TARGET Balances and Macroeconomic Adjustment to Sudden Stops in the Euro Area

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Abstract

This paper examines how membership of a monetary union affects macroeconomic adjustment of Euro Area countries to sudden stops. We focus on a key difference between a standard peg and a monetary union: the availability of external financing from the common central bank via the TARGET system. For this purpose, we use a modified version of the Mendoza (2010) model which incorporates central bank financing, based on an empirical analysis of TARGET flows. Our results show that the availability of such financing greatly mitigates the collapse in GDP, consumption and investment during sudden stops (relative to a regime in which such financing is not available). However, a welfare analysis shows that TARGET financing only results in modest welfare gains in the affected country, since it exacerbates the tendency towards over-borrowing, leading to an increased incidence of sudden stop episodes.

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Key words: sudden stops, TARGET balances, binding constraints

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1 Introduction

In the course of the Euro Area crisis since 2007, a number of "stressed" Euro Area countries (Cyprus, Ireland, Greece, Italy, Portugal and Spain) have experienced sharp reversals in capital inflows. The reversal of capital flows seen in Europe was part of a broader global development, since a number of non-Euro Area and non-European countries also experienced capital flow reversals. For example, Milesi-Ferretti and Tille (2010) document that at a global level, gross capital flows declined from a pre-crisis level of 20% of world GDP to around 3% in 2009.

Sharp reversals in capital flows are not new phenomena. Since the 1980's many countries have experienced sudden stops. Famous episodes are: the ERM crisis of 1992/1993 in Europe, Mexico in 1994 (the Tequila crisis), Hong Kong, Indonesia, Malaysia, South Korea, Thailand, during the Asian crisis of the late 1990's and Russia and a number of other countries in 1998 (the "Russian crisis").

An extensive literature has emerged which documents that these sudden stops led to severe contractions in domestic demand and output, sizable turnarounds in current account positions and large real depreciations (see, for example, Barkbu et al. (2012) or Mendoza (2010) for recent reviews of the evidence on various episodes). This is also true of the most recent wave of sudden stops in the Euro Area (Lane and Milesi-Ferretti (2011)).

A distinguishing feature of the Euro Area case, however, is the fact that sudden stops occurred in a set of countries which are part of a monetary union. In this situation, a common central bank conducts a single monetary policy aimed at ensuring broadly similar monetary conditions across participating countries. Under this regime, net private capital outflows were to some extent "automatically" compensated by the actions of the central bank. Increased central bank provision of liquidity to banks in the affected countries implied offsetting capital inflows via the central banking system which were reflected in a sizeable rise in so-called TARGET balances. These balances are referred to as TARGET Balances, after the name of the payments system (**T**rans-European **A**utomated **R**eal-time **G**ross settlement Express **T**ransfer system)[1].

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[1] The details of the mechanism are discussed more fully below. In addition, it is notable

Such funding via the central bank has important implications for the macroeconomic adjustment of the countries experiencing a sudden stop in capital flows. In principle, it enables such countries to maintain a higher level of domestic expenditures than would otherwise be the case. The macroeconomic effects of the sudden stop are thus mitigated. .

The paper addresses the question of how TARGET financing affects the macroeconomic adjustment to a sudden stop in private capital flows. Since we do not observe counterfactuals in the data, we use a model-based approach. Specifically, we develop a micro-founded general equilibrium model and conduct a number of simulations with and without TARGET balances.

For this purpose we modify the small open economy model of Mendoza (2010). This model has five attractive features. First, the model has been shown to be able to generate sudden stop events which match key empirical facts found in the data over a range of countries and time periods, such as the frequency of sudden stops and the response of macroeconomic aggregates such as output, consumption and investment. Second, in the model sudden stop events are generated by normal business cycle shocks (to total factor productivity (TFP) and world interest rates) rather than by assumed exogenous "sudden stop shocks". Third, the model is based on rigorous microfoundations, and avoids a number of ad-hoc elements which have been used in alternative frameworks. Fourth, the model incorporates important linkages between asset prices, collateral values and and borrowing constraints which have played an important role in the recent crisis. Finally, the model, though highly nonlinear, is relatively compact so that the use of appropriate global solution techniques is computationally feasible.

We make two main modifications to this model. First, we allow for downward nominal wage rigidity since this potentially has important implications for macroeconomic adjustment under fixed exchange rate regimes such as the Euro Area (Schmitt-Grohe and Uribe (2011)). Second, and more to the point, we integrate a TARGET-style financing system into the model. We base our implementation of this feature on the empirical evidence on the link between TARGET balances and county-specific interest rate spreads.

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that Greece, Ireland, Portugal and, more recently, Cyprus also obtained external financing from EU Member States, the EU Commission and the International Monetary Fund (IMF) in the context of the respective adjustment programs.

We switch this feature on and off to explore its effect on macroeconomic adjustment to sudden stops.

As well as conducting a positive analysis of the effect of TARGET balances on macroeconomic aggregates we also conduct a welfare analysis. How does the presence of TARGET financing affect the welfare of a country in a monetary union that is also subject to sudden stops?

The structure of this paper is as follows. In Section 2, we document the occurrence of sudden stop episodes in Euro Area countries over the period 2008-2012 and examine how the evolution of key macroeconomic aggregates compares with previous sudden stop episodes. The results obtained confirm that the sudden stop paradigm is relevant to the Euro Area experience, motivating the approach taken in the remainder of the paper. In Section 3 we review the mechanics of TARGET balances and document the extent to which TARGET flows have compensated private capital outflows. We empirically model the link between TARGET balances and interest rate spreads as a basis for calibration of the general equilibrium model used later. In Section 4 we present the model we employ while Section 5 deals with calibration and the solution methodology. Section 6 presents the results, including an analysis of the welfare implications of TARGET financing. Section 7 concludes.

2 Euro Area Sudden Stops in Historical Perspective

After the crises of the 1990s a sizeable literature on sudden stops in capital flows emerged, building on the pioneering contribution of Calvo (1998). This literature put forward methods for identifying sudden stops, examines their macroeconomic implications and develops models which predict the occurrence of these events ("early warning models"). A related strand in the literature, which we review later, attempts to explain the occurrence of sudden stops and their macroeconomic effects in the context of general equilibrium models. A broad consensus in the empirical literature is that sudden stops are associated with sharp contractions in domestic demand and output, sizeable reductions in current account deficits and real depreciation.

The literature generally follows the Calvo definition in which which a sudden

stops are defined as "*large and unexpected falls in capital inflows that have costly consequences in terms of disruptions in economic activity*" (Calvo et al. (2004b)p.14).

A number of authors (for example, Lane (2013) and Merler and Pisani-Ferry (2012)) have noted that some Euro Area countries - in particular, Cyprus, Greece, Ireland, Italy, Portugal and Spain - have experienced sudden stops in capital flows since 2008. In particular, Merler and Pisani-Ferry (2012) establish this fact by applying the Calvo methodology to identify sudden stop episodes in Europe.

In this Section, we build on this work in a number of respects. First, we apply a consistent methodology for identifying sudden stops to data for 56 countries in and outside the Euro Area over the period 1980 to 2012. Using this consistent definition, we compare the experience of Euro Area countries with prior episodes of sudden stops elsewhere in the world. Secondly, in identifying sudden stops for Euro Area countries, we use two measures of capital flows: the raw data on the Financial Account reported in the IMF Balance of Payments Statistics and an adjusted measure of private capital flows which corrects for TARGET flows and Official lending in the context of IMF/EU programs.

Details of the dataset and the analysis employed appear in Appendix 1. Two main points emerge from the analysis. First, our results provide further confirmation of the Merler and Pisani-Ferry (2012) result, that the countries listed above experienced sudden stops in capital flows in the period after 2007. This is true regardless of the definition of capital flows employed.

A second key finding is that the macroeconomic response of the affected Euro Area economies to the sudden stop events is similar to previous experience elsewhere. This can be seen in Figure 1. In this figure, we follow Mendoza (2010), by looking at the "average" dynamics of key variables before and after the event for a span of five years[2]. The year in which the sudden stop starts is denoted $t = 0$, with the level of each variable (except for capital flows and net export ratios) for the preceding year ($t = -1$.) being normalised to unity. The figure shows the average dynamics for all sudden stop episodes found in the data as as well as for the Tequila, Asian and Euro Area crises.

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[2]With the exception of capital flow and net export ratios, all variables in the Figure are computed using deviations with a Hodrick-Prescott filter.

Figure 1 shows that the most severe drops took place in Asia. In terms of GDP, consumption and investment, the collapse in the Euro zone was not as severe as the Asian and Mexican crises. But the patterns are similar and the earlier crises represented signs of things to come elsewhere in the world.

Overall, these results suggests that the sudden stop paradigm is relevant to understanding the experience of "stressed" Euro Area countries during the recent crisis. Thus in developing our model to analyse this phenomenon, we build on this experience as documented in these recent studies.

3   The TARGET System and Capital Flow Reversals

Faced with a sudden stop in capital flows, an economy normally has three options. In the first place, if it has a sufficient stock of foreign exchange reserves, it may draw these down to cover the gap in its external financing. Secondly, it can approach international institutions such as the IMF to obtain official financing. Finally, it can contract domestic demand and imports to improve its current account position. This latter option is typically associated with painful recessions.

In the case of a monetary union with a single monetary policy, such as the Euro Area, there is a "fourth option". The economy can obtain external financing automatically via the operation of the Eurosystem's monetary policy operations and associated cross-border capital flows within the central bank system.

The mechanism works in the following way. A stop or reversal of private capital flows leads to a loss of liquidity for banks in the affected economy[3]. When Euro area money markets are functioning smoothly, banks can normally replace this lost liquidity by borrowing from foreign counterparties on the money market. In this case, one type of external private financing will

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[3] This can happen directly if foreigners withdraw deposits from the domestic banks, refuse to roll over their holdings of debt securities or if domestic investors move deposits to banks abroad. In BOP statistics, such transactions are classified under "Other" flows (ref BPM6). Capital flow reversals under FDI or Portfolio holdings will also normally lead to a shortage of liquidity in domestic banks. For example, if foreigners reduce their holdings of domestic bonds by selling them to domestic non-bank residents, the resulting transfer of funds from the buyer to the seller will need to be financed by the domestic banks.

be replaced by another. However, in the context of a sudden stop foreign counterparties are by definition unwilling to lend to the domestic banks.

In a monetary union, however, the domestic banks can replenish the lost liquidity by borrowing from the central bank in the context of its regular monetary policy operations. In line with the provisions of the Maastricht Treaty, such lending must be backed by adequate collateral[4].

These transactions in turn create movements in assets and liabilities of the national central bank (and the domestic economy as a whole in its International Investment Position, or IIP) with respect to the rest of the Eurosystem. These balances are referred to as TARGET Balances, after the name of the payments system (**T**rans-European **A**utomated **R**eal-time **G**ross settlement **E**xpress **T**ransfer system).

Table 3 illustrates this mechanism. This shows how TARGET balances between countries can arise (for a set of more elaborate accounting examples, see Bindseil and Koenig (2011)). Our example takes the incremental balance sheets of four entities: a German private bank, and Irish private bank, the German central bank (Bundesbank) and the Central Bank of Ireland.

Initially the German bank (which we denote Deutsche) has lent 100 to an Irish bank (which we denote AIB), leading to the initial position shown in Table 1. Then Deutsche decides to withdraw its deposit, repatriate its funds and place them in the deposit facility of the Bundesbank.

The partial effects of the transactions are shown in the second panel of Table 1. A reduction in Deutsche's deposit at AIB is replaced by a deposit at the Bundesbank. To replenish the loss of reserves due to the lost deposit, AIB borrows 100 from the Central Bank of Ireland (denoted Repo) in Table 1. Finally, to pay back the Deutsche deposit, AIB instructs the Irish Central Bank to make a payment via the TARGET payment system of 100 to Deutsche Bank's account at the Bundesbank. Due to this payment flow the central bank incurs a TARGET liability of 100 vis-a-vis the Bundesbank.

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[4]In the event that the bank does not have sufficient eligible collateral then it may seek Emergency Liquidity Assistance (ELA) from its national central bank. The NCB in turn must obtain approval from the ECB Governing Council to extend the loans which are typically remunerated at a rate in excess of the marginal lending facility. In contrast to regular operations any losses made on these loans are not shared among the central banks but are borne by the national central bank making the loan. ELA loans have identical effects on TARGET balances as regular operations.

In this example, the withdrawal of the Deutsche deposit has created a TAR-GET liability for the Central Bank of Ireland and a TARGET asset for the Bundesbank of 100[5]. In balance of payments terms, the capital outflow from Ireland via the private banks is compensated by a capital inflow via the respective central banks.

A macroeconomic perspective on the role of TARGET balances emerges by rewriting the standard balance of payments identity[6]:

$$Current\ account\ deficit = Capital\ inflows$$

We can further decompose this identity by separately identifying TARGET flows, official financing and the remaining flows, which we call the Private Financial Account:

$$Current\ account\ deficit = Private\ capital\ inflows \qquad (1)$$
$$\Delta\ TARGET\ liabilities + Official\ inflows$$

Official flows relate to receipts/payments in connection with European Union and International Monetary Fund (EU/IMF) programs such as those in effect in Greece, Ireland and Portugal. With data on TARGET balances, Official flows and standard Balance of Payments data, the private capital flows may be computed as a residual using (1).

Figure 2 shows monthly data on the ratio of TARGET balances to GDP over the period 2008 to 2012[7]. Prior to the crisis, TARGET balances were relatively limited since Eurozone money markets functioned smoothly and banks readily replaced lost funds by borrowing on the money markets. However, as the crisis emerged and intensified, peaking in mid-2012 amid market con-

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[5]In practice, at the end of the day TARGET balances are netted and transferred to the ECB, so that the Bundesbank would have a claim of 100 vis-a-vis the ECB while the Central Bank of Ireland would have a TARGET liability of 100 to the ECB.

[6]In this presentation, we allocate the Balance of Payments item "errors and omissions" to the capital inflows and neglect changes in reserve assets, which in the case of the Euro Area, are not quantitatively significant.

[7]The monthly data on TARGET balances has been compiled by the Institute of Empirical Economic Research of Osnabrueck and is available at the Euro Crisis Monitor website (http://www.eurocrisismonitor.com/). We scale by GDP to facilitate comparison across countries. We use 2007 nominal GDP rather than current GDP to avoid distortions coming from the denominator due the the sharp falls in nominal GDP in some of the countries concerned.

cerns about the survival of the euro, TARGET liabilities reached substantial levels as a percent of GDP[8].

Figures 3 and 4 present the decomposition of the right hand side of (1) for five of the stressed Euro Area countries (Greece, Ireland, Portugal, Italy and Spain). These figures present cumulative flows starting from 2005Q1 with these flows being expressed as percent of 2007 nominal GDP for the countries concerned.

In the case of Greece, Ireland and Portugal a somewhat different pattern is apparent. In Ireland, the decline in private capital flows started in 2008, earlier than in the other countries. Cumulative private flows fell from a peak of +15% of GDP to a trough of -60% at the end of our sample period. Initially, the downturn in private flows was compensated by a rise in TARGET liabilities, which reached a peak of 75% of GDP. However, as funds from EU/IMF program flowed into the country after 2010, TARGET liabilities declined.

A similar pattern is evident later in the two other program countries, Greece and Portugal. However, the rise in TARGET liabilities was less marked than in Ireland and there was little decline from peak levels over the sample considered here.

In the case of Italy and Spain (countries not on EU/IMF programs during the period under consideration[9]) there was a sharp decline in cumulative private flows after 2011 as the Euro zone crisis intensified. These flows are offset by increases in liabilities under the TARGET system.

The emergence of sizeable TARGET balances has given rise to a substantial literature. A comprehensive survey is provided by Cour-Thimann (2013)[10]. Triggered by a set of contributions by Hans-Werner Sinn[11], recent research

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[8]Subsequently, from mid-2012, the ECB announcement of the Outright Monetary Transactions Program led to an improvement in market sentiment towards the euro resulting in a decline in TARGET balances.

[9]In July 2012 the Eurogroup agreed a program of financial assistance for Spain for the purpose of bank recapitalisation. The first tranche of €39.468 billion (3.8 percent of 2013 Spanish GDP) was disbursed in December 2012.

[10]An incomplete list of the relevant papers includes: Auer (2013); Bindseil and Koenig (2011);Bindseil and Winkler (2012);Buiter and Rahbari (2012);Cecchetti et al. (2012);Cour-Thimann (2013);Mody and Bornhorst (2012);Sinn and Wollmershaeuser (2012) and Whelan (2012)

[11]The main arguments are summarized in Sinn (2012), the title of which may be translated as "The TARGET Trap: A Danger for our Money and our Children".

largely focuses on controversial aspects of the TARGET system including the cross-country distribution of risks associated with TARGET balances, the role of TARGET balances in financing current account balances, moral hazard and the pros and cons of proposals to place restrictions on the size of these balances.

Despite diverse views on these issues, a clear consensus in the literature recognises the fact that the level of TARGET balances is very closely linked to the provision of liquidity by the central bank to national banking systems. Private capital outflows, by definition, lead to drains in domestic bank liquidity. The Eurosystem, however, aims for comparable monetary conditions across the Euro Area, (which it refers to as "addressing impairments to the transmission mechanism") and pursues a policy of "equal treatment" of banks in different countries of the Euro Area. The end result is the provision of liquidity by the central bank leading, automatically, to what is in effect a capital inflow via the central bank system. This inflow (at least partially) compensates for the private capital outflow.

The connection between TARGET balances and the conduct of the single monetary policy aiming for relatively uniform financial conditions across the Euro Area can be clearly seen by looking at the relationship between these balances and interest rate spreads vis-à-vis the "safe country" in the Euro Area, Germany. In a reduced form manner, one can model central bank liquidity provision to the national banking system (proxied by TARGET balances) as a function of the interest rate spreads:

$$\frac{TARGET\ Balance}{GDP} = \alpha_0 + \alpha_1 Spread \tag{2}$$

Private capital outflows lead to a tightening of financial conditions in the affected country. This tightening is reflected in the spread between domestic interest rates vis-a-vis rates in other countries in the monetary union. (This is also a feature of the theoretical model which we present in the next Section). The central bank responds to these pressures by increasing liquidity supply to banks in the country concerned, leading to a rise in TARGET liabilities.

The data in Figures 5 show that empirically this is an accurate characterisation. The Figure plots monthly data on TARGET balances (again expressed as a percent of 2007 nominal GDP) for Greece, Spain, Ireland, Italy and

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Portugal" against a measure of the spread between the country-specific interest rate and the corresponding German rate. Among the broad range of possible candidates for the interest rate variable, we chose the interest rate charged by banks to non-financial corporations on loans (new business) of below Euro 1 million. The maturity is 3 months to 1 year. For each Euro area country, monthly data on this variable is available on the ECB's website[12]. This measure of the interest rate differential is regularly used by the ECB as an indicator of impairment to the transmission mechanism across countries. Moreover, of the available interest rate series, this one corresponds most closely to the relevant concept in the model we present below.

The data in the chart show a clear relationship between borrowing via the TARGET system and interest rate differentials. Higher spreads, which reflect greater financial stress as a result of private capital outflows, are associated with increased TARGET liabilities. Not surprisingly, given the heterogeneous nature of the countries considered, there are evident cross country differences. In particular, Ireland appears as an outlier with higher (absolute) levels of TARGET to GDP ratio and a more steeply sloped relationship with the spreads. Nonetheless, even looking at data for individual countries shows a clear negative relationship between spreads and TARGET balances.

Formal tests are presented in Tables 2 and 3. Table 2 reports panel estimates (with and without country and time fixed-effects) of equation (2) while Table 4 presents the results when the equation is estimated separately for each individual country.

In the panel model without country fixed effects (column 1) the estimated α_1 implies that a rise in the spread of 1 percentage point is associated with a rise in the TARGET/GDP ratio of 12 percentage points. The coefficient rises and becomes much more significant when we allow for country fixed effects. Allowing for both country and time fixed effects reduces the estimated coefficient but it still remains highly significant.

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[12]The data can be accessed at http://sdw.ecb.europa.eu/browse.do?node=bbn173. Even before the crisis there were notable cross-country differentials in this interest rate. Apart from purely statistical reasons, these differentials reflected factors such as differences across countries in bank competition, regulatory and tax regimes and collateral policy (for a comprehensive explanation, see European-Central-Bank (2006)). To take these country-specific effects into account, we subtract from the data on the interest rate differential the pre-crisis country mean of the differential.

Looking now at the individual country equations reported in Table 3, we observe that the estimated value of α_1 is very similar in the case of Italy, Greece, Portugal and Spain, lying in the interval (-0.15,-0.1). In each of these cases, the coefficient is highly significant and the relationship is strong with R^2 values ranging from 0.6 to 0.93, high values in the context of a bivariate equation on monthly data. Again Ireland appears to be an outlier with an estimated coefficient of -0.29. Although this is highly significant, the R^2 is much lower.

Both the graphical and the econometric evidence confirm the link between financial stress (as proxied by interest rate spreads) and TARGET balances. Whilst caution is needed in interpreting OLS estimates of a relationship between two endogenous variables, it seems plausible to argue that this equation is picking up, in a shorthand manner, the behaviour of Eurosystem in supplying liquidity to national banking systems. We will later make use of these results for the calibration our model in the next section.

Before concluding this Section, we stress that the "elastic" provision of liquidity to national banking systems, which gives rise to TARGET balances, is a unique feature of a monetary union. Looking at a range of sudden stop episodes since the 1980s, Barkbu et al. (2012) show that the volume of official lending via the IMF or bilateral loans has increased over time and plays an increasing role, in accounting terms, in compensating for private capital outflows. While program flows may, from an accounting point of view, have similar effects to TARGET flows, this accounting feature misses a crucial point. TARGET flows are an inherent part of a monetary union in which the central bank pursues a single monetary policy.

By contrast, official flows in the context of adjustment programs can and do take place in a range of exchange rate regimes. Official flows are predicated on political and economic decisions by international institutions and are subject to strong conditionality. Moreover, there are notable lags between the occurrence of a sudden stop and the response of official institutions. TARGET balances are a very different phenomenon. They arise automatically from the operation of the single monetary policy and are not subject to country-specific conditionality[13]. There are essentially no lags between

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[13] Although their level is dependent on features of the central bank's operational framework such as the modalities of allocating liquidity (fixed-rate versus variable rate tenders)

private capital outflows and the TARGET inflows and the volume of TAR-
GET balances can change by substantial amounts in a single day. The fact
that TARGET balances are an inherent feature of the monetary union and
their automaticity have been stressed repeatedly by the ECB and its officials.
A few examples include:

> *"The presence of TARGET claims and liabilities is natural given
> the decentralized structure of the Eurosystem..the current high
> levels of TARGET balances reflect the supportive role played by
> the Eurosystem in relation to the banking system and its inter-
> mediation role on the money markets during the ongoing finan-
> cial market tensions. To some extent, TARGET balances thus
> constitute a substitute provided by the public (central bank) sec-
> tor for what would normally be private claims among commer-
> cial banks, with associated implications in terms of risk shifting
> from the private sector to the balance sheet of the Eurosystem"*
> (European-Central-Bank (2013), p. 112).

> *"The possibility for internal positions to emerge between central
> banks is at the core of the functioning of a currency union." (ibid,
> p114)*

> *"..it must be recognized that the unlimited and unconditional char-
> acter of TARGET2 balances is at the very heart of monetary
> union. The ability of banks to transfer deposits across national
> central banks constitutes the genuine single currency. Imposing a
> limit to such transfers and thus making those transfers impossible
> would de facto imply a reintroduction of two currencies with pre-
> sumably different prices, marking the end of monetary union"*
> (Bindseil and Winkler (2012), p. 37).

There are thus fundamental differences between financing via TARGET bal-
ances and official financing via adjustment programs and the two should
not be viewed as substitutes. This is our rationale for focusing on TAR-
GET balances during sudden-stop episodes as we do in the remainder of this
paper.

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and the central bank's collateral policy.

4   Model

In this Section, we first review the existing literature on the modelling of sudden stops. Then we set up the basic model and derive the first order conditions. We subsequently modify the model for downward nominal wage rigidity and for the provision of TARGET financing. Finally, we discuss the general equilibrium process of the model when the collateral constraint binds and when it does not.

4.1   Modelling Sudden Stops

On the theoretical front, during the past decade, sudden stop phenomena have been the subject of different general equilibrium frameworks. Models differ depending on a number of respects such as: single country versus two country, the type of sectoral breakdown (single good versus traded/non-traded split), the type of frictions included (e.g. sticky versus flexible prices and capital adjustment costs), and the type of shocks considered.

Calvo et al. (2004a,c) drew attention to sudden stops arising as a consequence of uncertainty about fiscal or real exchnage rate sustainability. This approached was soon challenged by Chari et al. (2005), who argued that sudden stops were simply a consequence of expected negative shocks to real output.

This controversy is mirrored in the theoretical literature. One set of models treats sudden stops as exogenously determined events. Another set of models treats sudden stops as endogenously generated events, or recurring set of events, with the productivity, terms of trade or foreign interest rates as the forcing variables driving the economy

Braggion et al. (2009) model the sudden stop as an exogenous permanent regime switch from one steady state to another. In the initial state, there is no borrowing constraint on the economy. The sudden stop is then modelled as a shift towards a permanently binding borrowing constraint. Cúrdia (2008) use the framework of Bernanke et al. (1996) in which the economy faces an external finance premium. The sudden stop takes the form of an exogenous shock to an external financing premium. Unlike Braggion et al. (2009), this shock is not permanent.

Devereux et al. (2006) also examine the role of the external financing premium

in the spirit of Bernanke et al. (1996). Unlike Cúrdia (2008), the premium is endogenously determined by the stochastic shocks driving the model (terms of trade and world interest rate shocks). They also embed nominal frictions in terms of sticky prices and imperfect exchange-rate pass through.

In contrast with the above approaches, Mendoza and Arellano (2003); Mendoza (2010) use a small-open economy real business cycle framework with financial frictions in the form of collateral constraints on international borrowing, following the specification of Kiyotaki and Moore (1997a). In this framework, shocks take the usual form of recurring productivity, foreign interest rate, and external price changes. Sudden stop phenomena emerge as endogenously recurring, albeit infrequent, events, arising when collateral constraints become binding. When the borrowing constraint hits, consumption and investment fall. At the same time, the working capital channel induces firms to reduce inputs, leading to a fall in output. This mechanism is exacerbated by a "debt deflation mechanism" with falls in the q-ratio leading to a further tightening of the borrowing constraint.

Benigno et al. (2013) and Fornaro (2013) also make use of models with endogenously generated sudden stops. The former has two sectors in a small open-economy model but no capital accumulation, hence the debt-deflation mechanism is absent, while the second makes use of a Mendoza-type framework with money. In the former, sudden stop events are triggered by exogenous falls in traded output which force the economy to hit the external borrowing constraint, with changes in the relative price of non-traded goods impacting on the severity of the borrowing constraint. In the latter, the sudden stop follows the Mendoza specification.

This paper takes as its starting point the Mendoza (2010) setup. We adopt and adapt this model, since the model has a number of attractive features. First, sudden stop events are endogenous, generated by regular shocks to TFP and interest rates rather than relying on assumed exogenous sudden stop shocks. A sudden stop arises following the low probability event of a sequence of adverse shocks which leads the economy to hit the borrowing constraint. The model thus addresses the critique of Chari et al. (2005) noted above. Second, the model is rigorously microfounded and avoids a number of ad-hoc elements which have been used in alternative frameworks. Third, it also incorporates important linkages between asset prices, collateral

values and borrowing constraints which have played an important role in the recent crisis. Fourth, and most important, the model has been shown to be able to generate sudden stop events which match key empirical facts found in the data over a range of countries and time periods. These features include the frequency of sudden stop events and the response of macroeconomic aggregates such as output, consumption and investment.

Korinek and Mendoza (2013) expand on Mendoza (2010) for a wider class of models. They note that their models capture well the observed dynamics of GDP, consumption, investment, and net exports. Using a similar framework, Bianchi (2013) examines the role of bailouts following the onset of financial crises. He points out that in the wake of a credit crunch, a collective transfer to firms at this time allows all households to obtain higher dividends and higher lobar income in the future. For particularly severe credit crises, the benefits of bailouts outweigh the costs stemming from a higher incidence of crises due to reduced precautionary savings.

Since the model we us is a real business cycle framework, the issue of monetary policy/exchange rate regime choice is set aside. Since our interest is in comparing economies under different types of fixed exchange rate regimes (peg versus monetary union) this is not a major limitation for us.

4.2 Benchmark Model

Following Mendoza (2010) the small open economy contains a representative firm-household model which produces a single good using three factors of production: lobar L_t, capital k_t and imported intermediate goods v_t. In addition to the usual intertermporal budget constraint, agents are subject to a working capital requirement on labour and intermediate inputs, quadratic adjustment costs for capital accumulation and the usual intertemporal borrowing constraint. In addition agents are subject to occasionally binding external borrowing constraints.

The representative household optimizes an intertemporal welfare function V_t positively related to consumption c_t and negatively related to lobar L_t.

In order to ensure stationarity of net foreign assets the welfare function

embodies an endogenous discount factor D_t

$$V_t = U[c_t - N(L_t)] + D_t V_{t+1} \qquad (3)$$

$$U(\cdot) = \frac{1}{1 - \sigma_c} [c_t - N(L_t)]^{1-\sigma_c} \qquad (4)$$

$$N(L_t) = \frac{1}{\omega} L_t^{\omega} \qquad (5)$$

The parameters σ_c and ω represent the relative relative risk version coefficient and the Frisch elasticity of lobar supply in the lobar component of the utility function, $N(L_t)$. This specification of the utility function, which follows Greenwood et al. (1988), implies that there are no wealth effects on labour supply. This has important implications for the ability of the model to match the response of the economy to sudden stop episodes. As noted by Chari et al. (2005) standard preferences would imply an increase in labour supply (and thus output) following the imposition of a borrowing constraint on an economy. Suppressing the wealth effect on labour supply as done here eliminates this counterfactual feature.

The discount factor D_t has the following functional form:[14]

$$D_t = \rho(c_t - N(L_t)) \qquad (6)$$

$$\rho(c_t - N(L_t)) = \exp\{-\gamma \ln[1 + c_t - N(L_t)]\}$$

The budget constraint for the household is given by the following relation:

$$c_t + i_t + g_t = y_t - p_t \nu_t - \phi(R_t - 1)(w_t L_t + p_t \nu_t) - q_t^b b_{t+1} + b_t \qquad (7)$$

where y_t represents total domestic output at time t, c_t consumption, i_t investment, g_t government spending, b_t one-period international bonds. The price index p_t is the cost of the intermediate goods for the firm, w_t the real wage rate, and q_t^b the price of international bonds.

The working capital requirement for the representative firm is given by the parameter ϕ while $(R_t - 1)$ represents the net nominal world interest rate. The price of international bonds is exogenous, with $q_t^b = 1/R_t$.

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[14]Schmitt-Grohe and Uribe (2003) note that endogenous discounting is only one way for closing open-economy models. Other ways include a risk premium on foreign debt, an adjustment cost on foreign debt accumulation, and the assumption of complete markets.

The model does not include an explicit banking sector[15]. Instead, financial frictions are introduced by means of an occasional binding collateral constraint which foreign lenders impose on domestic borrowers. he following collateral constraint applies to international borrowing b_{t+1}:

$$q_t^b b_{t+1} - \phi R_t(w_t L_t + p_t \nu_t) + \kappa q_t k_t \geq 0 \qquad (8)$$

where q_t is the price of capital, and ϕ is the working-capital coefficient, giving the percent of the wage and intermediate-goods bill which must be financed . According to this constraint total foreign debt, including working capital loans, cannot exceed a fraction κ of the market value of capital. κ can be interpreted as the loan-to-value ratio and is assumed to be constant throughout. The collateral constraint is the principal financial friction in the model and is motivated by informational problems facing foreign lenders as in the model of Kiyotaki and Moore (1997b)

Capital accumulation is equal to investment, net of depreciation and adjustment costs:

$$i_t = \delta k_t + (k_{t+1} - k_t)\left[1 + \Psi\left(\frac{k_{t+1} - k_t}{k_t}\right)\right] \qquad (9)$$

The parameter δ is the rate of depreciation and Ψ is the adjustment cost function. The adjustment cost function in turn is quadratic:

$$\Psi\left(\frac{z_t}{k_t}\right) = \frac{a}{2}\left(\frac{z_t}{k_t}\right)^2 \qquad (10)$$

$$a > 0$$

$$z_t = (k_{t+1} - k_t)$$

where the variable z_t denotes capital accumulation $(k_{t+1} - k_t)$,at time t, and a is the adjustment-cost parameter.

For simplicity, net capital accumulation z_t may be expressed in the following way:

$$z_t = i_t - \delta k_t - \Psi\left(\frac{z_t}{k_t}\right) z_t \qquad (11)$$

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[15]Under certain conditions, the inclusion of an explicit banking system into the model would not change the results presented here. These conditions include: the absence of informational frictions between domestic borrowers and the banks; a competitive banking system; costless intermediation and the collateral constraint applying to the banks rather than households. Under these restrictive assumptions, the banking system acts as a "veil".

Government spending g_t is assumed to be unproductive and funded by a time-invariant *ad-valorem* consumption tax, *tc*. As noted by Mendoza, this tax does not distort the consumption-leisure decision [Mendoza (2010), p. 1952].

Production is based on a constant-returns-to-scale Cobb-Douglas function, multiplied by a total factor productivity shock, given by the exponent of ϵ_t^A :

$$y_t = \exp(\epsilon_t^A) A k_t^\beta L_t^\alpha v_t^\eta \tag{12}$$
$$0 < \alpha, \beta, \eta < 1$$
$$\alpha + \beta + \eta = 1$$
$$A > 0$$

4.3 First order conditions

The first order conditions for the representative household/firm are obtained by maximising function V_t subject to the intertemporal resource constraint, given by equation 7, the law of motion of capital, in equation 9, and the borrowing constraint, in equation 8, with respect to c_t, L_t, k_{t+1}, v_t and b_{t+1}.

For first order conditions for consumption and lobar (assuming flexible wages), given by c_t and L_t, we have the following expressions:

$$\lambda_t = u_c(c_t - N(L_t)) + \rho_c(c_t - N(L_t)) \mathbf{E}_t[V_{t+1}] \tag{13}$$
$$-\lambda_t w_t = -u_c(c_t - N(L_t)) N_L(L_t) - \rho_c(c_t - N(L_t)) N_L(L_t) \mathbf{E}_t[V_{t+1}] \tag{14}$$

where λ_t is the Lagrangean for the resource constraint and $\mathbf{E}_t$ is the expectations operator. The partial derivative of the discount factor with respect to consumption, $\rho_c(c_t - N(L_t))$, has the following form:

$$\rho_c(c_t - N(L_t)) = \left(\frac{-\gamma}{1 + c_t - \frac{L_t^\omega}{\omega}} \right) \exp\left[-\gamma \ln\left(1 + c_t - \frac{L_t^\omega}{\omega} \right) \right] \tag{15}$$

Dividing the lobar and consumption Euler equations, we obtain the following familiar lobar supply/real wage relation::

$$N_L(L_t) = w_t \tag{16}$$

The real wage w_t obeys the following first order condition:

$$\lambda_t \left(exp(\epsilon_t^A)F_L(k_t, L_t, v_t) - w_t(1 + \phi(R - 1)) \right) - \mu_t \phi R_t w_t = 0 \qquad (17)$$

Similarly, for intermediate goods, v_t, the following first order condition applies:

$$\lambda_t \left(exp(\epsilon_t^A)F_\nu(k_t, L_t, v_t) - p_t(1 + \phi(R - 1)) \right) - \mu_t \phi R_t p_t = 0 \qquad (18)$$

In both of these equations, the variable μ_t , as mentioned above, represents the Kuhn-Tucker multiplier applied to the borrowing constraint.

When the borrowing constraint does not bind, with $\mu_t = 0$, the above first order condition simply states that the marginal productivity of intermediate goods, multiplied by the marginal utility of income, should be equal to the marginal cost, including working capital costs. The same is true for the marginal product of lobar with respect to the real wage w_t including working-capital costs. When the borrowing constraint binds ($\mu_t > 0$), the multiplier acts like a tax on the use of intermediate inputs and labour, inducing firms to use less of them.

The first-order condition for the international bond b_{t+1} implies the following asset-pricing relation between the price of bonds and the marginal utility of income:

$$\lambda_t q_t^b = \mu_t q_t^b + D_t \lambda_{t+1} \qquad (19)$$

The condition implies the following law of motion for the marginal utility of income, λ_t :

$$\lambda_t = \mu_t + D_t R_t \lambda_{t+1} \qquad (20)$$

The gross real interest rate on one-period domestic bonds (R_t^h) satisfies the usual condition which links it to the stochastic discount factor:

$$\frac{1}{R_t^h} = \frac{\mathbf{E}_t[D_t \lambda_{t+1}]}{\lambda_t}$$

When the collateral constraint is not binding ($\mu_t = 0$) the domestic and foreign rates are identical. However, when the collateral constraint binds (with

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$\mu_t > 0$), a spread between the two rates emerges. This spread is the difference between the effective real interest rate, given by R_t^h and the international interest rate, R_t :

$$R_t^h - R_t = \frac{\mu_t}{\mathbf{E}_t \lambda_{t+1}} \tag{21}$$

Optimizing with respect to investment k_{t+1} leads to the following expression:

$$
\begin{aligned}
D_t \lambda_t \exp(\epsilon_{t+1}^A) F_k(k_{t+1}, L_{t+1}, v_{t+1}) + q_t \left\{ - \left[1 + \Psi\left(\frac{z_t}{k_t}\right) \right] - z_t \Psi_z\left(\frac{z_t}{k_t}\right) \frac{1}{k_t} \right\} + \\
q_{t+1} \left\{ -\delta + \left[1 - \Psi\left(\frac{z_{t+1}}{k_{t+1}}\right) \right] + z_{t+1} \Psi_z\left(\frac{z_{t+1}}{k_{t+1}}\right) (1 + \frac{z_{t+1}}{k_{t+1}}) \frac{1}{k_{t+1}} \right\} \\
+ \mu_{t+1} \kappa q_{t+1} = 0
\end{aligned}
\tag{22}
$$

The symbol D_t is the discount factor, equal to $\rho(c_t - N(L_t))$.

To simplify the first-order condition for the capital stock, we first define expected dividends, d_{t+1} as the expected marginal productivity of capital less depreciation plus the gains in the form of reduced adjustment costs by the higher stock of capital:

$$d_{t+1} = \exp(\epsilon_{t+1}^A) F_1(k_{t+1}, L_{t+1}, v_{t+1}) - \delta + \left(\frac{z_{t+1}}{k_{t+1}}\right)^2 \Psi_z\left(\frac{z_{t+1}}{k_{t+1}}\right) \tag{23}$$

Tobin's q in this model is derived from the familiar asset-pricing formula:

$$q_t = \mathbf{E}_t \left[\sum_{j=0}^{\infty} \left(\prod_{i=0}^{j} \left(\frac{1}{\widetilde{R}_{t+i+1}^{t+1}} \right) \right) d_{t+1+j} \right] \tag{24}$$

with the discount factor $\widetilde{R}_{t+i+1}^{t+1}$ defined in the following way:

$$\widetilde{R}_{t+i+1}^{t+1} = \frac{\lambda_{t+i} - \mu_{t+i}\kappa}{\lambda_{t+i+1}} \tag{25}$$

As equations (24) and (25) make clear, if the borrowing constraint binds (or is expected to bind in the future), the rate at which dividends are discounted will rise. This leads to a decline in the q-ratio. Since the borrowing constraint itself depends on q, the fall in q will in turn lead to a tightening of the borrowing constraint, leading to further falls in q. This debt-deflation mechanism is a key feature of the model and plays an important role in driving

the macroeconomic response to sudden stops. Furthermore, the debt deflation mechanism increases the financing cost of working capital, depressing investment, employment and output even more.

4.4 Downward Nominal Wage Rigidity

Schmitt-Grohe and Uribe (2011) have drawn attention to downward nominal wage rigidity (DNWR) as the key source of nominal frictions in the economy which weakens the ability of the economy to adjust under fixed exchange rate. In their setup, nominal wages can not adjust (sufficiently) downwards in response to adverse shocks. This implies that exchange rate pegs will lead to higher levels of unemployment on average than a flexible exchange rate regime with an optimal monetary policy. The implied costs are large. On average, the unemployment rate is more than 10 percentage points higher and the welfare cost of a currency peg under this form of rigidity amounts to 4 to 10% of consumption. In a complimentary paper, Schmitt-Grohe and Uribe (2013), advocate a Euro Area wide annual inflation rates of 4.3% in order to restore full employment to the Euro zone countries over a period of five years. This is more than twice the annual inflation target rate of 2%.

Given the importance of DNWR in recent policy discussion of the Euro Area , we embed this feature into our model. We implement DNWR by means of an asymmetric Calvo wage setting scheme. We base our modelling of DNWR on the results of Fagan (2013) who analysed micro data on wage changes for four countries (the US, Germany, Belgium and Portugal). He found that an asymmetric Calvo scheme best matches the cross sectional distribution of wage changes. He also shows that the case of a strictly binding constraint on wage cuts, as in Schmitt-Grohe and Uribe (2011), is a special case of this more general model.

In the asymmetric Calvo mechanism, nominal wages are free to adjust upwards. However, when nominal wages are required to fall, only a fraction of wage setters are free to cut wages, with the remaining fraction leaving their nominal wage unchanged. As in the regular Calvo setup, the optimal real wage rate chosen by those agents free to cut their wages is given by w_t^{num}/w_t^{den}, where

$$w_t^{num} = (1 + tc) \, \lambda_t \, L_t \, w_t^{\theta_w} \, L_t^{\omega - 1} + \psi_w \, \frac{D_t \, \lambda_{t+1}}{\lambda_t} \, w_{t+1}^{num} \, (1 + \pi)^{\theta_w} \qquad (26)$$

and

$$w_t^{den} = L_t \, w_t^{\theta_w} \, \lambda_t \, + (1 + \pi)^{\theta_w} \, \psi_w \, \frac{D_t \, \lambda_{t+1}}{\lambda_t} \, w_{t+1}^{den} \qquad (27)$$

In contrast to Schmitt-Grohe and Uribe (2011), who assume that "world" inflation is zero, we assume an inflation rate of 2%, in line with the ECB target for the Euro Area as a whole. This implies that DNWR will be less binding in our case. Our assumption on world inflation allows us to express the Calvo first order conditions in terms of real wages as in (27) and (28)[16].

For the economy-wide real wage, we have the following expression:

$$w_t = \left(\psi_w \, (s) \left(\frac{w_{t-1}}{1 + \pi} \right)^{1 - \theta_w} + (1 - \psi_w(s)) \left(\frac{\theta_w}{\theta_w - 1} \frac{w_t^{num}}{w_t^{den}} \right)^{1 - \theta_w} \right)^{\frac{1}{1 - \theta_w}}$$

$$(28)$$

This expression replaces the households first order condition for labour given by (5). The parameter $\psi_w(s)$ captures the state-contingent degree of DNWR in the economy at time t. It is zero if nominal wages are rising, so that nominal wages are flexible in this case. Where nominal wages are falling, DNWR kicks in and $0 < \psi_w(s) \leq 1$.

Since we are solving our model using a global solution method, the introduction of this highly nonlinear form of wage setting poses no additional problems apart from adding an additional state variable (the previous period's wage).

4.5   TARGET Balances

To capture the differences between a monetary union and a pure fixed exchange-rate regime, we note that net foreign assets may be decomposed

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[16]Specifically, we assume that the world price level evolves deterministically, increasing at a rate of 2% per annum. The Calvo expressions for wages is normally in terms of nominal wages. However, dividing the first order conditions for the Calvo wage-setting by the deterministic price level allows us to express the Calvo conditions in real terms as in (27) and (28).

as the sum of two components: private net foreign assets (b_t^{PR}) and central bank TARGET balances (b_t^{CB}), with borrowing via the TARGET system being recorded as a negative value for b_t^{CB}:

$$b_t = b_t^{PR} + b_t^{CB} \tag{29}$$

In our model, we assume that the borrowing constraint applies private to net foreign assets rather than to total net foreign assets:

$$q_t^b b_{t+1}^{PR} - \phi R_t(w_t L_t + p_t \nu_t) \geq -\kappa q_t k_t \tag{30}$$

This is a crucial assumption which we discuss further below. To complete the model, we need to specify how TARGET balances are determined. Building on the empirical analysis in Section 3, we assume that the level of TARGET balances is a linear function of the spread between the domestic and world interest rate given by (21):

$$-b_t^{CB} = \Phi(R_t^D - R_t)$$

As noted earlier, the difference the interest rate spread comes into play when the collateral constraint becomes binding. In this case, the emergence of a spread will trigger TARGET inflows. Otherwise, when the collateral constraint is not binding, TARGET balances will be zero. The parameter Φ reflects the elasticity of Eurosystem liquidity supply to the country. When it is zero, there is effectively no TARGET system in place. As Φ tends to infinity, liquidity supply becomes infinitely elastic. In this extreme case, private capital outflows in a sudden stop are completely offset by TARGET inflows: in effect there is no longer any external borrowing constraint on the economy. In this extreme case, the effects of sudden stops on macroeconomic variables are completely neutralised.

This relatively simple formulation of the supply of TARGET balances captures the main features of the data which we documented in Section 3: very low TARGET balances in calm periods and a strong link between TARGET balances and interest rate spreads during sudden stop periods. We will use our estimations in Section 3 for the model calibration.

The assumption in (30) that the borrowing constraint only applies to private net foreign assets is crucial to the results obtained below. An alternative - polar opposite - assumption is that the amount that private lending to the domestic economy would take into account borrowing from the central bank via TARGET as well as private foreign debt. This, for example, could reflect concerns regarding the seniority of official lending. In this case, introducing a TARGET system into the model would have no effect. The paths of all of the variables generated by the model would be the same as in the version of the model without a TARGET system: increases in TARGET liabilities would be offset one-for-one by reductions in private lending to the economy when the borrowing constraint binds. An alternative possibility would be to allow for official financing via TARGET balances to lead to an easing of the private borrowing constraint. This would be consistent with idea of a "catalytic" role of official financing: the fact that official financing is made available gives the country concerned a "good housekeeping seal of approval" which induces the private sector to lend more willingly. This mechanism is explored theoretically by Corsetti et al. (2006) and empirically by Saravia and Mody (2003), amongst others. In the context of our model, such a formulation of the borrowing constraint would imply that the role of TARGET balances in mitigating the macroeconomic effects of the private sudden stop would be even stronger than we assume.

Our choice for the formulation of the borrowing constraint (30) is designed to capture the central idea in the the existing empirical literature examined above: that TARGET balances allow higher levels of current account deficits than would otherwise be the case. An additional justification can be obtained by noting the the broad collateral framework of the Eurosystem's operations[17] renders crowding out of private capital flows by TARGET balances implausible. In addition, we are not aware of any evidence supporting a catalytic role for TARGET balances.

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[17]See Cheun et al. (2009)for a comparative overview of the collateral frameworks of the main central banks. Over the course of the crisis, the collateral framework of the Eurosystem was broadened further. In addition, an even wider set of assets is eligible as collateral for Emergency Liquidity Assistance.

4.6 Stochastic Shock Specification

Both total factor productivity and the gross interest rate R_t follow exogenously-determined stochastic processes. The total factor productivity shock, given by ϵ_t^A, has the following specification, with autoregressive coefficient ρ_A and innovation term η_t^A, normally distributed with mean zero and variance σ_A^2 :

$$\epsilon_t^A = \rho_A \epsilon_{t-1}^A + \eta_t^A \tag{31}$$
$$\eta_t^A \sim N(0, \sigma_A^2)$$

The gross real world interest rate has the following process:

$$\ln(R_t) = \rho_R \ln(R_{t-1}) + (1 - \rho_R) \ln(\overline{R}) + \eta_t^R + \rho_{RA} \cdot \eta_t^A \tag{32}$$
$$\eta_t^R \sim N(0, \sigma_R^2)$$

The logarithm of the gross world interest rate is driven by an innovation term which is in part idiosyncratic, represented by η_t^R and in part correlated with the innovation term to total factor productivity, η_t^A, given by the correlation parameter ρ_{RA}. We follow Mendoza (2010) in assuming a negative correlation between real world interest rate and productivity shocks.

Mendoza (2010) also specifies a stochastic process for the relative price of imported goods. We do not take this approach here in order to limit the size of the model (for computational reasons) and because it is not clear that shocks to intermediate goods prices have a played a significant role in the Euro Area crisis. Thus, in our specification, this price grows at the constant annual inflation rate of two percent.

4.7 General Equilibrium and Debt-Deflation Dynamics

The competitive equilibrium is defined by the sequence $\{c_t \ L_t \ k_{t+1} \ b_{t+1} \ v_r \ i_t\}_0^\infty$ and prices $\{q_t \ w_t \}_0^\infty$ such that the representative household maximizes the intertemporal stationary cardinal utility function, given by 3, subject to constraints 7, 9, and 8, taking as given the price vector $\{w_t, q_t, R_t\}$ and the initial conditions $\{k_0 \ b_0\}$. In the case of DNWR the first order condition for labour (16) is replaced by the wage-setting condition (28).

Wages and the price of capital must satisfy the following conditions:

$$w_t = \frac{\partial N(\overline{L}_t)}{\partial \overline{L}_t} \tag{33}$$

$$= \left(\begin{array}{c} \psi_w\left(s\right) \left(\frac{w_{t-1}}{1+\pi}\right)^{1-\theta_w} \\ + (1 - \psi_w(s)) \left(\frac{\theta_w}{\theta_w-1} \frac{w_t^{num}}{w_t^{den}}\right)^{1-\theta_w} \end{array} \right)^{\frac{1}{1-\theta_w}}$$

$$q_t = \frac{\partial i(\overline{k}_{t+1}, \overline{k}_t)}{\partial \overline{k}_{t+1}} \tag{34}$$

$$\overline{L}_t = L_t \tag{35}$$

$$\overline{k}_t = k_t \tag{36}$$

When the collateral constraint binds, $(\mu_t > 0)$, a wedge, in the form of an external financing premium on debt, emerges (21). There is also an external financing premium on working capital

5   Calibration and Solution Method

5.1   Parameter Values

The periods in the model are annual. The parameters we use in our analysis follow closely those used in Mendoza (2010) and appear in Table 6.[18] The additional parameters, beyond those specified by Mendoza, are for the Calvo wage setting and the TARGET equations. The intratemporal elasticity of substitution θ_w is usually set at 6. The Calvo coefficient (which measures the percentage of wage setters who are unable to change their wages when wages are falling) is set at 0.6 on the basis of estimates reported in Fagan (2013).

These parameters generate a deterministic steady state debt/gdp ratio of 86 percent. We also set the annual world inflation rate at 2% for the Calvo wage-setting equation. The target parameter Φ is is set to 0.13 based on the estimates reported in Section 3.

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[18]See Mendoza (2010), pp. 1951-53 for a fuller discussion of the parameter selections for this model.

5.2 Model Solution Method

Solving models with sudden stops is challenging since these models contain important non-linearities due to borrowing constraints. The current model incorporates the additional non-linearity, in the form of downward nominal wage rigidity. Solution algorithms based on local approximations (perturbation methods) such as log-linearization or quadratic approximation around the deterministic steady state or stochastic mean) are not suitable in our case. This is because our primary interest is in what happens when the binding borrowing constraint becomes binding. Points in the state space are typically far away from the deterministic steady state or even the stochastic mean since the constraint binds only occasionally. We therefore use a global solution technique within a class of global Projection methods which take into account nonlinearities and aim to achieve accuracy over the whole state space rather than a small neighbourhood of the steady state[19].

Specifically, the solution method we use for our model is the collocation method, discussed by Judd (1998) and Miranda and Fackler (2002). We make use of this method over the value function (VF) iteration used by Mendoza (2010).[20] Rendahl (2013) demonstrates that working with the Euler equations (as we do in our collocation method) yields a much greater degree of accuracy to the decision rules than VF iterations. The solution method is discussed in detail in Appendix 2.

6 Results

We illustrate our model's implications regarding the effects of a TARGET system using a number of different approaches. First we present impulse response functions, distinguishing between situations where the borrowing constraint binds and where it does not. We also examine how the presence of a TARGET system affects the response of the economy to shocks. Second, we provide further evidence using stochastic simulations. In this regard we first look at a set of key descriptive statistics for our model economy. Secondly,

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[19]An extensive review of alternative methods for solving dynamic stochastic general equilibrium models is contained in Judd (1999).

[20]In a more recent paper, using a model similar to the one of this paper, Mendoza no longer uses the value-function iteration. See Bianchi and Mendoza 2013).

we examine what Mendoza calls "event dynamics". Mendoza (2010) has already documented that the model we are using is capable of matching the key empirical features of sudden stops. Building on this, we examine, using the same methodology, how the presence of a TARGET system affects the dynamic response of the economy in sudden stop events.

To illustrate these implications further, we take a specific example of a crisis in our simulated data and show how the presence of the TARGET system affects the adjustment process. Next using actual data for the case of Spain over the period 2010-2012 we conduct a counterfactual analysis. We back out a set of initial conditions and shocks so that our model (with a TARGET system) replicates the path of key Spanish macro variables. Then we "switch off" the TARGET system and apply the same shocks to the model. Comparing the two sets of paths gives us an indication of the impact of the TARGET system which can be compared to actual data (as distinct from just simulation results).

All of these exercises lead to the conclusion that TARGET systems leads to sizeable differences in the behaviour of the economy in response to sudden stops. The TARGET system notably weakens the adverse effects of sudden stops on consumption, investment and, to a lesser extent, output. Using the simulated data, we compute the impact of a TARGET system on welfare. Contrary to initial expectations, we find that a TARGET system leads to a (very small) reduction in welfare in our model economy.

6.1 Impulse Response Analysis

We present impulse responses to a one standard deviation orthogonalized shock to TFP[21]. We present results for key macroeconomic variables: output, consumption, investment, employment, capital stock, the real wage, Tobin's q, net foreign assets, the interest rate spread, TARGET balances.

A key feature of our model is that the borrowing constraint has important effects on the behaviour of the economy but this constraint only binds occasionally (about 5% of the time in our simulations). To illustrate this important feature, we compute IRFs for the version of the model without

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[21]We have also computed IRFs for the interest rate shocks. These results are available from the authors on request.

TARGET from two different starting points: the stochastic mean of the state variables (where the constraint does not bind) and a selected point in the state space[22] where the borrowing constraint just binds. The purpose of this exercise is to illustrate the impact of the borrowing constraint on the response of the model to shocks.

Figure 6 shows the results of this exercise. We see that there is an across the board fall in all of the macro variables. However, there is one major difference. In the case of the binding borrowing constraint, the fall in investment and Tobin's q is much more severe, and, as expected, the increase in indebtedness (or fall in net foreign assets) is reduced, due to the binding borrowing constraint. Not surprisingly, with the binding borrowing constraint, the spread rises.

Figure 7 plots the same variables, for the same shock, with and without the availability of TARGET financing. In both cases, the borrowing constraint binds. The solid curves, of course, with no TARGET system are the same as the dashed lines in Figure 6. The most striking difference between the two charts relates to the spread, Tobin's q and investment. Without a TARGET system the the fall in q and investment is much larger. This points to a key role of the TARGET system in mitigating the effects of the debt deflation mechanism. The differences in the IRFs for consumption and much less marked while the output path is very similar in the two cases. This latter result reflects a decline in net exports in the TARGET case as the availability of external funding allows consumers to smooth consumption in the face of this shock.

6.2   Stochastic Simulations

Following Mendoza (2010), we summarize some key properties of our model by conducting stochastic simulations. Specifically, we draw 100,000 pairs of shocks from the joint distributions of η_t^R and η_t^A, the shocks to our stochastic processes for the world interest and the total factor productivity shock. We

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[22]This point is selected as follows. Let $\bar{X}$ denote the vector of stochastic means of our five state variables. Let $\tilde{X}$ denote the point in the state space where the interest rate spread (or equivalently the Kuhn-Tucker multiplier on the borrowing constraint) reaches its maximum. Then our point is chosen as: $X^o = \bar{X} + \lambda(\tilde{X} - \bar{X})$ where λ is chosen so that the constraint just binds at X^o

then feed these shocks into our model to derive paths for the endogenous variables. In turn we compute various statistics of interest from these simulated variables.

For comparison purposes, we also include information on the deterministic steady state of the model. These results appear in Table 5.

We see that the stochastic mean values of the key variables are lower than the deterministic steady state. This is due to the effect of precautionary saving, which cannot be captured by the deterministic steady-state solution methods. This point was also noted by Mendoza (2010). We also see that precautionary saving comes into play even in the absence of the borrowing constraint.

We see that the largest negative net foreign asset/GDP ratio, is well over 100 percent in the no borrowing constraint, reduced to slightly above 25% in the case of the borrowing constraint, but eased to slightly above 35% in the TARGET system.

We also see that the frequency of the borrowing constraint becoming binding is higher under the TARGET system. This result is consistent with the lower degree of precautionary saving in this regime.

The degree of real wage volatility does not change very much across regimes. In contrast to Schmitt-Grohe and Uribe (2011), the degree of downward nominal wage rigidity does not have much impact on the response of the economy under TARGET versus no TARGET.

The limited role of DNWR in the present case, reflects three factors. First, the calibration of the shock processes implies a much lower degree of volatility in nominal wage growth than the very high shock variance calibrations used by Schmitt-Grohe and Uribe (2011). Second, in our model the labour supply is more elastic, dampening the volatility of wages. (In the baseline model of Schmitt-Grohe and Uribe (2011) labour supply is perfectly inelastic). Third, we assume a 2% world inflation rate as against zero. These three factors imply that even in the absence of DNWR, wage cuts would be relatively rare in our model economy and thus the presence of DNWR has very limited effects in our simulations.

6.3 Event Dynamics

We take 100,000 annual observations generated by our stochastic simulations and, emulating the empirical literature on sudden stops, identify particular sudden stop episodes. We begin by identifying potential sudden stop periods based on the behaviour of the spread (and thus whether the borrowing constraint binds). A potential episode begins when the spread rises above 5 basis points and ends when the spread falls below 5 basis points. However, this is not sufficient for a sudden stop which matches the definition given in the empirical literature.

Following the definition provided by Calvo et al. (2004a) we specify in addition that the sudden stop be characterized by a large and unexpected reversal of capital flows and be associated with a contraction in output. We identify a sudden stop episode with two restrictions. First, the change in the net exports to GDP ratio is at least two standard deviations above its mean for at least one year during the episode. Secondly, output is at least one standard deviation below its stochastic mean during the episode.

The results of this exercise are presented in Figure 8. We capture the event dynamics by taking the median values for these episodes, with a normalization factor for each variable at unity one period before the sudden stop at time $t = 0$, the the exception of net exports which are normalized at zero.

We see that the provision of the TARGET financing greatly mitigates the collapse in GDP, consumption, investment and Tobin's q, and reduces the increase in the spread and in the net export/GDP ratio.

6.4 A Crisis Example

While the use of event dynamics is widespread in the literature on sudden stops and crises, it does have some potential limitations. For example, even in simulations the durations of crises can be very different. In our simulations, the length of episodes ranges between one and 17 years. Thus taking averages of such disparate experiences may mask some important features.

As a complement to the event analysis, we take one specific example of a sudden stop episode from our simulation and discuss it in somewhat greater detail. To select the specific event, we identify the point in the simulation

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of the model without TARGET where the spread is at a maximum (thus the borrowing constraint is at its most binding). We report data for three periods before and three after this point. Taking the same initial point in the state space and using the same shocks, we then simulate our TARGET model to provide a comparison of the two regimes.

Figure 9 shows the results. First we observe a classic boom and bust pattern. Prior to the borrowing constraint being hit, the economy experiences positive TFP shocks and negative world interest rate shocks (last two panels on the third row). There is an asset price boom and the q-ratio rises sharply. Investment increases by around 25% in the first three years, while output and consumption also increase notably. Not surprisingly there is a decline in the net export to GDP ratio. It is notable that under TARGET, the boom is stronger, mainly through the effect of TARGET on precautionary savings.

When both TFP and world interest rate turn adverse, the economy hits the borrowing constraint. The spread rises from zero to 250 basis points and the economy falls into a sharp recession. The q-ratio collapses and investment falls sharply. Consumption and GDP decline less steeply and the net trade ratio swings into positive territory. Again there are notable differences between the TARGET and non-TARGET regimes. In the former, the emergence of an interest-rate spread triggers a build up of TARGET balances (in this case to around 6 per cent of GDP). The rise in the spread is nearly 200 basis points less. As a result, the decline in q and investment is more muted. Not surprising in these circumstances, the fall in output and consumption is less extreme.

6.5 Counterfactual Simulation

Impulse response functions gave a useful and widely used picture of a model's response to typical shocks. However, in this model, as in reality, sudden stops are typically generated by a sequence of adverse shocks. A fuller picture of the implications of a TARGET system for macroeconomic adjustment can be given by a counterfactual simulation.

Using data from an actual sudden stop situation observed in the data, we back out of the model a set of shocks and initial state variables such that when these shocks are fed into the model, it reproduces the observable paths

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of macro variables of a country. This step follows the "wedge-accounting" methodology of Chari et al. (2007). We replicated this "baseline scenario" in a model with a version of the TARGET system in place Then we feed the same shocks into a version of the model which is identical to the base model, apart from the fact that the TARGET is "switched off". Comparison of the two sets of paths then yields an estimate of how the presence of a TARGET system has affected the economy under a collection of shocks which approximate a "realistic" crisis situation.

For our exercise, we use Spanish data over the period 2010 to 2012. We chose this country because, unlike other "stressed countries" it did not have an official EU/IMF program during this period. Hence, the results will not be distorted by official capital flows.

Since the model has more variables than shocks we have chosen the variables to match empirical counterparts. Clearly we cannot match variables which are not well measured (specifically Tobin's q). The first variable we chose to match is the ratio of TARGET balances to GDP. The choice of this variable is natural since it relates to a key concern of the paper. The second variable, real GDP, is also a natural candidate given its macroeconomic importance. Finally, since our earlier results highlight the important differences in the response of investment to shocks under TARGET regimes, we chose Gross Domestic Fixed Capital Formation as our third variable. Data on the macro variables come from the EU Commission's AMECO database and are suitably scaled. Our real GDP variable is an index (2010=1.0) detrended by a 2% annual growth trend. Similarly, we use an index for investment while the TARGET-GDP ratio comes from the raw data.

It should be stressed that the purpose of this exercise is not to provide a detailed account of the crisis in Spain. Our model has only two stochastic shocks and five state variables. It also omits a number of important features of the economy which are relevant to the Spanish crisis (specifically, the housing and banking sectors). Instead, our purpose is to illustrate the properties of the model under alternative scenarios by subjecting it to a set of shocks which, for a few variables, mimic patterns which have been observed in actual data.

The results of the exercise appear in Figure 10. This figures shows paths for 6 selected variables. The blue lines show the paths implied by the model

with a TARGET system. By construction, these paths for GDP, investment and the TARGET ratio match exactly the Spanish data for the 2010-2012 period[23]. The model suggests that the impact of the TARGET system has sizeable effects on the economy.

As in the impulse response functions, the main impact comes through the effect of TARGET financing in moderating the financial effects of the shocks. In the absence of a TARGET system, the borrowing constraint is more severe: the rise in the model-based measure of spreads is much larger (+12 basis points rather than +2bp over the 3 year period). As a result, the debt-deflation mechanism in the model kicks in strongly with the fall in the q-ratio being much sharper (-12% as against -7%). These financial channels lead to a much sharper decline in investment and, to a lesser extent, consumption. The difference in output paths is partially compensated by a sharper rise in net exports. Still, at the end of the horizon the difference in output between the two scenarios is four percent.

Our counterfactual analysis with our model thus points to sizeable macro effects of the TARGET system in crisis-like situations such as that experienced by the Spanish economy.

6.6 Welfare Analysis

Given the results in previous sections, one might expect that a TARGET system, which reduces the impact of sudden stops on consumption will imply a higher level of welfare compared to the case in which no such system is in place. However, as pointed out by Mendoza (2010), the decentralised equilibrium of the current model does not lead to a socially optimal allocation. The sub-optimality comes from the fact that there is a pecuniary externality in the model. In the decentralised equilibrium agents take asset prices as given. However, an increase in foreign debt increases the probability that the borrowing constraint will bind in the future and and hitting the borrowing constraint will lead to lower asset prices through the debt deflation mechanism.

In choosing the level of foreign debt, however, agents fail to internalize this

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[23]We do not examine how well the model fits the other variables for Spain, an issue which is beyond the scope of this exercise.

pecuniary externality between external debt and future asset prices. As a consequence, there tends to be "over borrowing" in the economy, with foreign debt exceeding socially optimal levels. This provides a potential role for policy intervention, such as capital controls or taxes on capital flows, to improve welfare (see, for example, Bianchi et al. (2012) and Schmitt-Grohe and Uribe (2012)). As we saw earlier, a TARGET system reduces the level of precautionary saving leading to a higher incidence of hitting the borrowing constraint. These effects could potentially lead to a lower level of welfare. A priori, therefore, it is an open question whether a TARGET system will increase or reduce the welfare of the country concerned.

To address this question, we compute the unconditional means of welfare following the method employed by Schmitt-Grohe and Uribe (2012). This takes into account the fact that the state variables in our model are stochastic, so we compute the unconditional expectation of welfare by integrating over the distribution of state variables obtained from the stochastic simulations. It also takes into account the effects on welfare from the transition from one regime to another.

We present results using the ergodic distribution of the state variables under the regime of no TARGET. At each point in the simulated state space, we compute welfare under the actual regime (no TARGET system in place) by computing the expected value of (3). Then for this point, using the decision rules for the TARGET regime, we then compute the welfare which would arise at this point in a TARGET regime. We express both values in terms of consumption equivalents. The ratio of the two values then gives us the welfare gain or loss of moving from a no TARGET regime to a TARGET regime, with a value greater than (less than) unity indicating a welfare gain (loss). We repeat this exercise for each of the points in the stochastic simulation. The distribution of this ratio is shown in Figure 11. Overall, the results point to very small gains on average. The mean value of the ratio is 1.0002, corresponding to gain of just two-tenths of a basis point of steady state consumption.

While the gains are generally small on average, Figure 11 shows that the welfare gains vary depending on the state of the economy. To explore this further, we follow Schmitt-Grohe and Uribe (2011) and examine how differences in the value of each state variable affects the potential welfare gain.

Specifically, for each of our 5 state variables (net foreign assets, previous period wage, capital stock, world interest rate and TFP) we compute the welfare gain for different values of this variable, holding the remaining four state variables constant at their ergodic means. We present values covering the min-max range of the variables found in the stochastic simulation. The results of this exercise are presented in Table 11. It is clear that the value of net foreign assets plays a particularly important role. At high levels of foreign debt, where the probability of hitting the borrowing constraint is higher (or, if it has already been hit, the borrowing constraint is tighter), the gains in welfare are highest. At the maximum value of foreign debt recorded in our stochastic simulations, the gain in welfare is equivalent to nearly 20 basis points of mean consumption. In contrast, when net foreign debt is low or when the economy has a positive net foreign asset position, the welfare gain is negligible. A similar, but less marked pattern, is evident in the case of capital. Low levels of capital, which imply that less collateral is available, are also associated with larger welfare gains, although the variation is less marked than in the case of foreign assets.

Thus the beneficial effects of smoothing consumption when the economy hits the borrowing constraint are offset by the adverse effects of a suboptimally higher average foreign debt and a higher incidence of "crises".

7 Conclusion

This paper documented that, during the crisis, "stressed" euro area countries have experienced sudden stops in capital flows, and associated macroeconomic developments, which are comparable to the experience in previous sudden stop episodes. We showed how a specific feature of the monetary union – financing from the common central bank reflected in TARGET balances - to some extent compensated for the reversal of private capital flows. We modified the workhorse sudden stop model of Mendoza (2010) to allow for such financing and compared how this feature affects the macroeconomic adjustment and welfare.

Two main results emerge from the analysis. First, we find that the availability of TARGET financing in a monetary union greatly mitigates the adverse effects of a sudden-stop episode on GDP, consumption, and, particularly,

investment. Second, despite this, we find that a TARGET system leads to only a small gain in welfare for the country concerned. This reflects the fact that such a system exacerbates the tendency towards over borrowing: precautionary saving is lower, and, as a consequence of this, the economy will experience sudden stops (hitting the borrowing constraint) more frequently.

Future research could extend this analysis in a number of directions. For example, it would be useful to extend the model to a two country-setting. This would allow for analysis of the effects of TARGET on the "lending" country as well as the "borrowing" country[24]. A second useful extension would be to introduce an explicit banking system[25], incorporating an interbank market, into the model. This would allow for a richer analysis of the links in a monetary union between central bank financing, bank liquidity, interbank markets and private capital flows. While considerable progress has been made in developing models with rich treatment of the financial sector (see, for example, ECB (2012) for a survey of recent work), computational difficulties mean that tradeoffs have to be made and all important elements cannot be included in the model simultaneously.

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[24] A recent example of a two-country model with sudden stops is Ozkan and Unsal (2010). This paper however does not address the issue of TARGET balances.

[25] Although the Mendoza (2010) model does not incorporate an explicit banking system, it can be easily demonstrated that the predictions of the model would not be changed by adding a "passive" banking system, where banks act a pure intermediaries between lenders and borrowers. Such a setup, however, would ignore important aspects such as moral hazard, default and systemic risk.

Table 1: Target and Capital Outflow via Banking System Example

Initial Position. Deutsche has an interbank loan of 100 with AIB:

Deutsche		Bundesbank		Central Bank of Ireland		AIB	
Loan 100							Deposit 100

Deutsche withdraws loan and puts proceeds in Deposit facility at the Bundesbank:

Deutsche		Bundesbank		Central Bank of Ireland		AIB	
Loan -100							Deposit -100
DepF+100		DepF +100					

AIB replaces deposit by borrowing from Central Bank of Ireland:

Deutsche		Bundesbank		Central Bank of Ireland		AIB	
Loan -100							Deposit -100
DepF+100		DepF +100					
				Repo +100		Repo +100	

Cross Border flows generate changes in Target Balances (TB):

Deutsche		Bundesbank		Central Bank of Ireland		AIB	
Loan -100							Deposit -100
DepF+100		DepF +100					
				Repo +100		Repo +100	
		TB +100				TB +100	

Table 2: Panel Estimates of Target Equation

	(1)	(2)	(3)
Coefficient	-0.117	-0.134	-0.051
Std Error	(0.0118)	(0.008)	(0.014)
R^2	0.251	0.74	0.83
Nobs	295	295	295
Co FE	No	Yes	Yes
Time FE	No	No	Yes

Table 3: Individual Country Estimate of Target Equation

	Ireland	Italy	Greece	Portugal	Spain
Constant	-0.233	0.045	-0.107	-0.100	0.090
	(0.069)	(0.005)	(0.009)	(0.020)	(0.013)
Coefficient	-0.290	-0.108	-0.130	-0.119	-0.147
	(0.050)	(0.006)	(0.009)	(0.013)	(0.009)
R^2	0.23	0.87	0.93	0.59	0.82
Nobs	59	59	59	59	59

Table 4: Parameters

Utility	
σ_c	2.0
ω	1.846
γ	0.16
Production	
α	0.592
β	0.305
η	0.102
A	7.389
Investment	
δ	0.088
a	2.750
Budget-Borrowing	
κ	0.225
ϕ	0.258
tc	0.168
tc	0.168
Φ	13.000
Wage Setting	
ψ_w	.60
θ_w	6.0
Stochastic Processes	
ρ_A	.57
ρ_R	.57
ρ_{RA}	-.98
σ_A	.011
σ_R	.012

Table 5: Moments of Simulated Data Across Regimes

Variable	St. State	Regime	Mean	Min	Max	σ_x/σ_y	ρ_{xy}
GDP	393.204	NBC	393.374	343.889	451.937	1	1
		BC	392.403	343.654	450.588	1	1
		T	392.893	344.089	451.640	1	1
Cons	263.115	NBC	267.722	220.130	307.005	1.050	0.831
		BC	272.392	240.976	308.197	0.922	0.904
		T	270.970	237.725	307.549	0.944	0.895
Invest	67.593	NBC	67.862	41.087	101.169	3.481	0.639
		BC	67.541	41.262	99.157	3.412	0.653
		T	67.684	41.167	99.779	3.445	0.644
Int. Goods	42.508	NBC	42.531	36.473	49.485	1.108	0.995
		BC	42.425	36.448	49.337	1.109	0.995
		T	42.478	36.495	49.451	1.107	0.995
Employment	16.692	NBC	16.678	15.315	18.121	0.623	0.991
		BC	16.656	15.309	18.092	0.624	0.991
		T	16.670	15.336	18.173	0.627	0.001
Wage Inflation	0.02	NBC	.02	-.006	.051	13.993	0.300
		BC	.02	-.006	.051	14.139	0.303
		T	.02	-.006	.051	13.939	0.296
Net Ex/GDP	0.047	NBC	0.033	-0.071	0.147	24.325	-0.138
		BC	0.017	-0.082	0.101	40.778	-0.109
		T	0.022	-0.077	0.110	32.366	-0.119
NFA/GDP	-0.378	NBC	-0.213	-1.097	0.452	-23.271	-0.134
		BC	-0.016	-0.262	0.496	-183.518	-0.368
		T	-0.081	-0.363	0.460	-39.565	-0.313
Spread	0.00	BC	0	0	0.025	253.410	0.052
		T	0	0	0.008	93.309	0.096
Target	0.00	T	0.002 0.096	0.00	0.100	93.309	0.096
Pr(BC)	0	BC	0.052				
		T	0.246				

Figure 1: Macro Dynamics with Sudden Stops (annual)
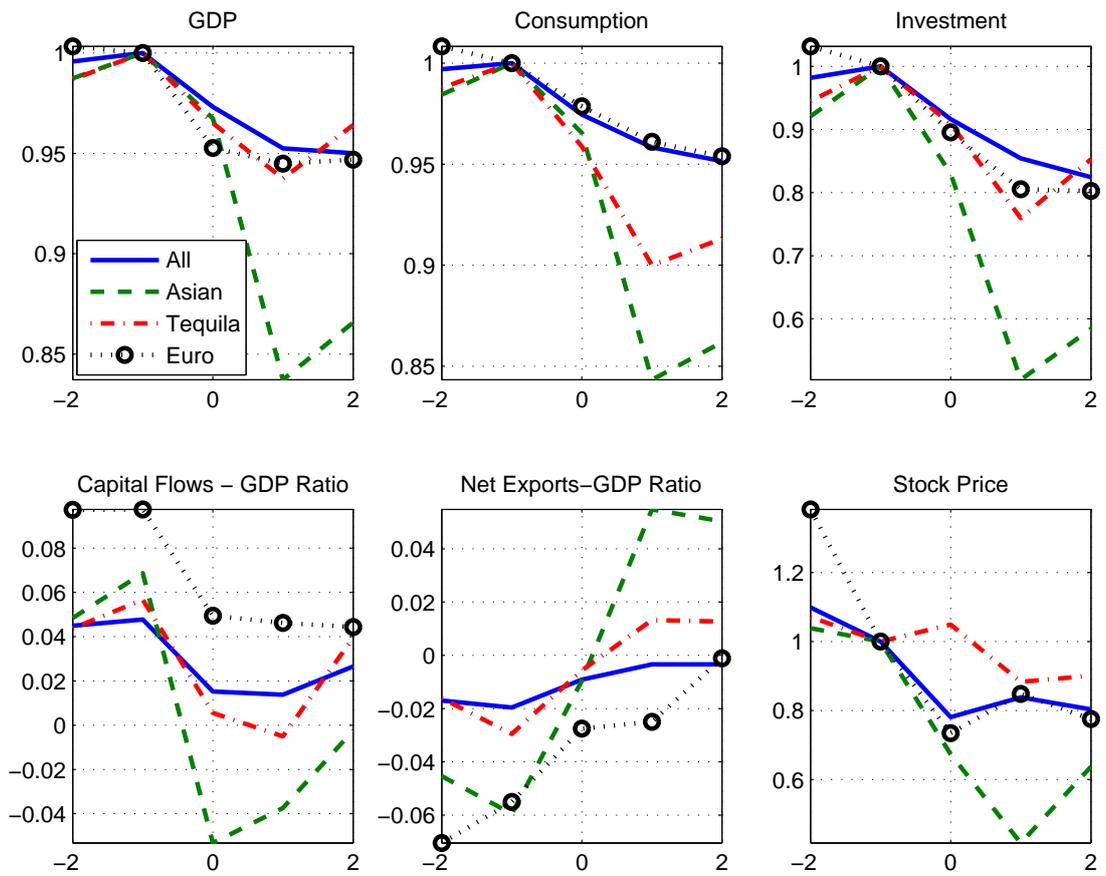
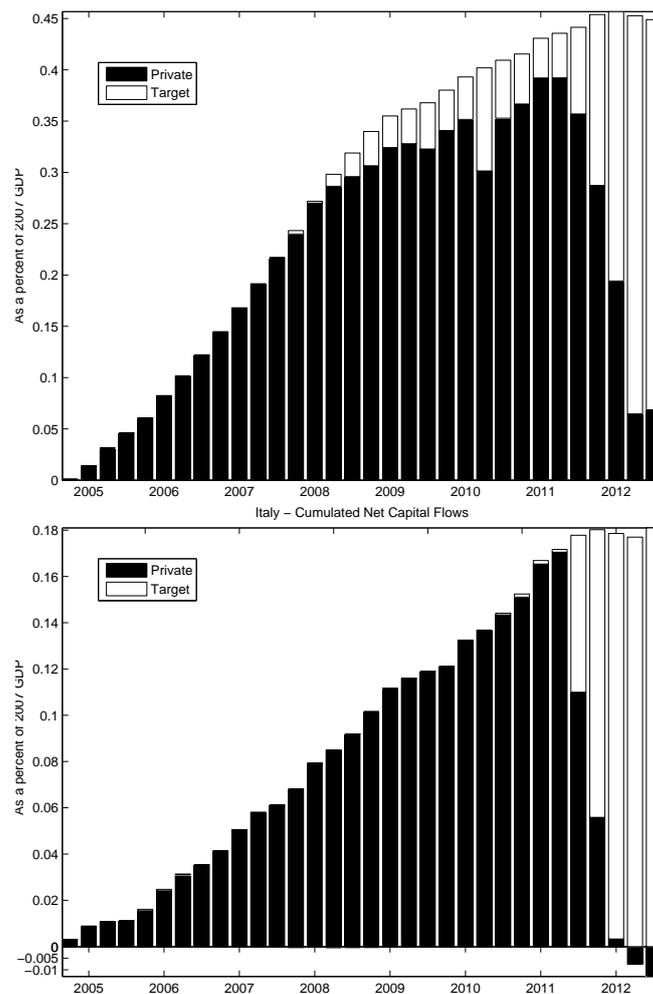Figure 2: Target balances (% GDP): Euro Zone
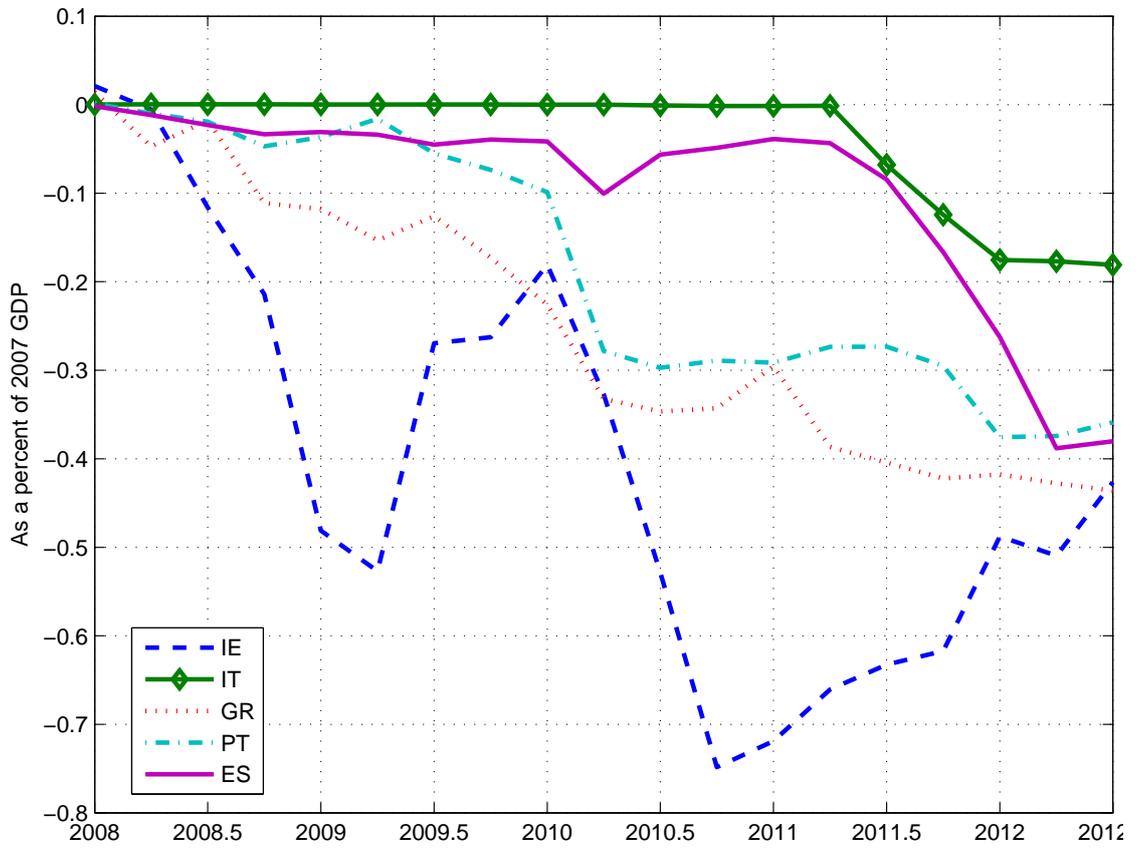
Source: Eurocrisis Monitor website.

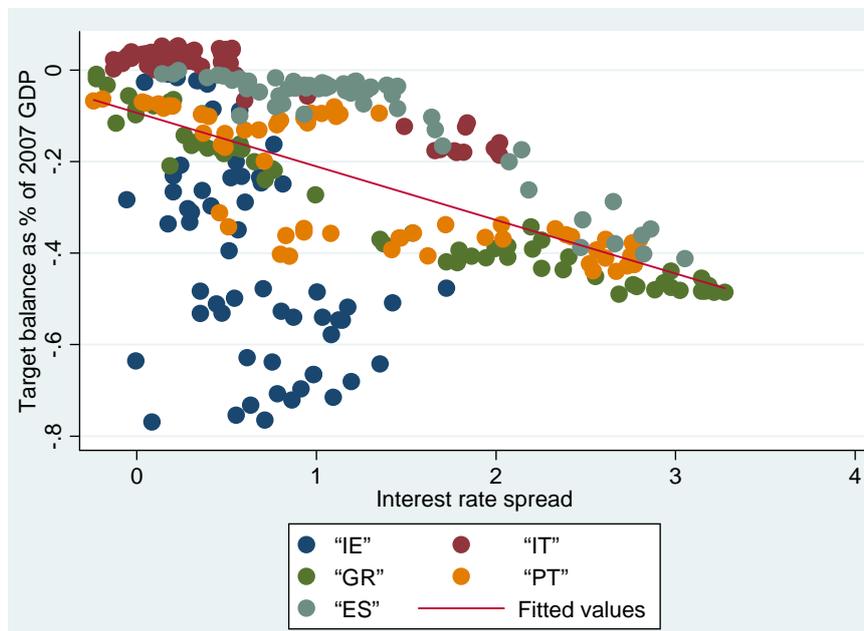Figure 3: Cumulative Net Capital Flows: Greece, Ireland and Portugal

Source: IMF Balance of Payments statistics and World Bank External Debt
hub.

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Figure 4: Cumulative Net Capital Flows - Spain and Italy
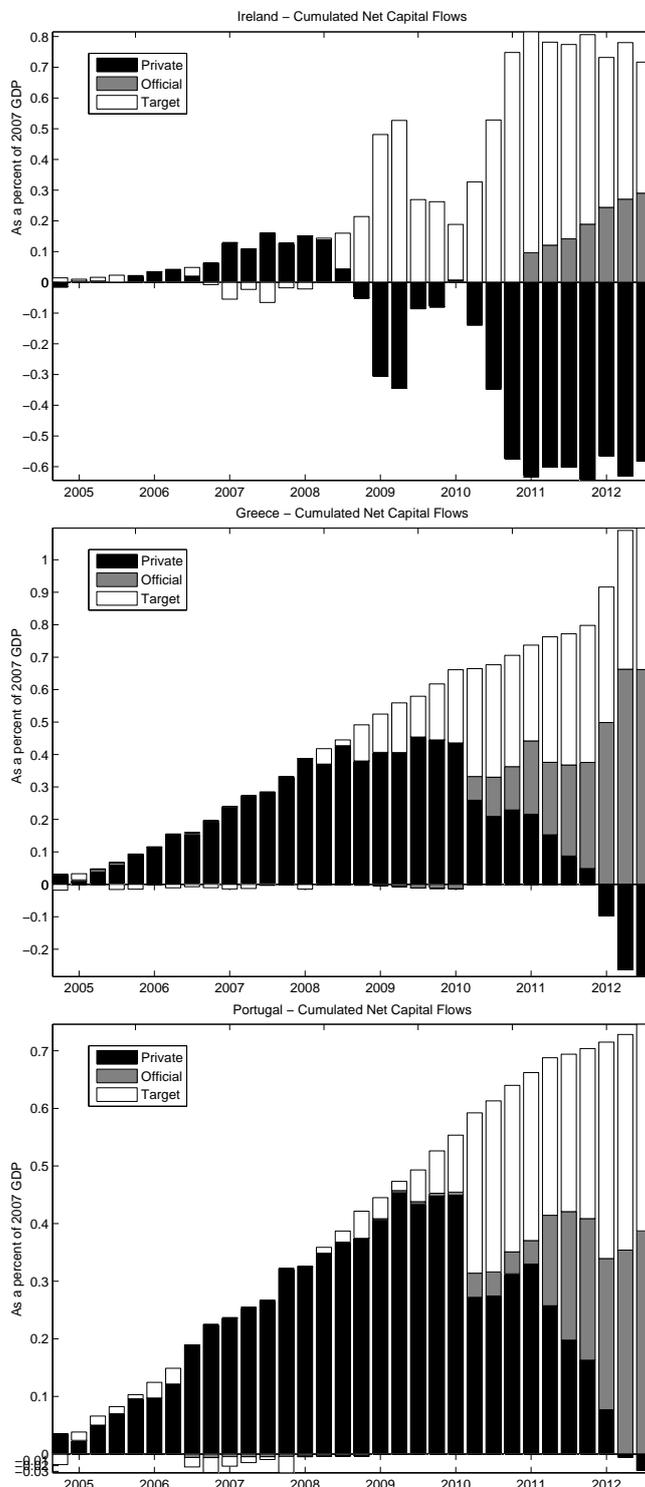
Source: IMF Balance of Payments statistics and World Bank External Debt
hub.

Figure 5: Target balances vs. Spreads in Euro Zone

Source: Eurocrsis Monitor website and ECB. The intreest rate spread vari-
able relatea to the MFI rate on new business loans to non-financial corpor-
ations for amounts less than EUR 1 million with a maturity of 3 months to
1 year.

Figure 6: IRF to a TFP Sock: Unconstrained vs. Constrained Borrowing
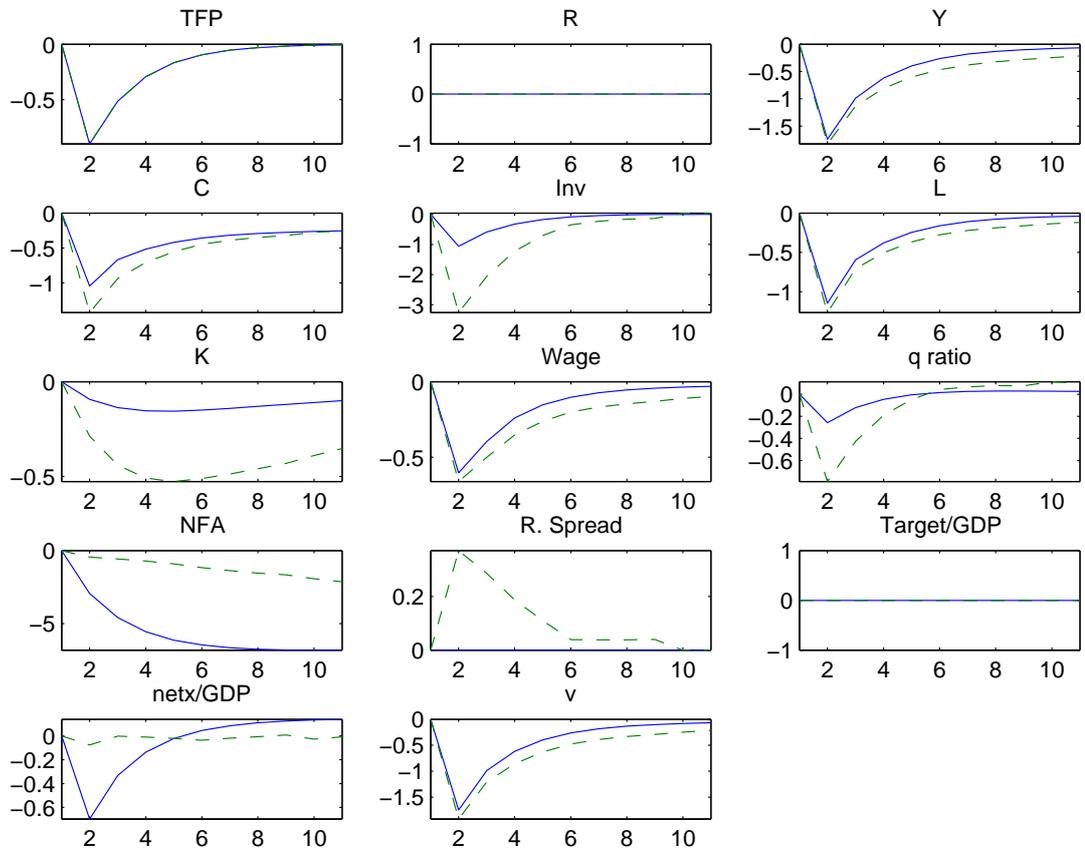
The solid lines refer to the IRFs at the stochastic mean, where the borrowing constraint in not binding. The dashed lines refer to IRFs when the borrowing constraint binds.

Figure 7: IRF to a TFP shock: Target vs No Target
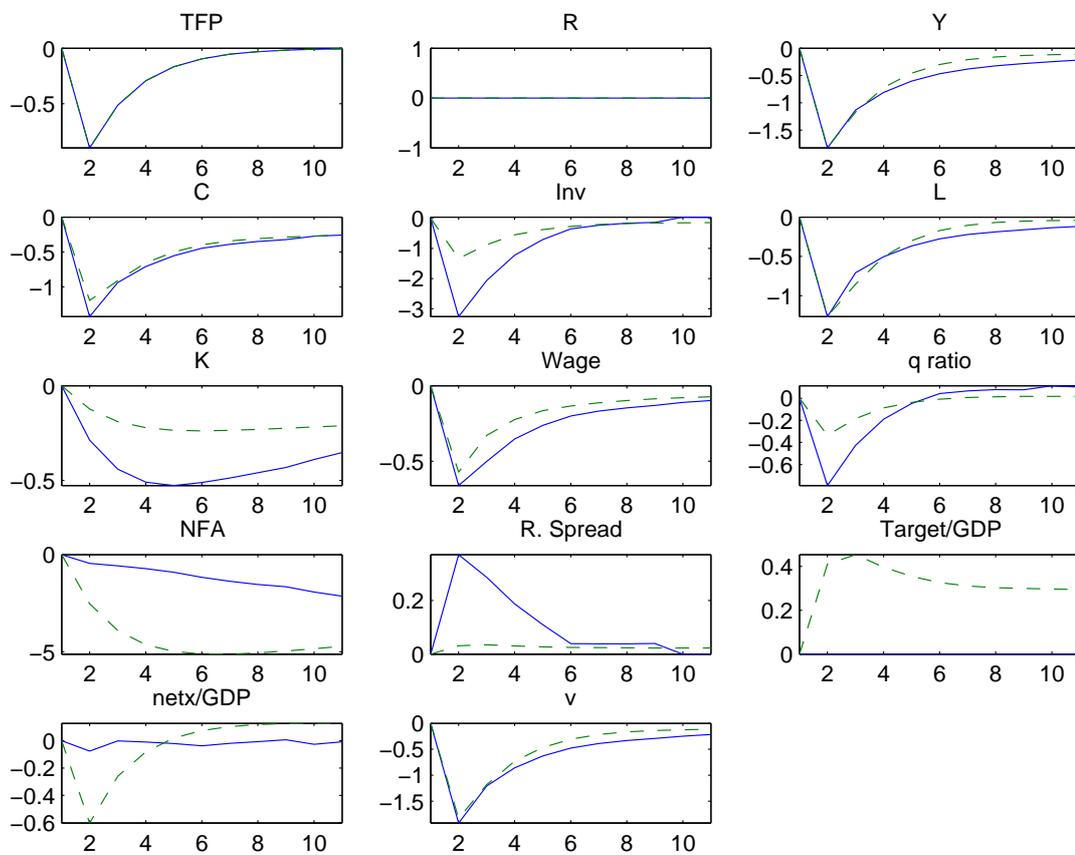
The solid lines refer to the IRFs of the no TARGET case while the dashed lines relate to the case where a TARGET system is present.

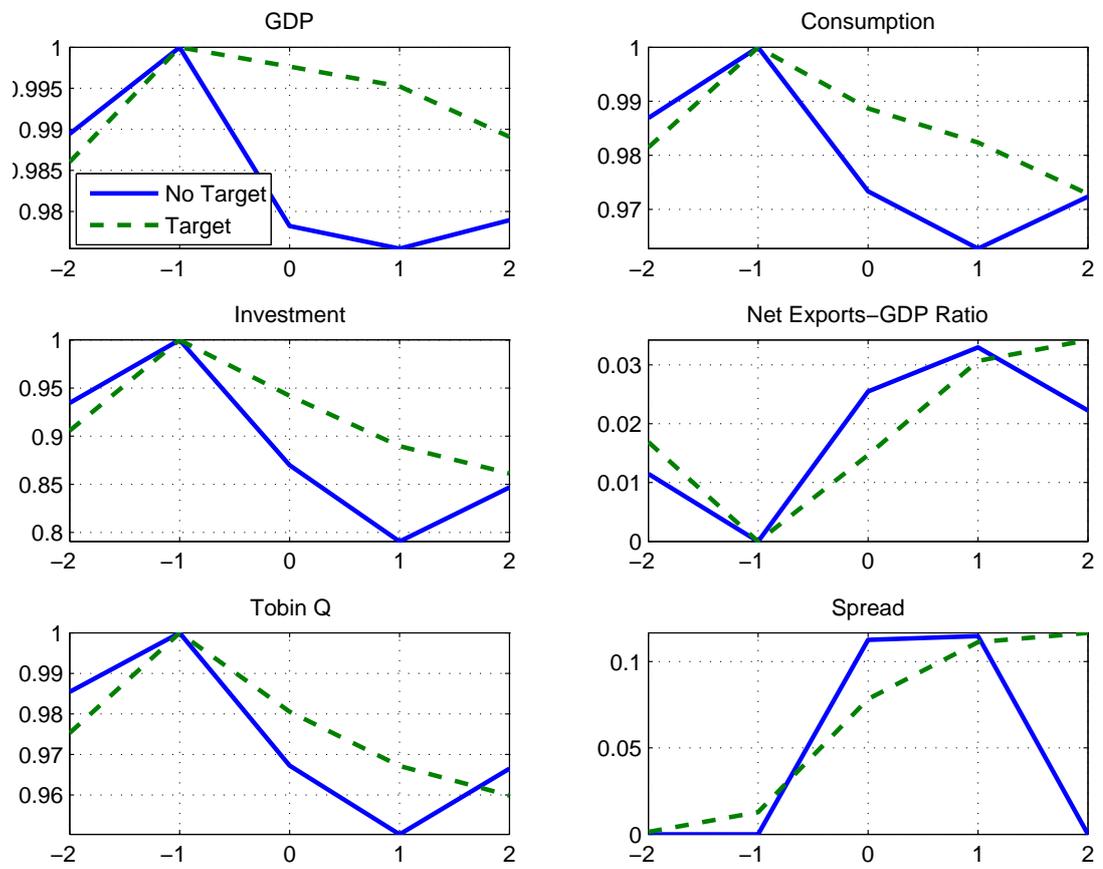Figure 8: Model: Sudden stop Dynamics: Target vs No Target
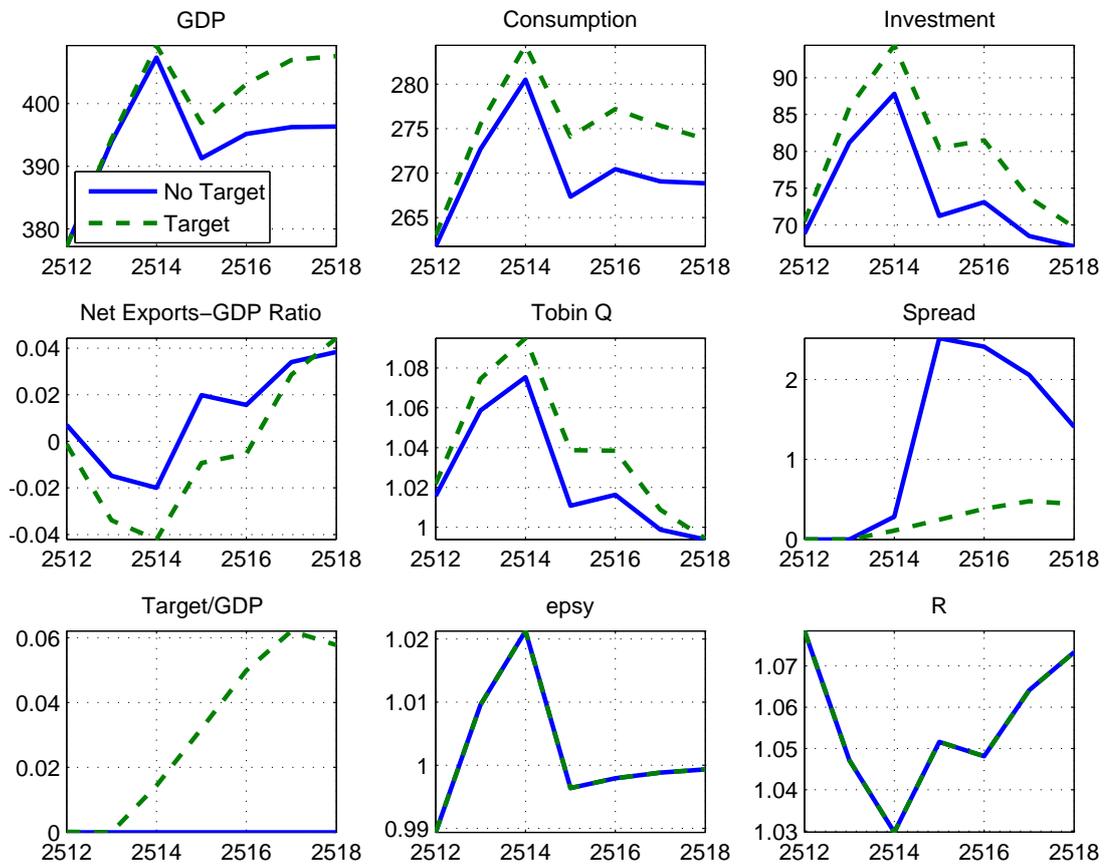
Figure 9: Crisis episode: Target vs No Target
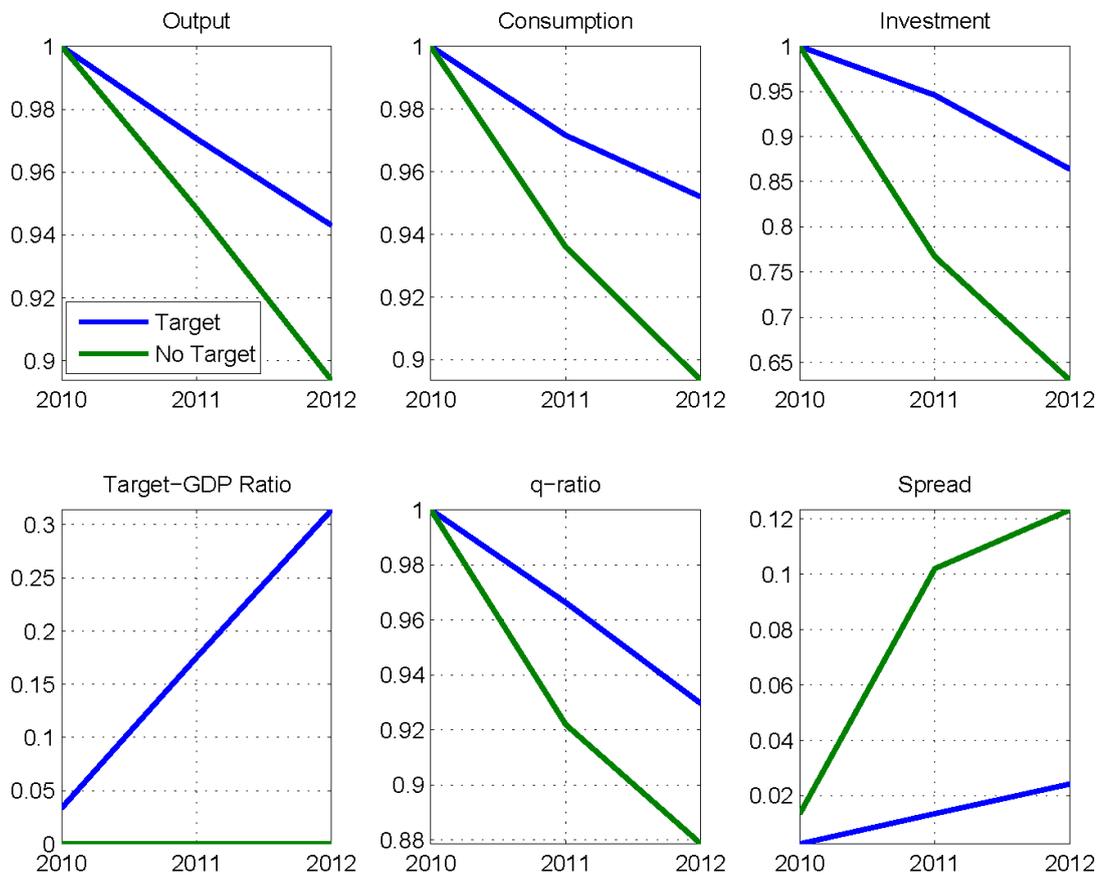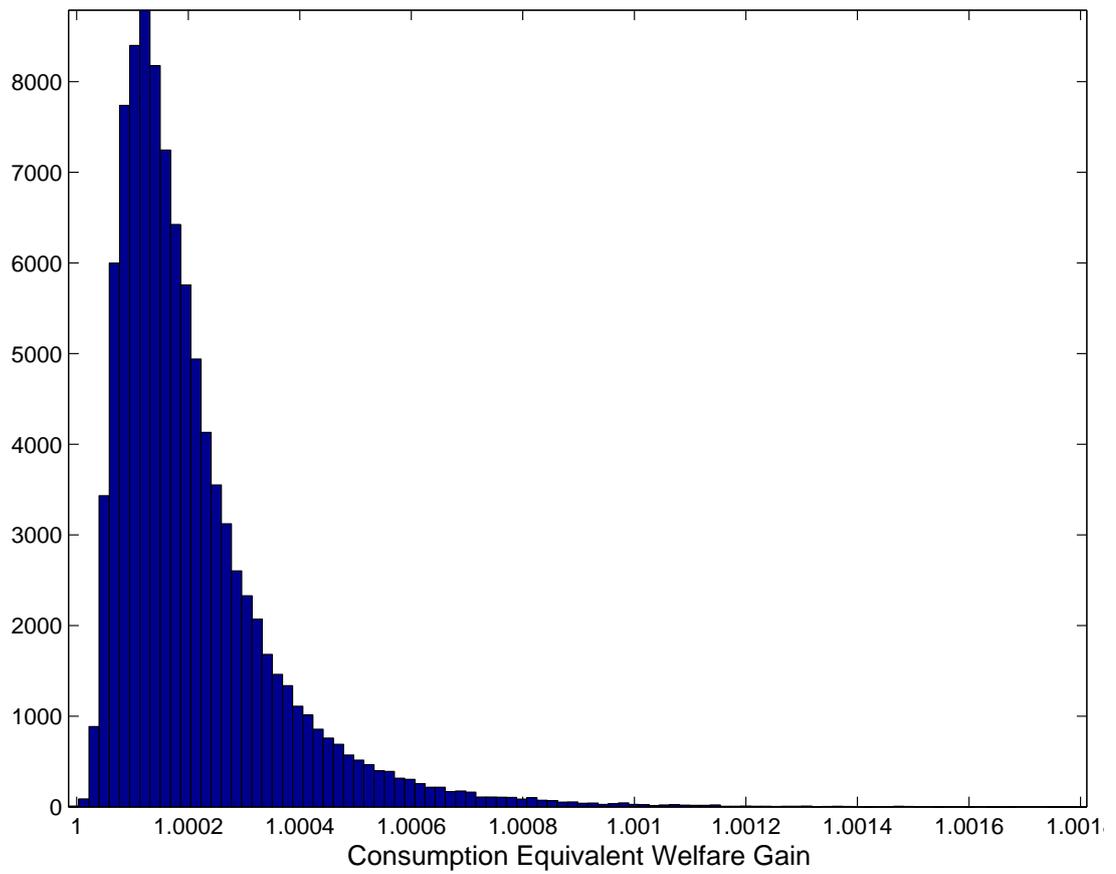
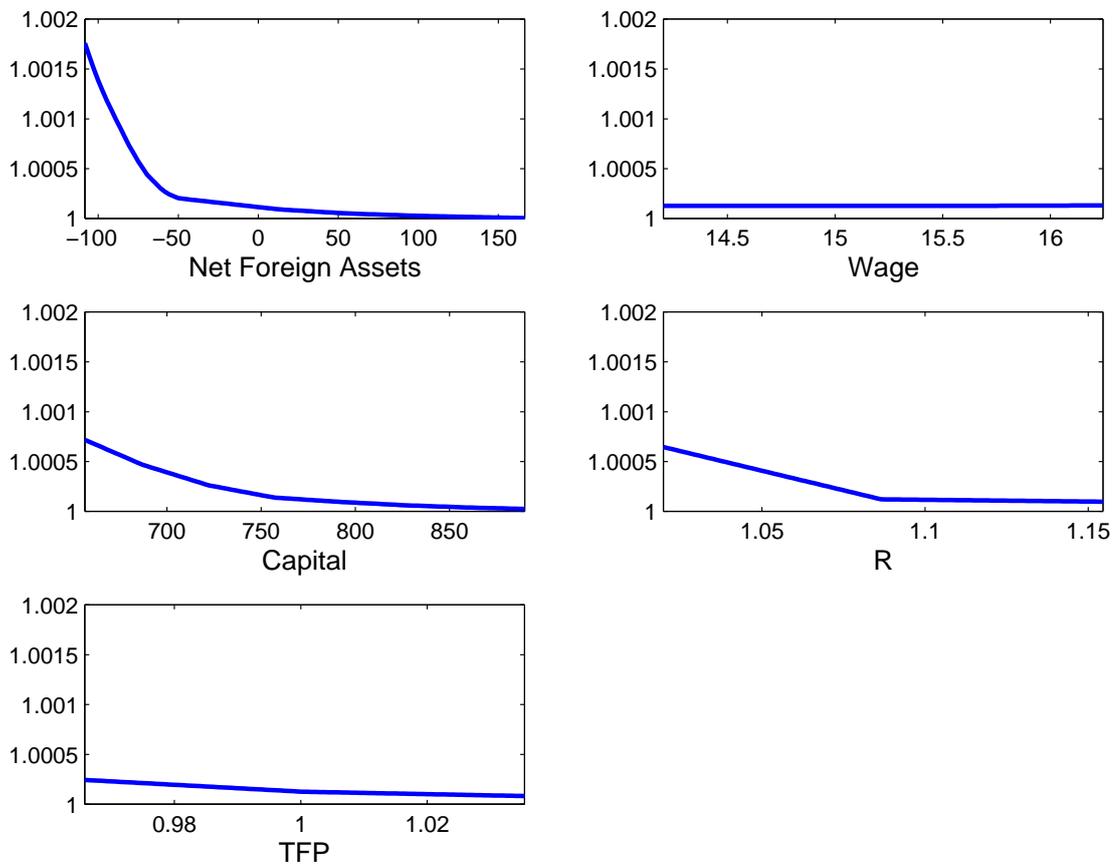Figure 10: Counterfactual Simulation

Figure 11: Distribution of Welfare Gains (Target vs No Target)

Computed over the ergodic distribution of the state vector in the No Target case.

Figure 12: Welfare Gains (Target vs No Target) as a Function of the State Variables

In each case, the gain is computed holding the other state variables at their ergodic mean values.

Appendix 1: Identifying Sudden Stop Episodes

We base our analysis of sudden stops episodes on quarterly balance of payments statistics for a range of advanced and emerging market countries. Our analysis is based on data from the IMF Balance of Payments Statistics and covers the period 1980 to 2012. In selecting countries for analysis, we follow the criteria outlined by Lane and Milesi-Ferretti (2011). These criteria involve the exclusion of oil exporters and very low income countries (per capita income in 2007 below $1000) and very small countries (with GDP below $20 billion in 2007). Oil exporters are excluded since movements in their financial account balances are dominated by changes in terms-of-trade reflecting movements in oil prices, while discrete changes in foreign aid tend to dominate movements in low income countries. These criteria, together with the requirement to have a sufficiently long span of data for the analysis, yields a list 57 countries. The countries, together with their available sample periods, are shown in Appendix Table 1.

In identifying sudden stop episodes we follow the Calvo definition of reflect "*large and unexpected falls in capital inflows that have costly consequences in terms of disruptions in economic activity*" (Calvo et al. (2004b)p.14). As in the various papers by Calvo and co-authors, our focus is on net rather than gross capital flows. Our measure of capital flows is the financial account balance plus net errors and omissions (we thus treat errors and omissions as unrecorded capital flows) as reported in the IMF database. Given quarterly data on our chosen variable, we identify potential sudden stop episodes using the algorithm put forward by Forbes and Warnock (2012). Specifically, this involves the following computations.

Let C_t denote the sum of the financial account balance over the previous 4 quarters:

$$C_t = \sum_{i=-3}^{0} FA_{t+i}$$

We then take the four quarter difference of this sum:

$$\Delta C_t = C_t - C_{t-4}$$

We then compute rolling means and standard deviations of ΔC_t over the previous 5 years. We subtract the rolling mean from ΔC_t to construct an

adjusted capital flow change indicator (X_t). A sudden stop is identified if
the following conditions are fulfilled:

1. X_t falls below (minus) one rolling standard deviation

2. During the episode, X_t falls below (minus) two rolling standard deviations for at least one quarter.

3. The sudden stop ends once X_t rises above (minus) one rolling standard deviation.

These criteria aim to capture the idea of *large and unexpected* capital flow
reversals. To capture the idea of *disruptions to economic activity*, we require
that, for an episode to qualify as a sudden stop, GDP must experience a
year-on-year decline at least one quarter during the episode.

Applying this algorithm to our data yields a total of 93 sudden stops which
are listed in Appendix Table 2. Appendix Chart 2 shows, for each year
between 1990 and 2012, the number of countries in our sample experiencing a
sudden stop. From this evidence a number of points are worth noting. First,
not surprisingly, the list of sudden stops is broadly in line with recent results
from the existing literature such as Forbes and Warnock (2011). Second,
from the plot it is clearly evident that there is a tendency for sudden stops
to occur in waves. In the early 1990s increases in the number of sudden
stops were associated with the ERM crisis in Europe and the Tequila crisis
affecting Mexico and other countries. A notable increase is also evident with
the Asian crisis of 1997 with a further episode corresponding to the Russian
crisis. The global financial crisis of 2008 on has been associated with a
very large number of countries experiencing sudden stops with 15 of our 57
countries experiencing a sudden stop in 2008. This reflects the drying up
of global capital flows during the crisis, documented by Milesi-Ferretti and
Tille (2010). Third, while the literature on sudden stops typically focuses
on emerging markets, advanced economies have been well represented among
the list of countries experiencing sudden stops. A particularly notable feature
is the high number of Euro Area countries experiencing sudden stops during
the recent crisis.

What are the effects of sudden stops on macroeconomic dynamics? To
illustrate we follow the approach of Mendoza (2010) and plot the beha-

viour of macroeconomic aggregates in a window covering two years before to two years after the start of the sudden stop. We use macroeconomic data from the World Bank World Development Indicators Databank or, for Euro Area countries, the EU Commission's AMECO database which conveniently provides forecasts for the period beyond 2012. Data on stock price indices for each country are taken from Bloomberg. The series in the chart are computed as follows. First, for GDP, consumption, investment and stock price indices we take deviations from a trend computed using the Hodrick-Prescott filter. For each of these series we convert the variables into index form with the value in the year prior to the sudden stop being set to 1. We then average these indices index across country episodes to arrive at an "average" index. Capital flows and net export contribution are not detrended, so the averaging is done using the "raw" data. We compute such averages for for four groups: 1) all sudden stops in the sample, 2) the sudden stops during the Tequila crisis, 3) the Asian crisis sudden stops and 4) the sudden stops experienced in stressed Euro Area countries during the most recent crisis.

The analysis of sudden stops just outlined is based on reported Balance of Payments data for the financial account. However, as noted in the main text, the Financial Account balances includes receipts of funding from Eurosystem via the TARGET system or borrowing from international institutions in the context of agreed programs. Thus, the headline Financial Account balance may mask the extent of private capital outflows. To allow for this, we apply the algorithm for identifying sudden stops to the measure of private capital flows excluding these two sources of funding outlined in the main text. Since our interest is in stressed Euro Area countries, we do this exercise for Cyprus, Greece, Ireland, Italy, Spain and Portugal for the the period starting in 2006. The list of sudden stops identified using this data are shown in Appendix Table 3.

Comparing the two lists of sudden stops, we observe a number of features. First, sudden stops are recorded in all of the countries concerned regardless of the measure of capital flows used. Second, and this is the important distinction, in general using a measure of private capital flows rather than overall capital flows leads to a a more nuanced picture of sudden stops in this group of countries. Typically there are more sudden stops for each country and the episodes are of shorter duration. This is consistent with the idea that

the euro crisis can be differentiated into a number of distinct phases (see for example, Cour-Thimann and Winkler (2013)): 1) the pre-Lehman Turmoil before September 2008, 2) the post-Lehman global financial crisis, 3) the Euro Area sovereign debt crisis from May 2010 and 4) the intensification of the Euro Area crisis and redenomination risk from mid-2011 on. These periods were interspersed by temporary periods of reduced quiescence. Using overall Financial Account balances (which include official flows) masks these subtle differences.

Appendix Table 1: Sudden Stop Experience: 1980-2012

Country	Start	End	Country	Start	End
Argentina	1980 Q1	2012 Q3	Japan	1980 Q1	2012 Q3
Australia	1980 Q1	2012 Q3	Korea	1980 Q1	2012 Q3
Austria	1980 Q1	2012 Q3	Latvia	1993 Q1	2012 Q4
Belgium	2002 Q1	2012 Q3	Lithuania	1993 Q1	2012 Q3
Bolivia	1988 Q1	2011 Q4	Malaysia	1999 Q1	2011 Q4
Brazil	1980 Q1	2012 Q4	Malta	1995 Q1	2012 Q3
Bulgaria	1991 Q1	2012 Q2	Mexico	1980 Q1	2012 Q3
Canada	1980 Q1	2012 Q3	Netherlands	1980 Q1	2012 Q3
Chile	1991 Q1	2012 Q3	New Zealand	1980 Q1	2012 Q2
China PRHK	1999 Q1	2012 Q3	Norway	1980 Q1	2012 Q3
China Mainland	2010 Q1	2012 Q2	Peru	1980 Q1	2012 Q2
Colombia	1996 Q1	2012 Q3	Philippines	1980 Q1	2012 Q3
CostaRica	1987 Q1	2012 Q2	Poland	1985 Q1	2012 Q3
Cyprus	1980 Q2	2012 Q2	Portugal	1980 Q1	2012 Q3
Czech Republic	1993 Q1	2012 Q3	Romania	1991 Q1	2012 Q2
Denmark	1980 Q1	2012 Q4	Russia	1994 Q1	2012 Q3
Estonia	1992 Q1	2012 Q4	Singapore	1995 Q1	2012 Q3
Finland	1980 Q1	2012 Q3	Slovakia	1993 Q1	2010 Q4
France	1980 Q1	2012 Q3	Slovenia	1992 Q1	2012 Q4
Germany	1980 Q1	2012 Q3	SouthAfrica	1980 Q1	2012 Q3
Greece	1980 Q1	2012 Q3	Spain	1980 Q1	2012 Q3
Greece	1980 Q1	2012 Q3	SriLanka	1980 Q1	2011 Q4
Guatemala	1980 Q1	2012 Q2	Sweden	1980 Q1	2012 Q3
Hungary	1989 Q4	2012 Q3	Thailand	1980 Q1	2012 Q3
Iceland	1980 Q1	2012 Q4	Turkey	1984 Q1	2012 Q4
India	1980 Q1	2011 Q4	Ukraine	1994 Q1	2012 Q3
Indonesia	1981 Q1	2011 Q4	United Kingdom	1980 Q1	2012 Q3
Ireland	1981 Q1	2012 Q3	United States	1980 Q1	2012 Q3
Israel	1980 Q1	2012 Q4	Uruguay	2000 Q1	2012 Q1
Italy	1980 Q1	2012 Q3	Venezuela	1994 Q1	2012 Q4

Appendix Table 2: List of identified sudden stop episodes

Country	Dates
Argentina	1989Q2-1990Q1 1989Q2-1990Q1 1994Q3-1995Q4 2000Q4-2002Q2 2008Q1-2009Q2
Australia	1991Q1-1992Q3
Austria	2008Q3-2008Q4
Bolivia	1999Q3-2000Q1
Brazil	1999Q1-1999Q2 2008Q3-2009Q3
Bulgaria	2008Q4-2010Q1
Canada	1989Q1-1989Q3
Chile	1998Q2-1999Q1
CostaRica	2008Q4-2009Q4
Cyprus	2009Q3-2010Q3
Denmark	1988Q2-1989Q4 2006Q1-2006Q2 2010Q2-2011Q2
Estonia	1998Q4-1999Q3 2008Q3-2010Q1
Finland	1991Q3-1992Q1
France	1991Q4-1992Q3 2009Q1-2009Q4
Germany	1993Q3-1993Q4 2001Q4-2003Q1
Greece	1992Q1-1992Q4 2009Q1-2010Q2
Guatemala	2009Q2-2010Q1
Hungary	2009Q4-2010Q3
Iceland	1993Q1-1993Q4 2001Q2-2002Q3 2007Q4-2008Q2 2009Q3-2010Q1
Indonesia	1997Q4-1998Q3
Ireland	2009Q1-2010Q4
Israel	1988Q3-1989Q2 1998Q1-1999Q1
Italy	1991Q2-1993Q1 2009Q3-2010Q2 2012Q1-2012Q3
Japan	1991Q4-1992Q4 1997Q2-1998Q3 2004Q4-2005Q3
KoreaRepublicof	1997Q3-1998Q3 2007Q3-2009Q1
Latvia	2008Q2-2009Q4
Lithuania	1999Q4-2000Q2 2008Q4-2010Q1
Malaysia	2008Q4-2009Q2
Malta	2002Q3-2003Q1 2004Q2-2004Q4
Mexico	1994Q1-1995Q4 2009Q1-2009Q4
Netherlands	2002Q4-2004Q4 2010Q1-2010Q4
NewZealand	1987Q4-1988Q3 1997Q2-1997Q4 2008Q2-2009Q3
Norway	1989Q1-1990Q1 2000Q1-2001Q3 2008Q1-2008Q4
Peru	1998Q1-1999Q3 2009Q1-2009Q3
Philippines	1992Q1-1992Q2 1997Q2-1998Q3
Poland	2001Q3-2002Q3
Portugal	1992Q3-1993Q2 2002Q2-2003Q4 2009Q2-2010Q1 2011Q2-2012Q3
Romania	1998Q3-1999Q3 2008Q3-2009Q4
RussianFederation	2008Q2-2009Q3
Slovenia	2009Q2-2010Q1
SouthAfrica	2008Q4-2009Q4
Spain	1992Q2-1993Q2 2008Q4-2010Q1
SriLanka	2001Q2-2001Q4
Sweden	1991Q4-1992Q3 2006Q4-2008Q2
Thailand	1996Q4-1998Q2 2009Q1-2009Q2 2011Q3-2012Q2
Turkey	1991Q1-1991Q4 1994Q2-1994Q4 1998Q3-1999Q2 2001Q1-2001Q4 2008Q4-2009Q4
Ukraine	2009Q1-2009Q4
UnitedKingdom	1991Q2-1992Q3 2007Q4-2008Q4
UnitedStates	1990Q2-1991Q4 2007Q2-2008Q3 2009Q1-2010Q1

Appendix Table 3: Sudden Stops in Euro Area Stressed Countries: Based on Private Capital Flows

Country	Start	End
Cyprus	2007Q4	2009Q2
Cyprus	2012Q1	2012.Q2
Greece	2008Q4	2009Q3
Greece	2010Q2	2011Q1
Greece	2012Q2	2012Q3
Ireland	2008Q1	2009Q2
Ireland	2010Q4	2011Q2
Italy	2009Q3	2010Q2
Italy	2011Q3	2012Q2
Portugal	2008Q4	2009Q1
Portugal	2010Q1	2011Q1
Spain	2008.Q3	2010Q2
Spain	2011Q4	2012Q3

Appendix Figure 1: Number of Sudden Stops
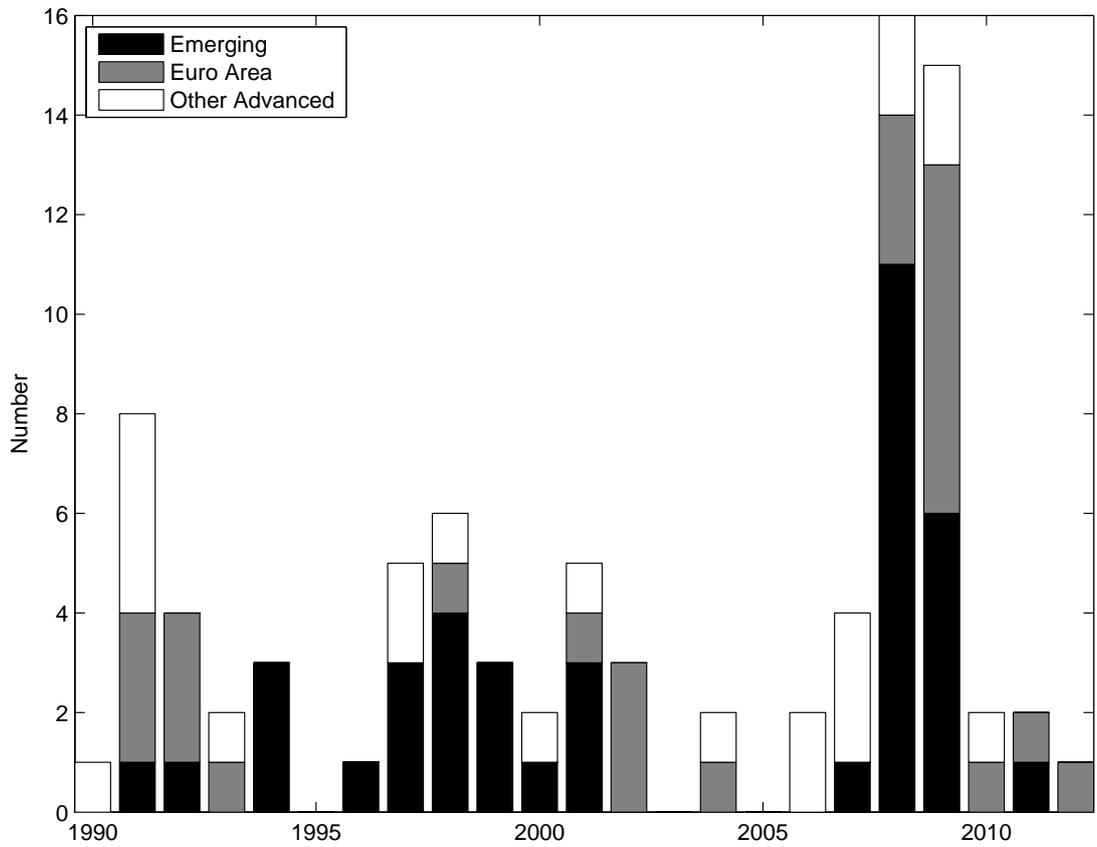
Appendix 2: Solution Methods

The important role of the occasionally binding borrowing constraint, together with DNWR, means that our model is highly nonlinear. For such models, local solution methods based on perturbation around the deterministic steady-state are not suitable (see, Brzoza-Brzezina et al. (2013) for a discussion and examples in which perturbation yields poor results in the context of models with occasionally binding constraints). This is particularly relevant given that we are primarily interested in what happens in the vicinity of the borrowing constraint rather than in a small neighbourhood around the deterministic steady-state or stochastic mean. Therefore in common with most of the literature using such models, we employ a global solution method. Specifically, we use the COMPECON package of Miranda and Fackler (2002) to solve the model using collocation methods.

The idea underlying the solution algorithm is as follows. Our model may be expressed in the general form:

$$f(s_t, x_t, E_t h(s_{t+1}, x_{t+1})) = 0 \tag{37}$$

where s_t is a vector of state variables at time t, x_t is a vector of endogenous variables, h is a function of future state and/or endogenous variables and E_t is the expectations operator. The state variables evolve according to:

$$s_{t+1} = g(s_t, x_t, \epsilon_{t+1}) \tag{38}$$

where ϵ_t denotes a vector of stochastic shocks. In the context of our model, the state variables are:

$$s_t = \{b_{t-1}, k_{t-1}, w_{t-1}, R_t, \eta_t^A\} \tag{39}$$

that is, beginning of period values for net foreign assets, the capital stock and the wage rate respectively together with current values of the world interest rate and the level of TFP.

$$x_t = \{b_t, k_t, w_t, c_t, \lambda_t, V_t, y_t, q_t, w_t^{num}, w_t^{den}, \mu_t\} \tag{40}$$

The expectation variables entering the model are[26]:

$$h_t = \{\lambda_{t+1}, V_{t+1}, zh_{t+1}, (\lambda_{t+1} w_{t+1}^{num}), (\lambda_{t+1} w_{t+1}^{den})\} \tag{41}$$

The solution algorithm aims at finding function (ϕ) which solves:

$$E_t h(s_{t+1}, x_{t+1}) = \phi(s_t) \tag{42}$$

Once we have obtained this function,we can solve (37) for x_t for any give vector of s_t. Drawing from the distribution of $\{\eta^A, \eta^R\}$ we can then simulate paths for all of the variables for the computation of impulse response functions and stochastic simulations.

We use projection (collocation) methods to approximate $\phi(s_t)$ by a flexible functional form. This involves three steps. First, we chose a family of approximating functions for ϕ, $\phi^a(s, c)$ where c is finite-dimensional vector of coefficients to be determined. Second, we select a set of points in the state space (collocation nodes) where the approximating function is to be fit. Third, we iterate on the coefficients of the approximating polynomial until (37) fits exactly at the collocation nodes. For the approximating function, we chose linear splines. This class is known to have good properties in models which discontinuities in the decision rules (such as our model). It also has considerable advantages over other alternatives in terms of computation time.

We use a total of 12,672 nodes over our five dimensional state space. In selecting the nodes we chose a narrow grid for foreign assets $\{b_t\}$ in the vicinity of the borrowing constraint. For the other state variables, we chose an equally spaced grid of 8 points for the remaining endogenous state variables $\{k_t. w_{t-1}\}$ and a grid of 3 points for the stochastic state variables for total factor productivity and the foreign interest rate, $\{\epsilon_t^A, R_t\}$. The bivariate distribution of the two shocks is approximated using with three nodes for each of the shocks using Gaussian quadrature weights. Expectation variables are then computed using Gaussian quadrature.

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[26]Note that where products of variables dated t+1 enter the model's equations, an explicit variable for these products are included to ensure that expectations are calculated correctly. Specifically, the variable $zh_{t+1}$is the expectation term entering the first order condition for capital. It is given by $zh_t = \lambda_t \left(\delta + \frac{a(k_{t-1}-k_t)}{k_{t-1}} - \frac{a(k_{t-1}-k_t)^2}{2k_{t-1}^2} - 1 - \beta \frac{y_t}{k_{t-1}} \right)$.

To solve the model with the borrowing constraint we use an iterative scheme to compute the Kuhn-Tucker multiplier $\mu(s_i)$ at each of the $i = 1 \ldots N$ collocation nodes (see Christiano and Fisher (2000) for a discussion of alternative methods of solving models with occasionally binding constraints). An initial guess for each of these multipliers is made based on: a) the difference between the admissible debt level under the borrowing constraint (b_t^{bc}) and the actual debt level (b_t^{nobc}) in the unconstrained case, and b) an initial estimate of the sensitivity of debt to changes in the multiplier $(\psi = \frac{db_t}{d\mu_t})$[27]:

$$\mu_i = \max\{0, \frac{b_i^{bc} - b_i^{nobc}}{\psi}\} \tag{43}$$

With these initial estimates, we can proceed solve the model. This gives us, for each node, an estimate of the sensitivity of foreign debt to μ. We check whether the borrowing constraint is satisfied at all nodes and whether it holds exactly at all nodes where $\mu_i > 0$ as required by the Kuhn-Tucker conditions. Using the estimated sensitivities and the differences of debt from the levels required, we update the estimate of μ_i at each node and solve the model again. We repeat this procedure until convergence is achieved.

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[27] The initial estimate is obtained from a Dynare version of the model, treating the multiplier as an iid shock variable. The impulse response of debt to a shock to μ then gives us an estimate of the effect of a change in the multiplier on debt.

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