	r	Root	Cointegrating vector β				
			d	r	d^*	r^*	μ
Bel	2	0.78	1	-9.67	-0.55	0	-2.27
			(-)	(-10.89)	(-9.65)	(-)	(-9.68)
			0	1	0	-0.88	-0.01
			(-)	(-)	(-)	(-10.40)	(-0.99)
Can	2	0.85	1	-16.51	0	0	-3.36
			(-)	(-8.23)	(-)	(-)	(-22.60)
			0	1	0	-1	-0.02
			(-)	(-)	(-)	(-)	(-2.87)
Den	1	0.72	1	-50.51	-3.02	27.31	8.46
			(-)	(-6.22)	(-5.98)	(2.71)	(4.77)
Fra	2	0.81	1	0	-1.90	6.71	3.25
			(-)	(-)	(-18.85)	(5.56)	(8.09)
			0	1	0	-1	0.00
			(-)	(-)	(-)	(-)	(0.42)
Ger	1	0.44	-	1	-	-1.19	0.01
			(-)	(-)	(-)	(-10.42)	(1.47)
Ire	1	0.36	0	1	0	-1.41	0.00
			(-)	(-)	(-)	(-7.84)	(-2.46)
Ita	1	0.49	0	1	0	-1	-0.01
			(-)	(-)	(-)	(-)	(-1.06)
Net	2	0.85	1	-25.19	0.65	0	-6.58
			(-)	(-8.07)	(3.93)	(-)	(-9.46)
			0	1	0	-0.65	0.01
			(-)	(-)	(-)	(-5.77)	(0.92)
UK	1	0.39	0	1	0	-0.88	-0.00
			(-)	(-)	(-)	(-10.89)	(-0.48)
US	2	0.77	1	0	-1	0	-0.67
			(-)	(-)	(-)	(-)	(-8.38)
			0	1	0	-0.67	0.01
			(-)	(-)	(-)	(-7.44)	(1.70)

Root is the largest characteristic root of the restricted cointegrated VARX model (corresponding with the cointegration rank). r is the cointegration rank.

Appendix B

The Sources and Persistent Effects of Shocks to the Net Foreign Assets in the EU Countries

Table B.1: ADF Test on the Net Foreign Assets

	Country	ADF(1)	ADF(2)	ADF(3)	ADF(4)
1.	UK	-2.21	-1.71	-2.13	-1.66
2.	Austria	-1.67	-0.22	-0.93	-0.98
3.	Belgium	-2.50	-2.24	-2.33	-2.22
4.	Denmark	-0.82	-0.73	-0.57	-0.58
5.	France	-2.13	-2.06	-2.31	-1.88
6.	Germany	-1.81	-1.90	-2.39	-3.29*
7.	Italy	-2.79	-2.07	-2.30	-2.32
8.	Nether.	-0.73	-1.02	-0.99	-0.85
9.	Sweden	-0.83	-0.68	-0.52	-1.21
10.	Swit.	-2.5	-2.76	-2.58	-2.21
11.	Greece	-1.45	-1.23	-2.09	-2.07
12.	Spain	-0.57	-0.12	-0.72	0.46
	IPS	2.03	2.79	1.68	1.66

Note: ADF(p) statistics are computed using ADF regressions with **an intercept, a linear trend** and p lagged differences of the dependent variable. The IPS test statistic is the normalised mean of the ADF statistics and compared to the standard normal distribution (Im et al., 2003).

The 1%, 5% and 10% critical values for the ADF tests are -2.63, -2.50 and -2.42.

The 1%, 5% and 10% critical values for the IPS tests are -2.58, -1.96 and -1.64.

'*' denotes significance at the 10%, '**' at the 5% and '***' at the 1% level.

Table B.2: ADF Test on the First Difference of Net Foreign Assets

	Country	DF	ADF(1)	ADF(2)	ADF(3)
1	UK	-7.07***	-6.16***	-3.19**	-3.88***
2	Austria	-5.21***	-5.64***	-2.73*	-2.13
3	Belgium	-3.39***	-3.39**	-2.79*	-2.74**
4	Denmark	-4.88***	-3.19**	-2.79*	-1.81
5	France	-5.79***	-4.60***	-2.94**	-3.23**
6	Germany	-4.77***	-3.67***	-2.67*	-2.14
7	Italy	-6.17***	-5.57***	-3.93***	-3.39**
8	Nether.	-8.22***	-4.25***	-3.30**	-3.00**
9	Sweden	-5.95***	-4.20***	-3.40**	-2.21
10	Swit.	-9.79***	-7.37***	-3.91***	-3.86***
11	Greece	-6.38***	-4.80***	-2.31	-2.28
12	Spain	-7.31***	-4.21***	-2.59	-2.86*
	IPS	-19.68***	-13.08***	-6.31***	-5.17***

Note: ADF(p) statistics are computed using ADF regressions with **an intercept** and p lagged differences of the dependent variable.

The 1%, 5% and 10% critical values for the ADF tests are -3.60, -2.93 and -2.60.

The 1%, 5% and 10% critical values for the IPS tests are -2.58, -1.96 and -1.64.

Table B.3: CADF Test on the Net Foreign Assets

	Country	CADF(1)	CADF(2)	CADF(3)	CADF(4)
1.	UK	-3.44	-2.93	-3.37	-2.83
2.	Austria	-1.89	-0.18	-1.03	-1.14
3.	Belgium	-3.66*	-2.71	-3.48*	-2.42
4.	Denmark	-2.19	-2.35	-2.20	-2.50
5.	France	-0.99	-1.05	-2.95	-2.41
6.	Germany	-2.00	-2.10	-2.58	-3.09
7.	Italy	-1.89	-0.91	-1.39	-0.73
8.	Nether.	-1.94	-0.99	-1.57	-1.37
9.	Sweden	-1.44	-0.87	-0.94	-1.00
10.	Swit.	-3.47*	-2.58	-2.97	-2.09
11.	Greece	-1.24	-0.80	-1.72	-1.46
12.	Spain	0.03	0.72	0.08	2.08
	CIPS	-2.01	-1.40	-2.01	-1.58

Note: CADF(p) statistics are computed using ADF regressions with **an intercept, a linear trend** and p lagged differences of the dependent variable, plus the lagged level and contemporaneous and p lagged differences of the cross-section average. The CIPS test statistic is the cross-section mean of the CADF tests. The critical values are tabulated in Pesaran (2007).

The 1%, 5% and 10% critical values for the CADF tests are -4.58, -3.82 and -3.46.

The 1 %, 5% and 10% critical values for the CIPS tests are -3.08, -2.85 and -2.73.

Table B.4: CADF Test on the First Difference of Net Foreign Assets

	Country	CDF	CADF(1)	CADF(2)	CADF(3)
1.	UK	-6.93***	-6.12***	-3.31*	-4.02**
2.	Austria	-5.30***	-5.90***	-2.86	-2.27
3.	Belgium	-3.24*	-4.29***	-2.97*	-3.78**
4.	Denmark	-5.43***	-3.60**	-3.10*	-2.54
5.	France	-5.94***	-3.78**	-1.75	-2.25
6.	Germany	-4.32**	-3.30*	-2.51	-2.26
7.	Italy	-5.42***	-5.38***	-2.89	-2.97*
8.	Nether.	-8.65***	-4.42***	-2.80	-2.92
9.	Sweden	-5.58***	-4.35***	-3.00*	-2.14
10.	Swit.	-9.51***	-7.79***	-3.77**	-4.24***
11.	Greece	-6.51***	-4.87***	-2.03	-1.88
12.	Spain	-6.61***	-3.33**	-1.50	-1.63
	CIPS	-6.12***	-4.76***	-2.71***	-2.74***

Note: CADF(p) statistics are computed using ADF regressions with **an intercept**, p lagged differences of the dependent variable, plus the lagged level and contemporaneous and p lagged differences of the cross-section average. The CIPS test statistic is the cross-section mean of the CADF tests. The critical values are tabulated in Pesaran (2007).

The 1%, 5% and 10% critical values for the CADF tests are -4.02, -3.32 and -2.95.

The 1 %, 5% and 10% critical values for the CIPS tests are -2.56, -2.33 and -2.21.

Table B.5: ADF Test on the Current Account Balances

	Country	ADF(1)	ADF(2)	ADF(3)	ADF(4)
1.	UK	-3.12***	-2.69***	-2.58**	-2.63**
2.	Austria	-2.75***	-2.46*	-2.29	-3.39***
3.	Denmark	-2.83***	-2.71***	-3.20***	-3.19***
4.	France	-1.34	-1.58	-1.75	-1.22
5.	Germany	-1.93	-1.79	-2.22	-2.76***
6.	Italy	-2.65***	-2.58**	-2.32	-2.06
7.	Nether.	-3.37***	-4.30*	-3.63***	-2.88***
8.	Sweden	-3.11***	-3.06***	-3.20***	-2.78***
9.	Swit.	-3.92***	-1.44	-2.63**	-1.24
10.	Greece	-2.69***	-2.13	-1.38	-1.04
11.	Spain	-3.35***	-3.71***	-2.25	-1.62
	IPS	-2.52**	-1.87*	-1.49	-0.89

Note: ADF(p) statistics are computed using ADF regressions with **an intercept, a linear trend** and p lagged differences of the dependent variable. The IPS test statistic is the normalised value of the mean of ADF statistics and is compared to the standard normal distribution (Im et al., 2003).

The 1%, 5% and 10% critical values for the ADF tests are -2.63, -2.50 and -2.42.

The 1%, 5% and 10% critical values for the IPS tests are -2.58, -1.96 and -1.64.

'*' denotes significance at the 10%, '**' at the 5% and '***' at the 1% level.

Table B.6: ADF Test on the First Difference of Current Account Balances

	Country	DF	ADF(1)	ADF(2)	ADF(3)
1.	UK	-5.11***	-4.93***	-4.25***	-3.58**
2.	Austria	-6.70***	-5.25***	-4.14***	-2.27
3.	Denmark	-7.78***	-5.05***	-3.33**	-2.89*
4.	France	-8.22***	-4.44***	-3.46**	-3.70***
5.	Germany	-4.95***	-4.14***	-2.95**	-2.43
6.	Italy	-6.68***	-5.03***	-4.49***	-4.11***
7.	Nether.	-5.68***	-3.81***	-4.38***	-4.75***
8.	Sweden	-6.94***	-4.54***	-3.23**	-3.38**
9.	Swit.	-6.06***	-8.58***	-4.19***	-5.20***
10.	Greece	-5.43***	-5.25***	-4.95***	-4.14***
11.	Spain	-4.45***	-3.73***	-5.29***	-5.11***
	IPS	-18.59***	-13.39***	-9.92***	-8.58***

Note: ADF(p) statistics are computed using ADF regressions with **an intercept** and p lagged differences of the dependent variable.

The 1%, 5% and 10% critical values for the ADF tests are -3.60, -2.93 and -2.60.

The 1%, 5% and 10% critical values for the IPS tests are -2.58, -1.96 and -1.64.

Table B.7: CADF Test on the Current Account Balances

	Country	CADF(1)	CADF(2)	CADF(3)	CADF(4)
1.	UK	-2.69	-2.29	-2.36	-2.56
2.	Austria	-2.64	-2.48	-2.14	-3.51*
3.	Denmark	-2.66	-2.83	-2.84	-3.01
4.	France	-1.97	-2.36	-1.85	-1.58
5.	Germany	-1.22	-0.86	-1.31	-2.16
6.	Italy	-2.63	-2.58	-2.19	-2.72
7.	Nether.	-2.49	-3.38	-2.83	-1.83
8.	Sweden	-3.06	-2.59	-2.14	-1.68
9.	Swit.	-4.00**	-1.36	-1.65	-0.64
10.	Greece	-2.20	-1.92	-1.33	-1.00
11.	Spain	-2.54	-2.72	-1.62	-1.28
	CIPS	-2.56	-2.30	-2.02	-2.00

Note: CADF(p) statistics are computed using ADF regressions with **an intercept, a linear trend** and p lagged differences of the dependent variable, plus the lagged level and contemporaneous and p lagged differences of the cross-section average. The CIPS test statistic is the cross-section mean of the CADF tests. The critical values are tabulated in Pesaran (2007).

The 1%, 5% and 10% critical values for the CADF tests are -4.58, -3.82 and -3.46.

The 1 %, 5% and 10% critical values for the CIPS tests are -3.08, -2.85 and -2.73.

Table B.8: CADF Test on the First Difference of Current Account Balances

	Country	CDF	CADF(1)	CADF(2)	CADF(3)
1.	UK	-4.68***	-4.46***	-3.55**	-2.72
2.	Austria	-6.56***	-4.90***	-3.93**	-1.97
3.	Denmark	-7.69***	-3.82**	-3.31*	-2.88
4.	France	-6.08***	-2.97*	-3.31*	-3.07*
5.	Germany	-4.96***	-3.93**	-2.81	-1.96
6.	Italy	-6.41***	-4.73***	-4.11***	-2.97*
7.	Nether.	-6.06***	-3.71**	-4.03***	-4.59***
8.	Sweden	-5.39***	-4.36***	-3.45**	-3.41**
9.	Swit.	-5.67***	-8.15***	-4.04***	-3.86**
10.	Greece	-5.18***	-4.32***	-4.05***	-3.36**
11.	Spain	-4.12***	-3.70**	-4.66***	-4.41***
	CIPS	-5.71***	-4.46***	-3.75***	-3.20***

Note: CADF(p) statistics are computed using ADF regressions with **an intercept**, p lagged differences of the dependent variable, plus the lagged level and contemporaneous and p lagged differences of the cross-section average. The CIPS test statistic is the cross-section mean of the CADF tests. The critical values are tabulated in Pesaran (2007).

The 1%, 5% and 10% critical values for the CADF tests are -4.02, -3.32 and -2.95.

The 1 %, 5% and 10% critical values for the CIPS tests are -2.56, -2.33 and -2.21.

Table B.9: ADF Test on Net Other Terms

	Country	ADF(1)	ADF(2)	ADF(3)	ADF(4)
1.	UK	-6.40***	-3.43***	-3.87***	-2.78***
2.	Austria	-7.70***	-5.19***	-3.96***	-4.22***
3.	Belgium	-3.54***	-2.91***	-3.36***	-3.68***
4.	Denmark	-4.22***	-4.40***	-2.82***	-3.15***
5.	France	-4.53***	-3.71***	-3.28***	-2.84***
6.	Germany	-4.20***	-2.62**	-1.40	-1.18
7.	Italy	-4.37***	-2.49*	-1.78	-1.85
8.	Nether.	-4.60***	-4.04***	-3.75***	-3.10***
9.	Sweden	-5.60***	-4.48***	-2.50**	-2.26
10.	Swit.	-4.88***	-3.41***	-3.00***	-2.33
11.	Greece	-5.37***	-3.14***	-2.24	-1.99
12.	Spain	-5.84***	-2.68***	-2.82***	-2.89***
	IPS	-11.85***	-5.76***	-3.11***	-2.56***

Note: ADF(p) statistics are computed using ADF regressions with **an intercept, a linear trend** and p lagged differences of the dependent variable. The IPS test statistic is the normalised value of the mean of ADF statistics and is compared to the standard normal distribution (Im et al., 2003).

The 1%, 5% and 10% critical values for the ADF tests are -2.63, -2.50 and -2.42.

The 1%, 5% and 10% critical values for the IPS tests are -2.58, -1.96 and -1.64.

'*' denotes significance at the 10%, '**' at the 5% and '***' at the 1% level.

Table B.10: CADF Test on Net Other Terms

	Country	CADF(1)	CADF(2)	CADF(3)	CADF(4)
1.	UK	-5.90***	-3.40	-3.82*	-2.57
2.	Austria	-7.22***	-4.15**	-3.51*	-4.98***
3.	Belgium	-4.52***	-2.83	-4.39**	-2.82
4.	Denmark	-3.94**	-4.12**	-2.68	-2.82
5.	France	-4.44**	-2.63	-2.47	-2.65
6.	Germany	-3.33	-2.08	-1.34	-0.83
7.	Italy	-4.09**	-2.05	-1.79	-1.63
8.	Nether.	-3.82*	-2.74	-3.19	-3.77*
9.	Sweden	-5.25***	-3.89**	-2.65	-2.29
10.	Swit.	-5.66***	-3.06	-2.74	-1.57
11.	Greece	-5.07***	-2.70	-2.50	-2.03
12.	Spain	-5.63***	-2.56	-3.28	-3.20
	CIPS	-4.91***	-3.02**	-2.86**	-2.60

Note: CADF(p) statistics are computed using ADF regressions with **an intercept, a linear trend** and p lagged differences of the dependent variable, plus the lagged level and contemporaneous and p lagged differences of the cross-section average. The CIPS test statistic is the cross-section mean of the CADF tests. The critical values are tabulated in Pesaran (2007).

The 1%, 5% and 10% critical values for the CADF tests are -4.58, -3.82 and -3.46.

The 1 %, 5% and 10% critical values for the CIPS tests are -3.08, -2.85 and -2.73.

Table B.11: Individual Country Basic Regressions

	UK	Austria	Belgium	Denmark	France	Germany
inpt	-0.02	0.00	0.01	0.02	-0.02	0.00
dlyi(-1)	-0.35	0.16	0.69	0.12	0.18	0.19
dlyi(-2)	-0.38	-0.36	-0.28	0.00	-0.12	0.00
sdly(-1)	-0.98	0.00	-0.62	0.25	0.80	0.00
sdly(-2)	-0.45	-0.06	1.45	0.71	-0.65	0.00
R^2	0.19	0.14	0.40	0.05	0.10	0.04
$\bar{R}^2$	0.05	0.09	0.26	0.07	0.00	0.01
S.E.	0.06	0.03	0.05	0.05	0.06	0.04
DW	1.85	1.72	1.59	1.93	1.65	1.94
MLL	54.14	78.48	62.60	60.60	55.33	76.35
SC $\chi^2(1)$	2.30	1.88	3.41	0.02	0.18	0.01
FF $\chi^2(1)$	0.65	1.26	0.51	1.80	0.00	0.00
N $\chi^2(2)$	0.03	1.45	3.35	0.31	13.59	2.97
H $\chi^2(1)$	0.07	0.19	3.15	0.26	0.00	0.00
	Italy	Nether.	Sweden	Swit.	Greece	Spain
inpt	-0.01	0.00	0.00	0.02	-0.03	-0.02
dlyi(-1)	-0.07	-0.23	0.07	-0.43	-0.14	-0.16
dlyi(-2)	-0.39	0.05	0.00	-0.16	-0.13	0.08
sdly(-1)	-0.12	0.80	-0.73	1.27	0.00	0.00
sdly(-2)	0.40	-2.25	1.27	2.05	0.00	0.00
R^2	0.13	0.25	0.18	0.27	0.03	0.04
$\bar{R}^2$	0.04	0.07	0.00	-0.08	0.05	-0.01
S.E.	0.03	0.09	0.09	0.05	0.13	0.09
DW	1.78	1.91	1.93	1.97	2.61	1.91
MLL	85.30	41.58	41.98	62.31	26.08	39.42
SC $\chi^2(1)$	0.44	0.19	0.00	2.01	7.46	0.58
FF $\chi^2(1)$	0.00	9.43	1.80	0.00	0.72	3.05
N $\chi^2(2)$	1.45	3.47	91.18	18.40	0.86	15.96
H $\chi^2(1)$	0.00	2.58	0.67	0.00	0.07	0.03

Table B.12: ADF Test on the Hypothesized Drivers

Drivers	ADF(1)	ADF(2)	ADF(3)	ADF(4)
IFI Index	-1.56	-1.18	-1.38	-1.51
EU12 Output	-2.38	-1.55	-2.37	-3.61***
Dollar	-2.93***	-2.80***	-3.06***	-3.09***

Note: ADF(p) statistics are computed using ADF regressions with **an intercept, a linear trend** and p lagged differences of the dependent variable.

The 1%, 5% and 10% critical values for the ADF tests are -2.63, -2.50 and -2.42.

'*' denotes significance at the 10%, '**' at the 5% and '***' at the 1% level.

Table B.13: ADF Test on the First Difference of Hypothesized Drivers

Drivers	DF	ADF(1)	ADF(2)	ADF(3)
IFI Index	-7.11***	-5.45***	-2.62	-2.06
EU12 Output	-4.50	-5.20***	-2.96**	-2.22
Dollar	-4.19***	-4.01***	-3.45**	-3.24**

Note: ADF(p) statistics are computed using ADF regressions with **an intercept** and p lagged differences of the dependent variable.

The 1%, 5% and 10% critical values for the ADF tests are -3.60, -2.93 and -2.60.

'*' denotes significance at the 10%, '**' at the 5% and '***' at the 1% level.

Table B.14: Individual Country Basic Regressions (with macro shocks)

	UK	Austria	Belgium	Denmark	France	Germany
inpt	-0.01	0.00	0.01	0.02	-0.03	0.00
dlyi(-1)	-0.30	-0.01	0.78	0.00	-0.21	0.00
dlyi(-2)	-0.32	-0.49	-0.34	0.00	-0.28	0.00
sdly(-1)	-1.24	0.00	-1.14	0.27	0.00	0.00
sdly(-2)	0.00	0.00	1.71	0.82	0.00	0.00
dlifiu	-0.25	-0.18	0.00	-0.42	0.32	0.21
dlyu	-0.26	0.00	0.00	-0.37	-0.09	0.00
dlexu	0.00	-0.26	0.00	-0.72	0.30	-0.25
dlifiu(-1)	0.00	-0.13	-0.21	0.00	0.00	0.00
dlyu(-1)	0.00	-0.11	0.00	0.00	-0.22	0.00
dlexu(-1)	0.00	-0.18	0.58	-0.27	0.29	0.00
dlifiu(-2)	0.00	0.00	0.00	0.00	0.00	0.00
dlyu(-2)	0.00	-0.16	0.00	0.00	0.29	0.00
dlexu(-2)	0.00	-0.34	0.00	0.00	0.73	0.00
R^2	0.30	0.47	0.50	0.50	0.45	0.17
$\bar{R}^2$	0.18	0.30	0.40	0.40	0.27	0.13
S.E.	0.06	0.03	0.05	0.04	0.05	0.03
DW	1.99	1.82	1.79	1.64	1.85	1.77
MLL	54.56	82.91	64.00	67.43	66.51	74.59
SC $\chi^2(1)$	0.00	0.83	1.37	1.39	0.14	0.46
FF $\chi^2(1)$	0.24	5.81*	2.33	0.69	3.06	0.01
N $\chi^2(2)$	0.98	0.99	3.18	4.52	1.41	4.01
H $\chi^2(1)$	6.45*	0.21	1.09	0.00	5.61	0.03

5% significance level of critical values for $\chi^2(1)$ and $\chi^2(2)$ are 3.841 and 5.991.

Table B.14: Continued

	Italy	Nether.	Sweden	Swit.	Greece	Spain
inpt	0.00	0.00	0.00	0.03	-0.02	-0.02
dlyi(-1)	0.24	-0.03	0.00	-0.55	0.00	0.00
dlyi(-2)	0.00	0.20	0.00	-0.34	0.00	0.00
sdly(-1)	0.00	1.36	-0.43	0.66	0.00	0.78
sdly(-2)	0.00	-3.22	0.00	1.87	0.00	0.61
dlifiu	-0.27	-0.42	0.00	0.52	-0.65	-0.46
dlyu	-0.13	0.00	0.00	0.00	0.00	0.02
dlexu	0.00	0.37	0.00	0.19	0.49	0.31
dlifiu(-1)	0.15	0.00	0.22	0.00	0.21	0.24
dlyu(-1)	0.00	0.34	0.00	0.00	0.00	0.30
dlexu(-1)	-0.36	-0.50	0.00	-0.10	-0.58	0.00
dlifiu(-2)	0.00	0.00	0.00	0.00	0.00	-0.26
dlyu(-2)	0.00	-0.69	0.00	0.00	0.00	0.00
dlexu(-2)	0.00	0.00	0.00	1.08	-0.94	0.00
R^2	0.52	0.62	0.23	0.61	0.48	0.46
$\bar{R}^2$	0.45	0.49	0.07	0.50	0.40	0.26
S.E.	0.02	0.07	0.05	0.09	0.07	0.05
DW	1.69	2.12	2.01	2.06	2.15	2.41
MLL	93.61	54.41	60.65	40.98	48.24	61.36
SC $\chi^2(1)$	2.79	0.38	0.01	0.08	0.59	2.15
FF $\chi^2(1)$	0.00	0.43	0.32	0.00	3.97*	0.04
N $\chi^2(2)$	0.89	3.54	4.04	0.90	1.06	3.55
H $\chi^2(1)$	0.43	0.63	7.62	0.08	2.02	5.92

5% significance level of critical values for $\chi^2(1)$ and $\chi^2(2)$ are 3.841 and 5.991.

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