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Downward Nominal Wage Rigidity and Macroeconomic Adjustment in a Monetary Union

by

Gabriel Fagan

A thesis submitted for the degree of

Doctor of Philosophy

Supervised by

Professor Philip R. Lane

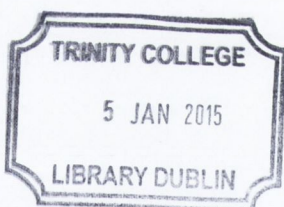
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Declaration

I declare that this thesis has not been submitted as an exercise for a degree at this or any other university. Apart from Chapter 3, which is co-authored with Paul McNelis, it is entirely my own work.

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Thesis 10423



Gabriel Fagan

Summary

The core of this thesis consists of three papers. Although independent, a common theme running through the papers is the macroeconomic adjustment of an open economy in a monetary union. In particular, we look at how adjustment to shocks is affected by two factors: downward nominal wage rigidity (DNWR) and central bank financing in a monetary union. The analysis in the papers combines the use of empirical data and estimation with the simulation of microfounded dynamic general equilibrium models.

The first paper (Chapter 2) uses cross-sectional data on individual wage changes from four countries (the US, Germany, Belgium and Portugal) to address two questions. First, are wages subject to downward nominal rigidity (DNWR)? That is, is there evidence that it is more difficult to cut wages than to increase them? Second, if DNWR is indeed prevalent, what is the best way to model and calibrate it, with a view to both matching the data and incorporating the results into general equilibrium models. In line with previous literature, we find that DNWR differs across countries: there is strong evidence for DNWR in the case of the US and Portugal while wages appear to be symmetrically flexible in the case of Belgium and Germany. In terms of the best way of modelling this phenomenon, we find that an asymmetric Calvo scheme fits the data better than a popular alternative, based on an asymmetric but continuous cost function. This Calvo scheme implies that wages are flexible upwards but when wage cuts are warranted, only a fraction of agents are able to make the cuts. The results in this paper are then used in the following two papers.

The second paper (Chapter 3) examines how central bank financing in a monetary union affects macroeconomic adjustment to sudden stops in capital flows. During the recent financial crisis, a number of stressed euro area countries (Greece, Spain, Ireland, Italy and Portugal) experienced sharp reversals in private capital inflows. The extensive literature based on the historic experience of a range of countries documents that such “sudden stops” have major macroeconomic implications: they are associated with sharp contractions in domestic demand, falling output and large turnarounds in current account balances. There is, however, an important difference between the recent euro area experience and previous sudden stop episodes: euro

area countries are members of a monetary union with a common central bank. This means provision of liquidity by the central bank to banks in the affected countries (in part) offsets the effects of the private capital outflows. These liquidity flows are reflected in intra-Eurosystem balances in the payment system, TARGET (**T**rans-European **A**utomated **R**eal-time **G**ross settlement **E**xpress **T**ransfer). In the second paper we examine the impact of the TARGET system on the macroeconomic adjustment to sudden stops in stressed euro area countries. We first establish that these countries did indeed experience sudden stops in capital flows and show that the behaviour of key macroeconomic aggregates is comparable to previous sudden stop episodes. Second, we document how changes in TARGET balances partially compensated for private capital outflows and empirically model the link between TARGET balances and financial stress. To examine the impact of the TARGET system on macroeconomic adjustment we modify a workhorse model of sudden stops (Mendoza (2010)) by incorporating a TARGET system in the model and comparing the response of economies with and without such a system. We conclude that the TARGET system greatly diminishes the effects of sudden stops on domestic demand, output and current account balances. However, we find the the introduction of a TARGET system leads to only a negligible gain in welfare, since precautionary saving is reduced, resulting in more frequent sudden stop episodes.

Chapter 4 addresses the implications of DNWR on the unemployment rate in currency peg. Recent work by Schmitt-Grohe and Uribe (2011) suggests that the presence of DNWR implies that the average unemployment rate under a peg can be up to 14 percentage points higher than under a floating regime. This is because nominal wages cannot adjust sufficiently to adverse shocks. Their results, however, are derived under a specific assumption regarding the form of the DNWR, namely a binding constraint on wage cuts. As documented in Chapter 2, this assumption is not consistent with the micro evidence on wage changes. Instead the data favours an asymmetric Calvo scheme. We therefore modify the model to incorporate this alternative wage setting scheme and examine the implications for unemployment. We find that the unemployment rate is significantly lower with the asymmetric Calvo wage setting. Still, the average unemployment rate remains high.

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Chapter 1

Introduction

This thesis focuses on the impact of two factors on macroeconomic adjustment in a monetary union: downward nominal wage rigidity and central bank financing. In addressing these questions we use a range of techniques. These include GMM estimation using microdata, the analysis of aggregate macroeconomic data and the specification and simulation of dynamic general equilibrium models.

In Chapter 2 we address the question of how best to model DNWR in a way which is consistent with microdata on wage changes while, at the same time, being suitable for use in dynamic general equilibrium models. The chapter thus provides results which are used in the subsequent chapters. We obtain two key results. First, the extent of DNWR differs across countries, reflecting inter alia differences in labour market institutions. And, second, an asymmetric Calvo wage-setting scheme fits the data better than other alternatives which have been suggested in the literature.

In Chapter 3, we focus on the euro area. We ask how financing by the common central bank - which is reflected in funding balances between the participating national central banks (TARGET balances) - affects the adjustment of countries to sudden stops in private capital flows. We first establish that, during the recent crisis, a number of countries (Greece, Ireland, Italy, Spain and Portugal) experienced sudden stops. We show that the response of macroeconomic aggregates, in

particular domestic demand and the current account balance, was similar to previous sudden stop episodes. We then document the evolution of TARGET balances in these countries, linking their behaviour to private capital flows and interest rate spreads vis-a-vis Germany. To analyse the macroeconomic implications, we modify a workhorse general equilibrium model of sudden stops (Mendoza (2010)) to incorporate TARGET balances. The analysis shows that the presence of a TARGET system attenuates the adverse macroeconomic effects of sudden stops. However, it only leads to a modest gain in welfare in the affected countries. This is because TARGET exacerbates the tendency of these economies towards excessive foreign borrowing, leading to more frequent sudden stop episodes.

Chapter 4 explores the effect of DNWR on unemployment in an exchange rate peg. Using results from Chapter 2, we find that the way in which DNWR is modelled has important implications for the level of unemployment under a fixed exchange rate regime. We modify the model of Schmitt-Grohe and Uribe (2011) to examine the impact on unemployment of alternative ways of modelling DNWR. Using a form of DNWR which is consistent with the micro data (the asymmetric Calvo scheme) implies a significantly lower level of unemployment than has been found in the original paper, which used binding downward constraints on wage changes. Nonetheless, even allowing for this, we find that the resulting level of unemployment is still substantial.

Chapter 2

Estimating downward nominal wage rigidity

2.1 Introduction

Downward nominal wage rigidity (DNWR) has long been recognized as having important economic implications. A literature dating back at least to Tobin (1972) argues that DNWR has important implications for the optimal rate of inflation. An even older literature highlights the implications of DNWR for the choice of exchange rate regime.

DNWR affects the optimal rate of inflation because adverse demand shocks, whether sectoral or aggregate, will have larger and more protracted effects on output in low inflation environments. This stems from the fact that the (downward) adjustment of real wages is impaired and DNWR becomes more binding, the lower the inflation rate. The traditional rule put forward by Friedman (1969) calls for a rate of deflation equal to the equilibrium real interest rate. In more modern “New Keynesian” models without monetary frictions, the optimal rate of inflation is zero since this rate minimizes the price distortions which stem from price stickiness (Woodford (2003)). Schmitt-Grohe and Uribe (2011a) show that models which combine both

monetary frictions and price stickiness imply that the optimal rate of inflation lies between zero and the Friedman rate. A wave of recent papers examines how the introduction of DNWR into the models alters this conclusion¹. This more recent literature suggests that the optimal rate of inflation lies in the region of 0 to 2%, coinciding with the the inflation targets which have been adopted in recent years by central banks as documented in Roger and Stone (2005).

Regarding the exchange rate regime, the classic paper by Friedman (1953) argues that DNWR strengthens the case for flexible exchange rates. In general, sluggishness in the adjustment of wages means that real exchange rates are slow to adjust in fixed exchange rate regimes. This impairs the external adjustment to shocks. In particular, he pointed out that, with DNWR, adjustment to an adverse demand shocks will require long and protracted deflations, accompanied by higher unemployment, before the economy returns to internal and external equilibrium. More recently, Schmitt-Grohe and Uribe (2011a) and Schmitt-Grohe and Uribe (2012b) use a calibrated DSGE model for a small open economy to address this issue. They model DNWR as a binding non-negativity constraint on aggregate nominal wage changes (it is not possible to cut nominal wages) and calibrate their model on the basis of data for Argentina. The results they obtain are striking. The presence of DNWR leads to a dramatic deterioration in economic performance under a currency peg. Averaging over long realizations of stochastic simulations, they find that DNWR leads to an unemployment rate that is up to 14 percentage points higher in an economy under an exchange rate peg.

The results obtained in the literatures on optimal inflation rate and the welfare costs of exchange rate pegs are, however, sensitive to the way in which DNWR is introduced into models. This has two aspects. One relates to the functional form employed when introducing DNWR. A range of possible alternatives includes: binding constraints on nominal wage changes, continuous asymmetric wage adjustment

¹Examples include Benigno and Ricci (2011), Kim and Ruge-Murcia (2011), Fahr and Smets (2010) and Fagan and Messina (2009).

cost functions, menu costs and Calvo-type schemes. The second question relates to the quantification within each scheme: given a particular scheme, what values should be assigned to the parameters? In principle, both of these questions can be addressed by estimating alternative models using macroeconomic data and choosing the model and parameters which best fit the data. However, a practical problem arises in using macro data from the last few decades for this purpose. At a macro level, DNWR only kicks-in when aggregate nominal wages need to fall, a situation which only applies to periods of very low or negative inflation and/or a very large contraction of activity. However, this case has not applied to advanced economies over the last 60 years, perhaps with the exception of the recent crisis. For example, in the US over the period 1964 to 2012, average hourly earnings growth amounted to 4.4% (reflecting the inflation and productivity growth experienced during this period). In such an environment we would not expect to observe falls in aggregate nominal wages even if wages were fully flexible. Indeed, in the the lowest value of nominal wage growth observed in the data over this period is +1.1 %².

Micro data on wage changes offers the potential to overcome this problem and provide a basis for selecting an appropriate form and parametrisation DNWR. An example of how this could work in practice can be seen from the experience of using micro data on individual prices to inform the treatment of price stickiness in DSGE models. There is now an extensive literature using microdata on individual price changes to identify and analyse features such as the frequency and size of individual price changes. (A comprehensive survey is provided by Klenow and Malin (2010)). This analysis has helped to identify suitable ways of incorporating price stickiness into macromodels as well as providing a basis for the calibration of such models (see, for example, Mackowiak and Smets (2008) for a survey).

While the variation of aggregate wages is limited, there is “a remarkable amount of variation in percentage wage changes across individuals in nearly every coun-

²The data used in this calculation refers to the BLS series Average Hourly Earnings of Production and Nonsupervisory Employees in the total private sector obtained from the FRED database of the Federal Reserve Bank of St. Louis (code: AHETPI).

try in every year” (Dickens et al. (2007), p.196), reflecting the dominant role of individual-specific (or firm-specific) idiosyncratic, rather than aggregate, shocks. As in the price-setting case, one can reasonably expect that micro data on individual wage changes will provide information on DNWR which is just not available from macroeconomic data.

Since the 1990s, there is a growing literature which uses micro data on wage changes to study the extent of DNWR. The studies relate to both individual countries, mainly the United States, and cross-country studies. Fares and Lemieux (2001) provide a survey of the earlier literature while recent examples of cross-country studies include the International Wage Flexibility Project (IWFP) (Dickens et al. (2007)) and a set of papers in a Special Issue of the Economic Journal (Goette et al. (2007)).

These studies use statistical approaches to identify and quantify DNWR. They compare the actual cross-section distribution of wage changes with a notional distribution which is assumed to prevail under symmetric wage flexibility. The idea is that in the presence of DNWR, those workers who would, under flexibility, have received wage cuts will instead experience wage freezes. This implies that, compared to the notional distribution, the actual distribution will be characterized by a large mass (“spike”) at zero wage changes and a relative lack of mass at negative wage changes. The extent of DNWR is thus measured by indicators of the incidence of wage freezes and of wage cuts.

The statistical approach is highly valuable in identifying DNWR, where it is present. However, it suffers from two disadvantages. First, the indicators employed (such as the percent of wage freezes) are likely to vary with the state of the economy, particularly with the rate of inflation and, to a lesser extent, with trend productivity growth. In a high inflation regime (say steady state inflation of 20%) we are much less likely to observe zero wage changes than in an environment of low inflation (say 2%) even if DNWR is present. This dependence on the state of the economy also complicates comparisons of the degree of DNWR across countries. Second, it is difficult to incorporate the results from such analyses into macro models to derive

the macro implications of DNWR. Simply knowing that 15% of the labour force is potentially subject to DNWR does not tell us how to incorporate DNWR into macro models for the purpose of exploring the implications of DNWR for economy's response to shocks and for optimal policy.

In this paper, we attempt to estimate the extent of DNWR using micro data on individual wage changes. We thus exploit the rich variation found in micro data to obtain a more complete picture of the nature and extent of DNWR. Our approach is to write out an economic model in which wage setting is subject to DNWR. We model DNWR using two parametric cost functions for changing wages. The first function is an asymmetric stochastic menu cost setup developed by Fagan and Messina (2009). As we show later, this function turns out to be highly flexible and can take on as special cases number of forms of rigidity used in the literature, including: flexible wages, menu costs, a binding constraint on wage cuts, a Calvo setup and an asymmetric Calvo setup. The second function we use is an asymmetric Linex function which has recently been used in macromodels which incorporate DNWR by Kim and Ruge-Murcia (2011) and Fahr and Smets (2010). DNWR is captured by our wage adjustment cost functions and the focus in this paper is the estimation of these functions. We carry out the estimation using cross-sectional data on individual wage changes by means of the Generalised Methods of Moments (GMM) estimator. The estimates then allow us to compare the fit of alternative wage adjustment cost functions and to quantify the importance of DNWR. Once estimates of the wage adjustment cost functions are at hand, these can be incorporated, as in the price-setting literature, into macromodels in order to assess the impact of shocks and to conduct policy analysis.

An important finding of cross-country studies such as the IWFP and the ECB Wage Dynamics Network (ECB (2009)) is that there are notable differences across countries in the nature and extent of DNWR. These differences are linked to country-specific features of labour markets such as legal restrictions on wage changes and institutional features of the labour market, in particular the

centralisation of the bargaining processes and the role of trade unions (Dickens et al. (2007)). In view of these cross-country differences and in order to obtain a range of plausible estimates, we estimate our adjustment cost functions using data from a sample of countries. We chose the countries to include high DNWR cases and low DNWR cases on the basis of the analysis of the IWFP. This leads us to focus on the US and Portugal, on the one hand, where DNWR has been found to be high and Germany and Belgium on the other where the evidence for DNWR is weak.

The structure of this paper is as follows. The data is described in Section 2.2 while the economic model of wage setting that we use is presented in Section 2.3. Sections 2.4 and 2.5 present the estimation methodology and the empirical results while Section 2.6 concludes.

2.2 Data

The data used in this study comes from the International Wage Flexibility Project (IWFP)³. This project brought together teams of researchers and combined micro datasets on wage changes from 16 different countries. The datasets include survey and administrative data. Using a common methodology, the different datasets were used to construct various indicators of downward rigidity (Dickens et al. (2007))⁴. Essentially, the methodology of the IWFP focuses on a comparison of the observed distribution of wage changes with a hypothetical distribution which is assumed to prevail in the absence of DNWR. The actual distributions were derived by using the microdata to construct histograms of wage changes of individual job-stayers for each year and country in the sample. In calculating the distributions, an algorithm to correct for measurement errors in the individual wage change data, developed by Dickens and Goette (2005) was employed. This method suggests that, in cases where measurement error is a major feature of the data, a significant proportion of

³I am grateful to Julian Messina for providing the histogram data from the IWFP

⁴Subsequently, the IWFP analysis has been extended to 3 further countries in the context of the Eurosystem Wage Dynamics Network (Hungary, Spain and Luxembourg), see WDN Final Report.

the wage cuts observed in micro datasets are due to small measurement errors. Thus, as we will see below, correcting for measurement error leads to a higher incidence of wage freezes. Typically measurement error is more acute in survey rather than administrative data so correcting for measurement error also helps to increase the comparability across countries and dataset types. From the histograms of the error-corrected data, an indicator of DNWR was computed (e.g. the ratio of wage freezes to the sum of wage freezes plus wage cuts). The underlying assumption in this calculation is that, in the absence of DNWR, those workers who had zero wage changes would have experienced wage cuts.

An important finding of the IWFP is that the incidence of DNWR differs significantly across countries. In view of the computational burden involved in estimating DNWR with the methods used in this paper, we apply the analysis to a subset of the countries examined in the IWFP project. We chose the countries carefully in order to span the range of DNWR, including countries which the IWFP suggests have relatively high DNWR and countries where the evidence for DNWR is weak or absent. The evidence of DNWR was strongest in the case of the US and Portugal, whereas there is no evidence for Belgium while Germany is an intermediate case. On the basis of this evidence, we analyse the data from these four countries. In this way, we span the range of possible estimates of DNWR and are able to provide upper and lower bounds for the extent of DNWR. An additional consideration is the high quality of data for Germany, Belgium and Portugal (discussed further below). The main features of the datasets that we use are summarized in Table 2.1. In the next few paragraphs, we provide a more detailed description.

For the US, we rely on a dataset derived from the Panel Survey of Income Dynamics (PSID) in the case of the US. The period covered by our data is 1987-1997. The PSID provides information on hourly wages for individuals paid by the hour and an estimate of the hourly wage for salaried workers. We focus here on individuals paid by the hour, since the lack of accurate hours worked data makes the wages of salaried workers more prone to measurement errors. Hence, the wage variable is

regular hourly wages excluding top-coded observations. The number of individual observations is much more limited in this case, averaging around 3,000 workers per year. In contrast to the other countries, the US data is based on a household survey and thus is likely to be more affected by measurement error. For the US case, therefore, we use two sets of histograms, one without the correction and one with the correction. In what follows below, these will be denoted US(a) and US(b) respectively.

The German data spans 1987 to 2001, and is obtained from the Regional File of the IAB Employment Subsample (IABS-R).⁵ The IABS-R is based on a 2% random sample drawn from the German Social Security records, collected from employers, who are legally obliged to provide information on paid earnings. The wage information available covers all earnings subject to statutory Social Security contributions. Wages are reported as gross earnings per day, rounded to the lower integer. Reported earnings are censored at the top. On average, we have 150,000 individual observations per year.

The Portuguese data covers the period 1991-2006 and is obtained from Quadros de Pessoal (QP), which provides a longitudinal matched firm-worker data. The survey is carried out every year by the Ministry of Employment. Compliance is compulsory and legally binding. Hence, the response rate and data quality is extremely high.⁶ The QP data set includes monthly base wages for all dependent workers and hours worked during the month, allowing to construct a measure of hourly wages. The sample covers 2.5 million workers per year on average.

The Belgian data, which covers the period 1992 to 2002, comes from a social security database of labour earnings⁷. The social security database covers about one third of workers in the private sector. The measure of wages employed in the analysis is annual earnings divided by number of days worked in a given year by full-time job stayers. As in the case of Portugal, there is very limited evidence of measure-

⁵Bauer et al. (2007) provides a fuller description of the data.

⁶See Carneiro et al. (2012) for a more detailed description of the data.

⁷See Caju et al. (2007) for a fuller description of the dataset

ment error, again reflecting the high quality of this administrative dataset. After trimming, there are just over 340000 observations per year in the sample analysed. Following previous literature, our wage change histograms are constructed for job stayers, i.e. for workers who are continuously employed with the same employer in two consecutive years. Representative histograms⁸ for the four countries are presented in the right-hand panel of Figure 2.4. For the two US datasets two notable features stand out. The first is the large spike at the zero wage change and the second is the relatively low incidence of wage cuts relative to wage increases. These features have been identified in the previous literature as strong prima facie evidence for DNWR. The data for Portugal presents a similar picture, with even less evidence of wage cuts. The data for Germany are very different: there is only mild evidence of a spike at zero and a considerable evidence of wage cuts. In Belgium there is no spike at zero.

It is interesting to note that correcting for measurement error strengthens the evidence for DNWR. It leads to a doubling in the proportion of wage freezes while the incidence of wage cuts is almost halved (compare the histograms marked US(a) and US(b)). Given this important result, we carry out the analysis for the US using corrected and uncorrected data. For the other countries, which are based on high quality administrative datasets, the effects of error correction are small (not shown) and we will not conduct separate analysis for corrected and uncorrected data in these cases.

Summary statistics on the set of histograms, which will play a significant role in our analysis below, are presented in Table 2.2. For each country and for each year, we compute a set of moments and then report the average of these moments over the whole sample. Apart from the average percentage wage change, we present averages for: the percentage of wage changes which are zero, the percentage of wage changes which are negative and the percentage of small wage increases. A comparison across

⁸We chose the histogram for the year which is the midpoint of the sample in each country as our representative example.

countries confirms the impression from the histograms. Specifically, we see a high incidence of zero wage changes in the US and Portugal and a relatively low incidence of wage cuts.

An important feature of all datasets is the high cross-sectional standard deviation of wage changes relative to the standard deviation of the aggregate wage change in the respective country over the same sample period. This can be seen by comparing the second last and last rows of Table 2.2. In the US, for example, the cross-sectional standard deviation is 18 times larger than the aggregate standard deviation. This underscores the value of micro data for identifying features of wage setting, such as DNWR, which are difficult, if not impossible, to identify in macro data.

2.3 A Wage-Setting Model with DNWR

In this section we set out the wage-setting model which is used later in the GMM estimation. The model assumes that wages are set by households who enjoy some degree of market power in the labour market because the labour services they provide are differentiated across households. In order to generate cross-sectional variation in wage changes so that the model produces wage change histograms which may be compared to the data, we assume that households are subject to idiosyncratic productivity shocks. These shocks induce otherwise identical households to choose wage levels (and changes) which differ across household. In setting wages, households are subject to wage adjustment costs.

We assume that the household is operating in a stationary environment in which aggregate variables (such as output and the price level) are evolving along balanced growth paths. In solving the wage setting problem, households in the model take the value of aggregate variables as given. Our model thus abstracts from aggregate shocks. This treatment of aggregate uncertainty is motivated by three factors. First, our focus is on the cross-sectional distribution of wage changes, reflected in our histogram data, rather than the time-series properties of individual or aggregate

wage changes. Second, incorporating aggregate uncertainty into our model would greatly complicate the analysis: it would require that a heterogeneous agent general equilibrium model would have to be solved at each iteration of the GMM estimation. This is computationally infeasible. Third, for the sample period we examine, the cross sectional variance is substantially larger than the time series variation in aggregate wage data. For example, the standard deviation of the aggregate wage change⁹ over the comparable sample periods are shown in the last row of Table 2.2. This can be compared with the “average” standard deviation in the cross-section data reported in the 2nd last line of the table. The differences are striking. In the US, for example, the average cross-sectional standard deviation is 9% compared to a standard deviation of 0.5% in the aggregate data. Thus movements in our data are dominated by cross-sectional idiosyncratic variations rather than aggregate variations and thus our omission of aggregate shocks is unlikely to have a material impact on our estimation results. Moreover, in order to minimise effects from aggregate volatility on our estimates, we confine our sample periods to the “Great Moderation” era, a period which was characterised by low output volatility and low and stable inflation, as documented inter alia by Stock and Watson (2003).

The model of household wage setting that we use follows closely the model set out in Erceg et al. (2000) (EHL). It is assumed that the labour supplied by different households are imperfect substitutes and thus households enjoy some degree of monopoly power. Specifically, we assume that the household faces the following labour demand function¹⁰:

⁹In this computation, average wage change refers to the percentage change in compensation per employee reported in the EU AMECO database.

¹⁰As is EHL, the labour demand function is derived from the optimisation problem of a labour aggregator which bundles labour from different households and supply composite labour services to firms. The aggregator is assumed to have the following Dixit-Stiglitz technology:

$$L_t = \left[\int_0^1 (q_t(h)l_t(h))^{\frac{1}{\theta_w}} dh \right]^{\theta_w} \quad (2.1)$$

with $\theta_w > 1$. In this setup, the elasticity of labour demand (ϵ_w) is given by $\epsilon_w = \frac{\theta_w}{1-\theta_w}$.

$$l_t(h) = q(h)^{\frac{1}{\theta_w - 1}} \left(\frac{w_t(h)}{W_t} \right)^{\epsilon_w} L_t \quad (2.2)$$

$l_t(h)$ denotes the demand for the labour of household h . $q_t(h)$ and $w_t(h)$ denote respectively the productivity shock and wage rate set by household h . W_t and L_t denote the aggregate per capita wage and employment. Ceteris paribus, an increase in the productivity of an individual household implies an increase in labour demand for that household, while labour demand depends negatively on the relative wage charged by the household, with an elasticity ϵ_w . It is assumed that $q_t(h)$ follows an AR(1) process:

$$\log(q_{t+1}(h)) = \rho \log(q_t(h)) + \epsilon_{t+1}(h) \quad (2.3)$$

We assume that there is a wage setter in each household. Each period, the household wage setter chooses the wage rate for its household, taking as given the household's consumption path and the demand for labour from the aggregator, which is given by (2.2). Thus we assume a right to manage setup in which the level of hours worked is determined by the employer.

We assume that the household's instantaneous utility function, $U(c_t(h), l_t(h))$, depends only on household consumption ($c_t(h)$) and labour effort ($l_t(h)$) and is given by:

$$U_t = \frac{c_t^{1 - \frac{1}{\sigma}}}{1 - \frac{1}{\sigma}} - \gamma \frac{l_t^{(1+\chi)}}{1 + \chi} \quad (2.4)$$

In principle, the wage-setting problem of the household should be solved as part of the household's overall optimisation problem (including the choice of consumption and assets). However, in order to avoid later computational burdens associated with the curse of dimensionality, we adopt a simpler approach in which the household delegates the choice of its nominal wage to a wage setter. The wage setter is assigned the objective to maximise the following expression:

$$E_t \left[\sum_{i=t}^{\infty} \beta^{(i-t)} \phi_t \right] \quad (2.5)$$

where:

$$\phi_t = \frac{U'(c_t)}{P_t} [w_t(h)l_t(h) - c_w(w_t(h), w_{t-1}(h))] - \gamma \frac{l_t(h)^{1+\chi}}{1+\chi} \quad (2.6)$$

The last term on the right hand side of this expression is the household's disutility of effort. The remaining part is the real net labour income of the household (wage income minus wage adjustment costs). This term is multiplied by the marginal utility of consumption to ensure that, in its decentralised decisionmaking, the wage setter takes into account the value to the household of an extra unit of real income¹¹. In the absence of wage adjustment costs, this setup leads to the standard result that the optimal wage is a markup over the marginal rate of substitution between consumption and leisure.

To complete the model we consider two specifications for the the function determining the cost of changing wages. The first functional form follows Fagan and Messina (2009) by assuming that households face an asymmetric stochastic menu cost setup while the second follows Kim and Ruge-Murcia (2011) and assumes that the cost of wage changes are given by an asymmetric linear function. We describe these setups in more detail in the following subsections.

2.3.1 An Asymmetric and Stochastic Menu Cost Setup

In this setup, it is assumed that household wage changes are subject to asymmetric menu costs. DNWR implies that the menu cost for cutting wages is larger than the menu cost for increasing wages. One disadvantage of pure menu cost schemes is that they imply a "zone of inaction" for small shocks which means that we would not observe small wage changes. This feature is unattractive since we do in fact

¹¹This formulation of the wage-setter's optimisation problem ensures that the solution for wages chosen by the wage setter will be identical to the optimal wage which would be chosen by the household in the context of the full optimisation problem.

observe small wage changes in our data (see the histograms in Figure 2.1). To address this, we follow Stokey (2009) and Benigno and Ricci (2011) by allowing for periods in which households face no menu costs. The presence or otherwise of menu costs is stochastic: depending on the realisation of a stochastic process, in each period the household either faces menu costs or these costs are zero.

Specifically, in this setup the cost of changing wages is given by the following function:

$$c_w(w_t(h), w_{t-1}(h), I_t(h)) = \begin{cases} I_t(h)c_+W_t & \text{if } w_t(h) > w_{t-1}(h) \\ I_t(h)c_-W_t & \text{if } w_t(h) < w_{t-1}(h) \\ 0 & \text{if } w_t(h) = w_{t-1}(h) \end{cases} \quad (2.7)$$

where $I_t(h)$ is an *iid* Bernoulli variable given by:

$$I_t(h) = \begin{cases} 1 & \text{with prob } \omega \\ 0 & \text{with prob } (1 - \omega) \end{cases} \quad (2.8)$$

c_+ is the cost of changing the wage (expressed as a percent of the economy-wide wage) when the wage is increased. c_- is the cost of changing the wage when the wage is decreased. I_t is a Bernoulli variable taking on a value of 1 or zero with a probability given by ω . When I_t is 1, menu costs apply in period t whereas with $I_t = 0$ there are no menu costs in this period.

This representation of the cost of changing wages turns out to be remarkably flexible. Depending on the parameter values, it is able to represent 5 different versions of wage (or price) setting schemes which are found in the literature. These are summarised in Figure 2.2, which shows the implied parameter restrictions for each variant as well as a representative histogram generated by the respective version. The first case is flexible wages. This arises when either $\omega = 0$ (the probability of facing a menu cost is zero) or when menu costs themselves are zero, $c_+ = c_- = 0$. The second case, where $\omega = 1$ and $c_- \rightarrow \infty$, approximates the case of a strictly binding non-negativity constraint on wage changes. Such a setup is employed by Benigno and

Ricci (2011) and Schmitt-Grohe and Uribe (2011b). Cutting wages is prohibitively expensive and thus household will never chose this option. The case where $\omega = 1$ and the cost of cutting and increasing wages are equal yields a third variant, which is the standard menu cost model first formulated by Caplin and Spulber (1987) and subsequently used by a wide range of authors in the context of price-setting (see Alvarez (2008) for a survey). The standard symmetric Calvo (1983) model, in which households can only change wages at random occasions, is also a special case of our setup. It arises when where $\omega \in (0, 1)$ and $c_+ = c_- \rightarrow \infty$. This setup is explored extensively in Schmitt-Grohe and Uribe (2006). Finally, an important variant, which we will consider more closely below, is an asymmetric Calvo scheme. In this setup, households can only cut wages at random occasions, as in the Calvo scheme, but are free to costlessly increase them at any time. This implies $\omega \in (0, 1)$, $c_- \rightarrow \infty$ and $c_+ \geq 0$.

2.3.2 Kim Ruge-Murcia Approach

Kim and Ruge-Murcia (2011) model DNWR by using a modified version of the Rotemberg (1987) adjustment cost function which allows for an asymmetry in the costs of changing wages. Specifically, they use the following Lindex function:

$$c_w(w_t(h), w_{t-1}(h)) = \phi \left(\frac{\exp(-\psi(w_t(h)/w_{t-1}(h) - 1)) + \psi(w_t(h)/w_{t-1}(h) - 1) - 1}{\psi^2} \right) \quad (2.9)$$

An illustrative plot of this function is given in Figure 2.3. The parameter ϕ determines the overall importance of wage adjustment costs. For $\phi = 0$ there are no wage adjustment costs while their importance increase as ϕ increases. The function (2.9) allows for asymmetry in the cost of changing wages. The degree of asymmetry depends on the parameter ψ . For $\psi > 0$ it implies that the cost of cutting wages,

by say 1 percent, is larger than the cost of increasing wages by the same amount¹². As ψ increases, the wage adjustment costs become more asymmetric. Interestingly, this function encompasses the standard quadratic adjustment cost function of Rotemberg (1987): as $\psi \rightarrow 0$ the function converges to the quadratic adjustment cost function¹³.

Like the quadratic cost function, this cost function implies that adjustment costs rise rapidly with the absolute magnitude of the percentage wage change. In short, it is more expensive to make a large (absolute percentage) wage change than a small one. As is well known, this cost function implies that, following a shock, the ensuing adjustment in the wage would be implemented gradually, by means of a sequence of small wage changes. With asymmetry, this feature is accentuated in the case of negative wage changes. This model thus implies that a distribution of wage changes characterised by a large share of small wage changes and few large changes. This prediction contrasts sharply with the predictions of the menu cost models in the previous subsection.

Kim and Ruge-Murcia (2011) estimate the parameters of this function in the context of a DSGE model using Simulated Methods of Moments on US quarterly aggregate macro data covering the period 1964 to 2006. As noted above, it is questionable whether macro data for this period can be very informative about the parameter governing the asymmetry of adjustment costs. In contrast, the micro data used in this paper is potentially highly informative in this regard.

2.3.3 Solving the Wage-Setter's Problem

Regardless of the specific wage adjustment cost function, the wage setter's problem can be solved by value function iteration. This leads to a decision rule which expresses the optimal wage in the current period as a function of the household-

¹²When $\psi < 0$ the asymmetry is reversed and it is more expensive to increase wages rather than to cut them.

¹³This can be straightforwardly established using the l'Hopital rule.

specific productivity shock, the previous period's wage and (in the case of the menu cost setup) the Bernoulli variable. In order to allow for inflation and productivity growth, the model is expressed in terms of a normalised wage variable (nominal wage divided by the price level and trend productivity)¹⁴. To compute these normalising factors we use average inflation and productivity growth for each country over the relevant sample period (see Appendix for further details). The problem of the wage setter can now be expressed as a standard dynamic programming problem with the value function given by (2.10) where the maximisation is carried out with respect to \tilde{w}_t , the normalised wage rate for household h :

$$V(q_t(h), \tilde{w}_{t-1}(h), I_t(h); \Theta) = \underset{\tilde{w}_t(h)}{Max} [\phi_t + \beta E_t V(q_{t+1}(h), \tilde{w}_t(i), I_{t+1}; \Theta)] \quad (2.10)$$

The value function depends on a set of parameters (Θ) and 3 household-specific state variables: the current period idiosyncratic shock ($q_t(h)$), the previous period's wage set by the household ($\tilde{w}_{t-1}(h)$) and, in the menu cost model, the Bernoulli variable ($I_t(h)$), which indicates whether the household is subject to menu costs in the current period. The parameter vector (Θ) entering into the value function includes the relevant parameters of household preferences and firm behaviour. It also includes the values of the aggregate macroeconomic variables, which influence the wage-setter's choice of the household wage rate. These aggregate variables are assumed to be constant at their sample averages and are treated as parameters by the wage-setter.

The solution to the wage-setter's dynamic programming problem is a decision rule

¹⁴The cost function (2.7) is adjusted accordingly to take this normalisation into account. Thus a nominal wage change rate of zero ($\Delta \log(W_t) = 0$) corresponds to a change in the adjusted wage rate of $\Delta \log(\tilde{w}_t) = -\pi - g$. Rates of change of the adjusted wages are later converted back to unadjusted terms by adding back the trend inflation and productivity growth rates used in the normalisation.

for the current period normalised wage of the household:

$$\tilde{w}_t(h) = G(q_t(h), \tilde{w}_{t-1}(h), I_t(h)|\Theta) \quad (2.11)$$

In one special case of our model, where wages are flexible, the decision rule can be derived analytically in a straightforward manner. In this case, the wage rate is a log-linear function of the idiosyncratic productivity shock ¹⁵. However, in the presence of DNWR, the decision rule takes on a more complex form and we solve for this function using numerical dynamic programming.

Some insight into the workings of the model can be obtained by examining the resulting decision rules for the two adjustment cost functions. These decision rules are shown in Figure 2.4. For comparison, we also show the decision rule for the frictionless case.

The properties of decision rules in menu cost models have been extensively surveyed in Stokey et al. (1989) and Stokey (2009). Related models are widely used in the context of inventory behaviour and investment (see, for example, Dixit and Pindyck (1994)) and, more recently, in price-setting problems (e.g. by among others Golosov and Lucas (2007), Nakamura and Steinsson (2008) and Burstein and Hellwig (2008)). In the case of DNWR, Elsby (2009) explores the implications for wage-setting of a model in which the cost of reducing wages, equivalent to a menu cost, is modelled as a decline in productivity in the context of an efficiency wage model.

As in this literature, the decision rule for the menu cost model used in this paper (upper panel of Figure 2.4) is characterised by a ‘zone of inaction’: for sufficiently small shocks, agents do not change the wage, since the discounted gains from doing so would not cover the menu cost. When shocks become sufficiently large, however, it is profitable for agents to change wages. When the menu costs are asymmetric,

¹⁵Specifically, in the context of our model, the optimal frictionless wage is given by:

$$w(h) = Aq(h)^{\frac{-\chi}{(1-\theta_w)(1-\epsilon_w\chi)}}$$

where the constant A is a function of the parameters.

the resulting zone of inaction will also be asymmetric, as is clearly evident in the figure. When DNWR is present, agents require larger (in absolute magnitude) shocks to induce them to cut wages than to increase wages. As can be seen in Figure 2.4, however, for large productivity shocks, the wage set by the agent is indistinguishable from the frictionless wage. In this case, it is worthwhile for the agent to pay the menu cost and make a large adjustment to the wage.

In contrast, the decision rule for Kim and Ruge-Murcia (2009) does not involve the lumpy wage adjustments seen in the menu cost model since the decision rule is a smooth function of the state variables. Agents make frequent changes to wages in response to shocks. However, agents will prefer to spread the adjustment of wages over time by a sequence of small wage changes, since this will minimise the adjustment costs. In the case of DNWR, this effect is accentuated in the case of negative shocks so that wage adjustment will be asymmetric. Thus we observe that a large negative productivity shock will induce agents to only adjust wages by an amount much less than in the frictionless case. Indeed, for the case considered here, the decision rule mimics a binding downward constraint on wage changes.

2.4 Estimation

Given that our data relates to cross sections of individual wage changes, all of the relevant parameters cannot be estimated from the data, so some have to be calibrated. Given the calibration of these parameters, the key parameters of interest in the context of this paper, which reflect the importance of DNWR are estimated using a variant the Generalized Method of Moments (GMM) developed by Hansen (1982). Typically, in estimating complicated models researchers are not able to derive directly or analytically the moments implied by any parameter vector in their model. They thus have to resort to techniques such as Simulated Method of Moments (SMM) (see, for example, Ruge-Murcia (2012) for a recent example). This has the disadvantage the the estimates of the model-implied moments are subject

to simulation error, thereby reducing the efficiency of the estimates. In our case, however, we are able to derive the implied model moments without recourse to simulations and can thus estimate the parameters using GMM directly rather than the less efficient SMM.

2.4.1 Calibrated Parameters

The key features of the calibration we use are as follows. First, we assume that intertemporal elasticity of substitution (σ) is unity and thus the household utility function takes the following form:

$$U_t = \text{Log}(c_t) - \gamma \frac{l_t^{1+\chi}}{1+\chi}$$

The coefficient on labour in the utility function (χ) is set to 1.5, close to the posterior mean reported by Smets and Wouters (2007). This implies a Frisch elasticity of labour supply of $\frac{2}{3}$. The elasticity of the aggregator's demand for labour to -11 ($\theta_w = 1.1$), implying a steady state markup of the household wage over the marginal rate of substitution between consumption and labour of 10%. We assume that the annual discount factor (β) takes on a standard value of 0.95 on an annual basis. A final parameter which we need to calibrate is ρ , the AR1 coefficient in the process for idiosyncratic productivity shocks in (2.3). We chose 0.9, a value which lies in the midpoint of the estimates of the persistence of labour income for the US reported by Guvenen (2007). Other values needed for the solution of the model (per capita consumption, hours and wages) which in our cross-sectional are treated as constant (adjusting for trends) and are chosen using macro data for the respective countries (see Appendix).

2.4.2 GMM Estimation

The remaining parameters, which are estimated by GMM, determine the extent of wage rigidity and the cross-sectional variance of the wage changes. The parameters for the two versions of wage adjustment costs are shown in the Table below.

Menu Cost		Kim Ruge-Murcia	
ω	Probability of menu costs	ϕ	Importance of wage adjustment costs
c^+	Menu cost for increasing wages	ψ	Asymmetry of wage adjustment costs
c^-	Menu cost for cutting wages	σ	Std. Deviation of idiosyncratic shocks
σ	Std. Deviation of idiosyncratic shocks		

The GMM estimator chooses a vector of parameters to minimise a measure of distance between the moments in the data (derived in our case from the histograms of wage changes) and moments generated by the model at that parameter vector (derived from the histogram generated by the model). More specifically, let $m(x)$ denote the moments of interest in the data. Let S denote the variance covariance matrix of these moments. Now, let $m(\theta)$ denote the moments implied by model, depending on the p -dimensional parameter vector θ . Then the GMM estimator of θ is given by:

$$\hat{\theta} = \underset{\theta \in \mathbb{R}^p}{\operatorname{argmin}} \left[(m(x) - m(\theta))' S^{-1} (m(x) - m(\theta)) \right] \quad (2.12)$$

As shown by Hansen (1982) this estimator will, under certain regularity conditions, yield a consistent estimate of the parameters with an asymptotic variance covariance matrix of $\hat{\theta}$ given by:

$$V(\hat{\theta}) = (P' S^{-1} P)^{-1}$$

Here $P = \frac{dm(\hat{\theta})}{d\hat{\theta}'}$ is the Jacobian of model moments with respect to the parameters (θ). For GMM to be feasible: i) the number of moments must be at least as great as the number of parameters, ii) P must be a matrix of full column rank and iii) S must be non-singular.

Where the model is overidentified (the number of moments exceeds the number of parameters), a goodness of fit statistic is provided by the J-statistic which is computed as:

$$T \left[(m(x) - m(\theta))' S^{-1} (m(x) - m(\theta)) \right]$$

which is asymptotically distributed as a Chi-squared with degrees of freedom equal to the difference between the number of moments and the number of parameters. Heuristically, this measures the closeness of the moments generated by the model to the data moments. In the case where the model moments match exactly the empirical moments, this statistic would be zero.

In the case of the menu cost model, the requirement that P be of full column rank means that it is not possible to estimate the most general form of the menu cost model from our cross section data on wage changes. Specifically, it turns out not to be possible to jointly estimate in a precise manner the size of the menu costs (c_+ and c_-) together with the probability of menu costs (ω). Including these three elements into the model leads to a P matrix which is (nearly) singular. This points to a problem of observational equivalence between the (absolute) size of the menu costs and the probability of hitting menu costs. For example, a model with a low ω but high menu costs will generate a histogram which is, with the precision of the data we have available, difficult to distinguish from a histogram with small menu cost but a high value of ω .

In view of this, we confine ourselves to a more restricted model, specifically the “asymmetric Calvo model” (model number 5, in Figure 2.2). This involves setting c_- at a very large value while c_+ and ω are estimated freely. This setting implies that households will never cut wages when they are subject to a menu cost.¹⁶ Although restricted, this model is still very flexible. It incorporates the following special cases: a flexible form of downward nominal wage rigidity (model 5); flexible wages (model

¹⁶We set c_+ to 100,000 and checked that for this value households never cut wages when a menu cost is present

1) and a strictly binding non-negativity constraint on wage changes (model 2). Thus we fit 3 parameters in the menu cost model. GMM estimation of the the Kim-Ruge model also involves estimation of 3 parameters although their interpretation (apart from the standard deviation) is very different.

A crucial element in conducting GMM estimation is to chose a set of moments which are both precisely estimated in the data and informative about the parameters of interest. Given the nature of our data and the results from the IWFP on measuring downward nominal rigidity, we chose two moments to capture DNWR: the percentage of negative wage changes and the percent of zero wage changes. In addition, to provide information regarding the costs of increasing wages we choose the percentage of small wage increases (defined as increases of 1% or 2%). To capture the degree of cross-sectional variance, we choose the standard deviation of wage changes. Thus we have four moments to estimate three parameters in both the asymmetric Calvo and the Kim Ruge-Murcia setups. The data moments are calculated as follows. For each year for which data is available, we calculate the relevant moment from the histogram data for each country. We then compute, for each country, the averages of the four moments and their variance/covariance matrix which gives us the matrix S . The values for the moments we use are as shown in Table 2.2, discussed previously.

2.4.3 GMM Estimation: Description of Algorithm

Our procedure for computing the GMM estimates comprises the following steps:

1. Using the histograms of micro data on wage changes, compute moments of interest and their variance/covariance matrix.
2. Use a minimisation algorithm of find a vector θ which minimises the objective function given in (2.12) . Specifically, at each iteration:
 - (a) Solve for the model's value function and decision rule.
 - (b) Using decision rule, and the stochastic process for idiosyncratic shock,

derive the model's implied cross section distribution of wages and wage changes.

- (c) Compute model-implied moments of interest.
- (d) Use data and model moments to compute the value of the objective function.
- (e) Stop when minimum is reached.

3. Compute the Jacobian, the standard errors of the parameters and the J-Statistics.

Step 2 (a) is carried out using the numerical dynamic programming outlined in Ljungqvist and Sargent (2004). This computationally intensive task involves discretising the state space (which consists of the previous period's wage, the idiosyncratic productivity level and the Bernoulli variable) and iterating on the Bellman equation until a fixed-point is reached. Once the value function has been computed, it is straightforward to derive the decision rule on the discretised state space. Step 2(b) is carried out using the invariant density iteration scheme outlined in Heer and Maussner (2005). Further details on both of these step are presented in the Appendix.

In carrying out the minimisation in step (2) above, we face the problem that the objective function is highly irregular. Thus local optimisation routines run the risk of finding a local rather than a global minimum. Therefore, a global minimisation algorithm which searches over the parameter space to locate the global minimum would be appropriate. However, the model used in this paper is complex since the computation of the objective function at each iteration requires the solution of a Bellman equation. Thus using a global solution algorithm to find the minimum would be excessively time-intensive. We deal with this tradeoff by using a combination of global and local methods. We first use a global minimisation algorithm to find a crude estimate of the global minimum and then refine this estimate using a finer search in the vicinity of this initial estimate. Specifically, for the global

search we use a variant of the genetic algorithm.¹⁷ while the refined search uses the `Fminsearch` routine in the Matlab Optimization Toolbox.

Once the minimum has been located, we compute the Jacobian (P), standard errors and J-statistics.

2.5 Results

2.5.1 Asymmetric Menu Cost Model

GMM estimates of the parameters and standard errors for the menu cost Calvo model are presented in Table 2.3. A first notable feature is that for all countries considered the parameter c_+ , the menu cost for increasing wages, is not significant. This is evidence that there are no impediments to upward adjustment of wages. Recalling that the parameter c_- , the cost of cutting wages is set to a large number, the parameter ω captures the probability of wages being subjected to DNWR (“the Calvo parameter”). This parameter is significant in both of the US datasets and in Portugal. Comparing the two US datasets, the estimated ω is almost twice as large in the dataset corrected for measurement errors (0.71 versus 0.37). This confirms the earlier IWFP result that, in the US case, correcting for measurement errors in wage change data leads to a higher estimate of the incidence of DNWR. The estimate for Portugal (0.73) is comparable to the value for US error-corrected data. Since the model is expressed in annual terms, the estimates suggests that wage cuts are, depending on the dataset, prevented between 30% and 70% of the time. In both Germany and Belgium, the estimated Calvo parameter is not significantly different from zero. Together with the results on c_+ , this provides evidence that nominal wages in both countries are flexible in both an upward and a downward direction.

The J-statistics and their associated p-values, in the case of the US and Germany do

¹⁷We use the Matlab function `genetic.m` programmed by Nick Kuminoff which is included in the Compecon toolbox (Miranda and Fackler (2002)).

not point to problems with the fit of the model. In the case of Portugal the statistic is borderline while it is highly significant for Belgium, suggesting that the model does a poor job of matching the data moments for this country. Further insight into the fit of the model can be obtained by i) visually comparing histograms generated by the model with data histograms and ii) comparing data moments with moments generated by the model.

In regard to the first approach, the histograms generated by the model and data histograms are plotted in Figure 2.5. A caution is warranted here. The model is estimated to match average moments over the sample not the moments in a specific year. Of course, the data histogram shown refers to a single year, the midpoint of the available sample, so this comparison is for illustrative purposes only. Visual inspection of the two sets of histograms suggests that the fit of the model is particularly good for the case of US for both error-corrected and uncorrected data: the model clearly captures the spike at zero wage changes and the relative lack of mass at negative wage changes. In Portugal, while the model captures both the spike at zero and the low incidence of wage cuts, it has some difficulty in matching the right half of the distribution observed in the data in 2001. In Germany, the histogram generated by the model broadly matches the salient features of the data histogram, which is consistent with symmetric wage flexibility. In case of Belgium the fit of the model is poor.

As regards the second approach, Table 2.5 presents a comparison of model moments and data moments for each country. The relevant data moments are the same as in Table 2.2 but are repeated for convenience. The model fitted moments are shown in parentheses below the corresponding data moments. The results are consistent with the the discussion of the histograms above. For the US and Germany the model matches closely the data moments. In the case of Portugal the model overpredicts both the percent of wage freezes and the percentage of wage cuts. The model does a particularly bad job of fitting the Belgian data.

Overall, the results are consistent with the results IWFP (Dickens et al. (2007)).

There is strong evidence of DNWR in the case of the US and Portugal. In contrast, our results suggest that in Belgium and Germany wages seem to be symmetrically flexible. However, in the case of the US and Portugal, our results do not support “strong” versions of DNWR such as a binding non-negativity constraint on wage changes as employed by Benigno and Ricci (2011) Schmitt-Grohe and Uribe (2011b). In our model this would imply a value of ω equal to unity. Using a standard t-test we can comfortably reject this hypothesis. This is not necessarily surprising since we do in fact observe nominal wage cuts in the data, a feature which is inconsistent with such strong versions of DNWR.

2.5.2 Kim Ruge-Murcia Approach

GMM estimates for the Kim Ruge-Murcia version of our model are presented in Table 2.4. Recall from Section 3.2 that there are two key parameters in this setup: ϕ and ψ which measure, respectively, the importance and the asymmetry of wage adjustment costs. In contrast to the menu cost model, the magnitudes of these parameters are difficult to interpret economically and the implications of the model are better explored using model-generated histograms and decision rules. Nonetheless, for comparison purposes, we note that Kim and Ruge-Murcia (2011) report estimates of 280 and 3844 for ϕ and ψ , respectively.

As regards the first parameter (ϕ), it is found to be significant in all countries except Germany. This suggests that for those countries, wage adjustment costs are non zero in all cases. In Germany, the parameter is negligibly small and insignificant, pointing to symmetrically flexible wages. The asymmetry parameter (ψ) is significant in all countries. However, in the case of both Belgium and Germany this parameter is borderline significant. In Belgium, the estimated parameter is much smaller than in the other countries, pointing to limited asymmetry in the costs of changing wages. In contrast, in the case of the US datasets and Portugal, this parameter is sizeable and significant. This points to the presence of DNWR in these cases.

To get a view of the implications of the model and the estimated parameters, it is fruitful to compare the histograms generated by the model with the data histograms. These are shown in Figures 2.5 and 2.6. In the case of Germany, the low value of ϕ means that the model is very close to the case of flexible wages. The model histogram in this case is very similar to the Calvo histogram and also close to the histogram in the data.

In the other three countries we observe a common pattern. With the estimated parameters, the KRM setup implies that wage cuts are either absent or, where present, only restricted to very small wage cuts: large wage cuts are ruled out. In this sense, the histograms generated by the model are consistent with the binding constraint model used by Schmitt-Grohe and Uribe (2012b) in which wage changes are subject to the constraint that they are greater than zero or a small negative number. The incidence of wage freezes is much higher than implied by the Calvo model of the previous Section and is well above the level found in the data.

In nearly all cases, the J-statistics are large and highly significant, suggesting that in these cases the model does a poor job of matching the data. The only exception is Germany where the model replicates the flexible wage setting found in the data. Table 2.6 shows the data moments and (in parentheses) the moments predicted by the model. Confirming the previous results, the fit in Germany is good. However, in the other cases the model substantially overstates the percentage of wage freezes.

Overall, with the exception of Germany where wages appear to be flexible, the KRM specification does a poor job of matching the micro data on wage changes. While it is on occasion able to match the percent of wage cuts, it achieves this by bunching the cuts into a small range (typically -1%). The poor performance of the model in matching the micro data need not be surprising. The close cousin of this model – the Rotemberg model – has been found to perform poorly in matching features of micro data on price changes (Alvarez (2008)).

2.6 Conclusions

In this paper we used micro data on individual wage changes to estimate downward nominal wage rigidity using alternative wage adjustment cost functions. The results obtained lead to the following conclusions. First, the data favours a flexible menu cost scheme as distinct from the Linex approach put forward by Kim and Ruge-Murcia (2009). Second, we strongly reject a model of DNWR which has recently been employed by in macro models by Benigno and Ricci (2011) and Schmitt-Grohe and Uribe (2011b), namely a binding non-negativity constraint on wage changes. This latter setup is inconsistent with the micro data on wage changes and our empirical analysis shows that this model does a poor job of matching the data. Third, our estimates point to notable differences across countries in the degree of DNWR. Specifically, we find that the US and Portugal are characterised by a high degree of DNWR. In contrast, our estimates suggest that wages in Germany and Belgium are essentially flexible in both upward and downward directions. These findings are in line with the earlier findings of the IWFP reported in Dickens et al. (2007), who showed that cross-country differences in DNWR are linked to institutional differences in the wage bargaining. Finally, regarding the specification of macromodels, our result suggest employing an asymmetric Calvo scheme for wage-setting, in which nominal wages are flexible upwards but are “sticky” downwards. This approach is clearly more consistent with the micro data than alternatives which have recently been employed in the literature.

2.7 Appendix: Further details on computation and calibration

Computing the decision rule

We derive the decision rule for the household's wage using discrete state dynamic programming. We follow closely the method set out in Chapter 4 of Ljungqvist and Sargent (2004). Starting with an initial guess, we compute the value function over a discrete grid of the state space by iterating on the Bellman equation (2.10) until convergence is achieved. The state-space is discretised as follows. First, we employ a grid of 91 points with a grid width of 1% for the wage rate. This grid width is chosen to match the the fineness of the available data used in the analysis, which consists of histograms whose bins have a width of 1%. We chose a compatible¹⁸ 91 point grid for the idiosyncratic productivity level ($q_t(h)$). We assume that the idiosyncratic productivity shocks are $\epsilon_t(h)$ are distributed as *iid* Laplace (double exponential), a special case of the two-sided Weibull distribution. This choice is motivated by the argumentation in Dickens et al. (2007) who argue that this distribution better fits wage change data than the normal distribution. We use the Tauchen (1986) Markov chain approach to compute a discrete approximation of AR process for productivity. Overall, in the case of the menu cost model, the grid comprises a total of 16,562 points (91 for the wage times 91 for the productivity variable times 2 for the Bernoulli variable). In the case of the Kim Ruge-Murcia model, where there is no Bernoulli variable, the state-space has 8281 points. Given the computed value function, the decision rule, which gives the optimal wage at each point in the state space, is computed by a using straightforward search over all possible values using the Matlab Find command.

¹⁸To achieve compatibility, the grid for the productivity shock (q) is derived from the grid for wages using the inverse of the function for optimal frictionless wage. As noted earlier, this latter function can be derived analytically by solving the static household wage-setting problem under the assumption of no wage adjustment costs.

Deriving the cross-sectional distribution of wage changes

With an approximation to the decision rule (2.11) to hand, we use this rule together with the approximated process for q_t and the Bernoulli process to compute the joint stationary distribution of the state variables, $w_{t-1}(h)$ and $q_t(h)$. This is defined as:

$$F(w_{i,t-1}, q_{k,t}) = Prob(w_{t-1}(h) = w_i, q_t(h) = q_k) \quad (2.13)$$

where $i, k \in \{1 \dots 91\}$ index the point on the discrete state space for wages and productivity, respectively. This distribution is computed using an iterative algorithm set out in Heer and Maussner (2005). Starting with an initial guess for the distribution, we update our estimate F at each iteration as follows. (Note that we use the notation where a prime (') on a variable denotes the next period's value). For each point on the $w \times q$ joint grid (indexed by i, k), the discretised decision rule $i'_0 = g_0(i, k|I = 0)$ and gives us the index of the optimal choice of the current wage as a function of the indices of the previous period's wage and the current value of the individual productivity, conditional on the the Bernoulli variable taking on a value of zero (no menu costs). Similarly, and $i'_1 = g_1(i, k|I = 1)$ gives us the decision rule conditional on the Bernoulli variable taking on a value of unity (menu costs apply). The transition matrix for q gives us the probability of q_{t+1} taking on each of the $(1..Ns)$ possible values on the grid, indexed by k' , given a current level of q_t , indexed by k :

$$P(k', k) = Prob[q(h) = q_{k'} | q_t(h) = q_k] \quad (2.14)$$

At each iteration, denoted by j , we start from an initial value for F_{j+1} of zero. Then we update our estimate of F_{j+1} by looping over all possible values of $w(i)$, $q(k)$ and $q(k')$ and using the discretised decision rules to calculate:

$$F_{j+1}(i', k') = F_{j+1}(i', k') + P(k', k)F_j(i, k) \quad (2.15)$$

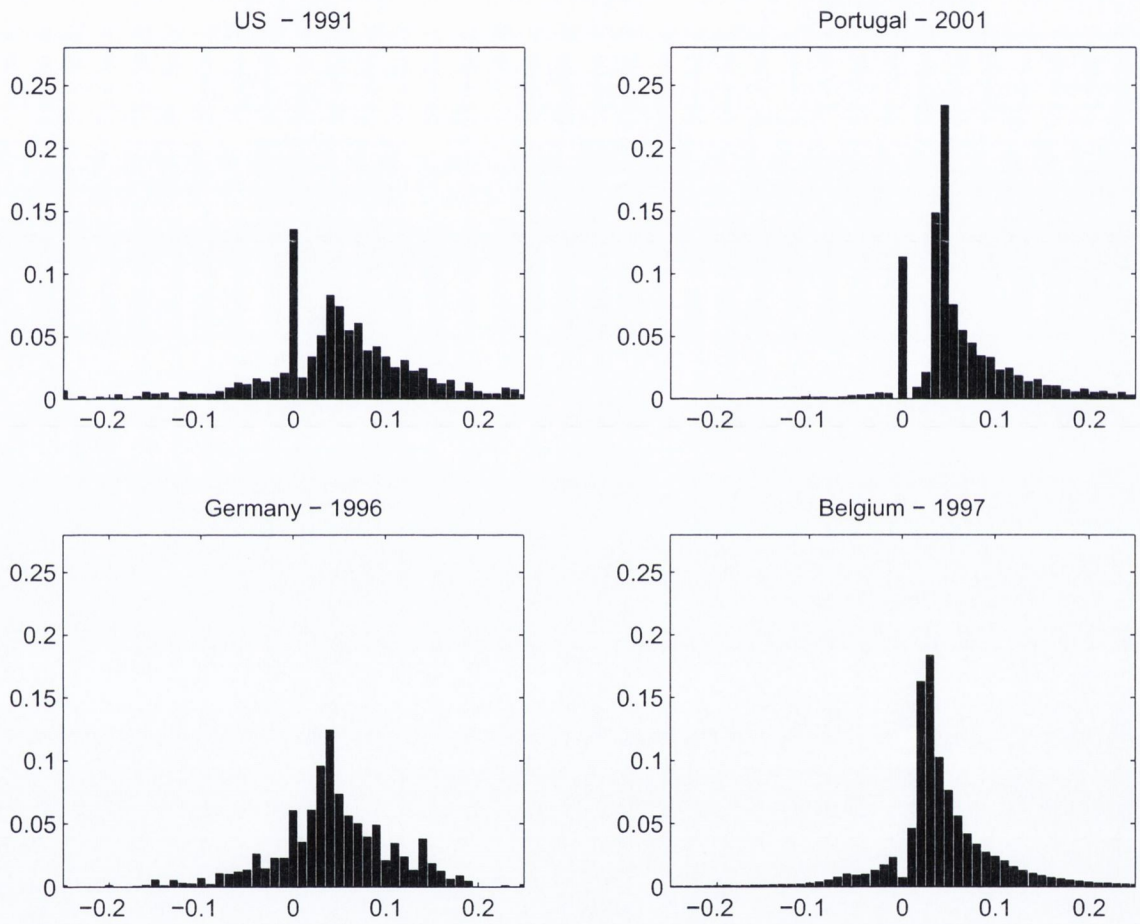
We repeat this process until our estimate of F converges.

From this joint distribution, we can compute the distribution of wage levels by integrating over q . Then, using the decision rule and the transition matrix for q , we compute the distribution of wage changes. This gives us a model-implied histogram of wage changes. From this wage change distribution, in turn, we calculate the moments of interest: the standard deviation of wage changes, the proportion of wage freezes, the proportion of wage cuts and the proportion of “small” wage increases.

Calibrating the wage setting parameters

In order to numerically solve the wage setter’s problem, we need values for some macroeconomic aggregates (such as consumption, aggregate hours, the aggregate wage rate, inflation and aggregate productivity growth). For these variables, we use actual data for the economies concerned over the relevant sample periods shown Table 2.2. The data we use for this purpose comes from the FRED database of the Federal Reserve Bank of St. Louis (for the US) and from the European Commission’s AMECO database for European countries. Per capita hours are normalised hours to unity. Then we normalise the aggregate wage rate on the basis of the average labour share in GDP. Similarly, normalised per capita consumption using the ratio of the share of consumption in GDP to the labour share. Inflation refers to the consumer expenditure deflator and is calculated as the average for the respective sample periods. Trend productivity growth is computed for each country by subtracting inflation rate from the average rate of change of wages in our micro data.

Figure 2.1: Representative Wage Change Histograms



These charts show the histograms for the year which is the midpoint of the sample used for each country. Data for the US are not corrected for measurement error.

Figure 2.2: Different Variants of the Stochastic Menu Cost Model

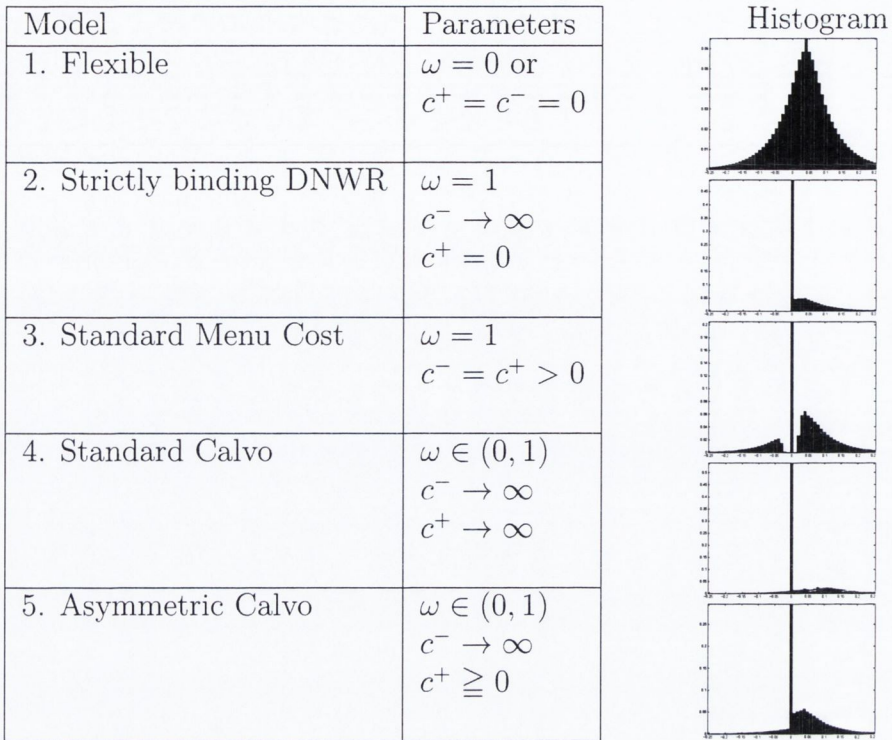


Figure 2.3: Wage Adjustment Costs: Kim-Ruge versus Rotemberg model

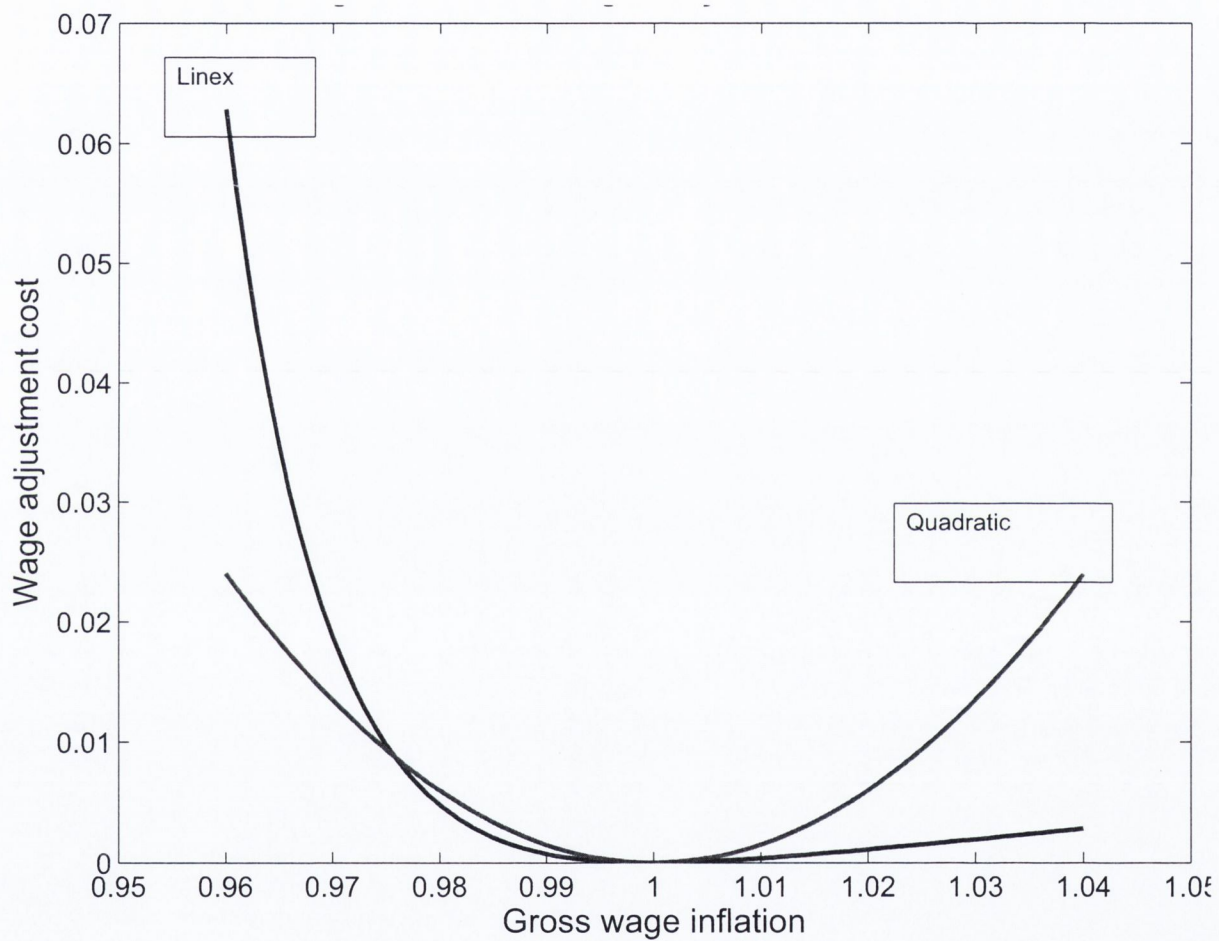
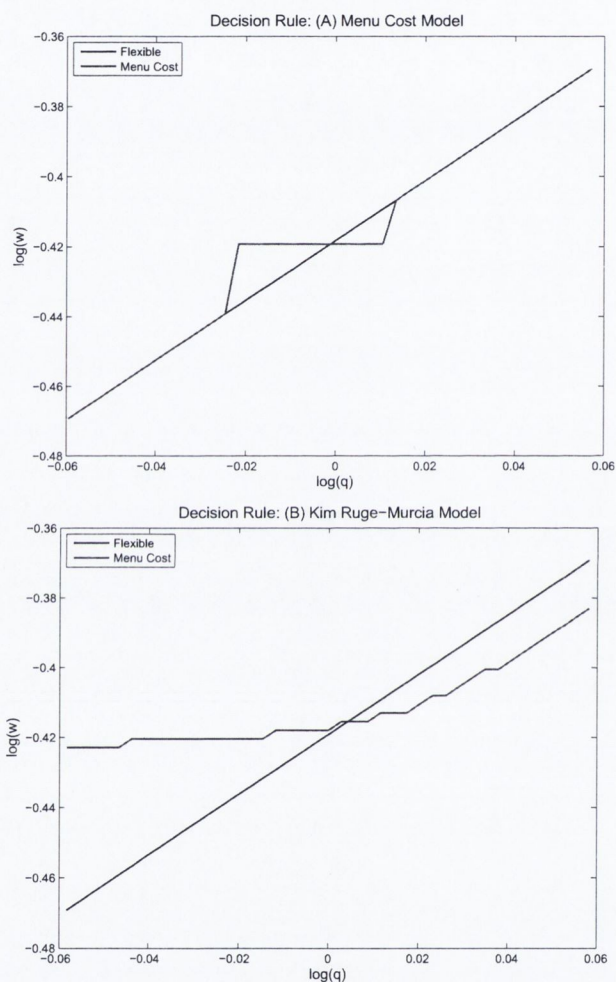


Figure 2.4: Decision Rules for Wage Setting



The above figures show the wage set by the household as a function of the productivity shock, assuming that the previous period's wage was at the average level. In both cases, the blue lines show the wage set in the absence of adjustment costs. The figures are based on the parameter estimates for Portugal

Figure 2.5: Actual versus Model Histograms - I

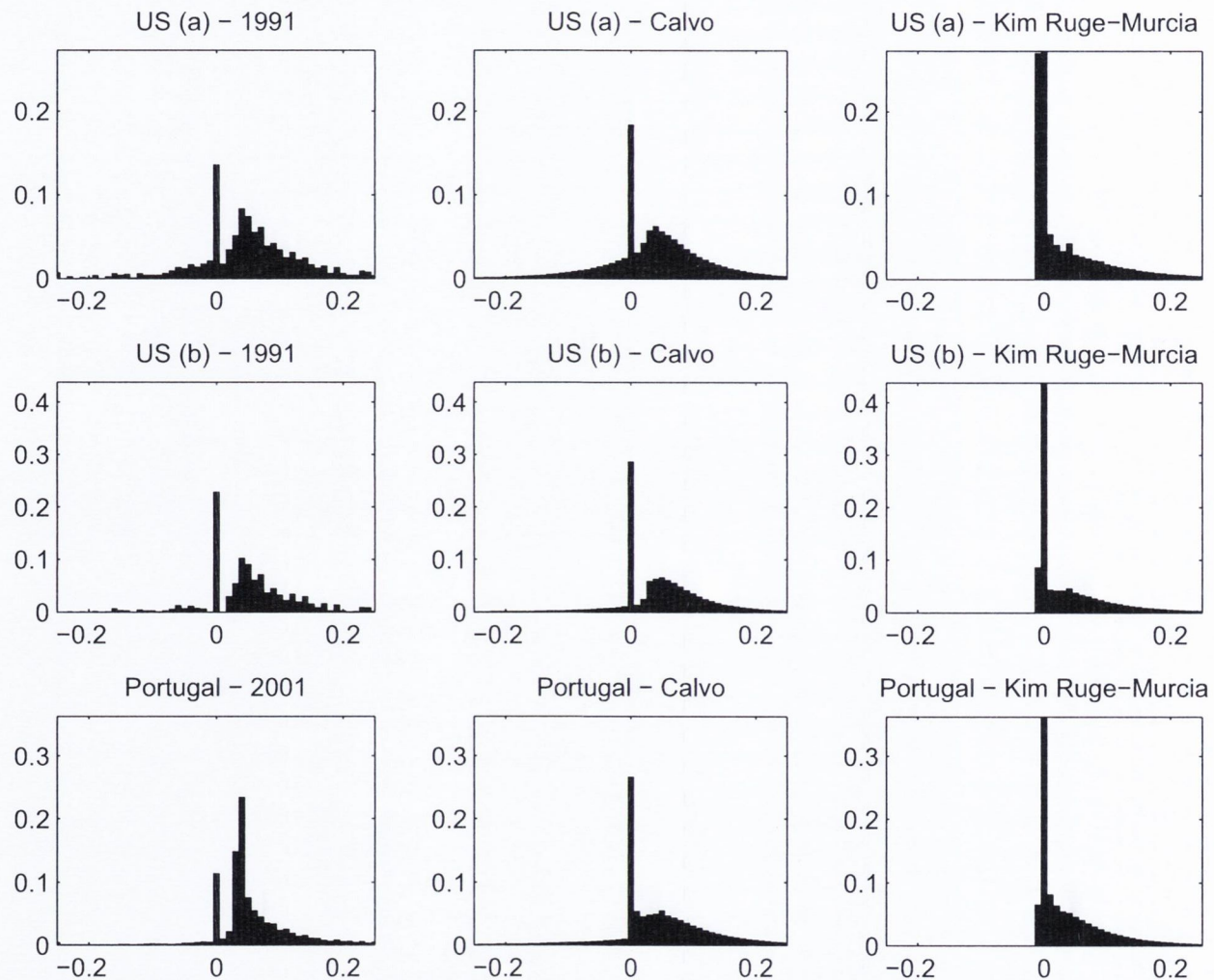


Figure 2.6: Actual versus Model Histograms - II

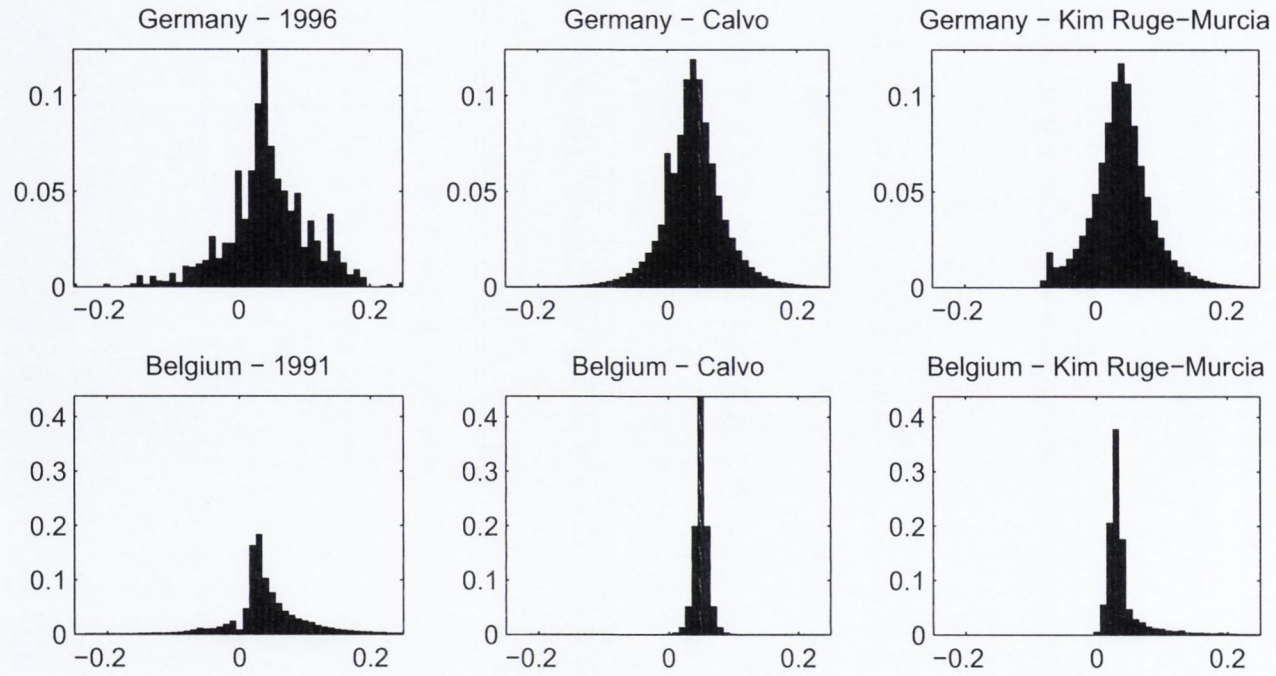


Table 2.1: Details of Data Used in the Estimation

Country	Years	Data Source	Variable
United States	87-97	PSID (HS)	Wage/hour
Germany	89-01	IADB	Earnings
Portugal	96-06	Quadros de Pessoal	Wage/hour
Belgium	92-02	Social Security	Earnings

Table 2.2: Key Data Moments

	US(a)	US(b)	Ger	Por	Bel
Sample	87-97	87-97	89-01	96-06	92-02
Mean	0.046	0.046	0.036	0.051	0.047
% zero	0.157	0.267	0.076	0.151	0.007
% negative	0.158	0.066	0.141	0.053	0.102
% 1-2%	0.071	0.039	0.160	0.048	0.168
Std. Dev.	0.090	0.074	0.046	0.076	0.063
Std. Dev. (Aggregate)	0.005	0.005	0.012	0.014	0.013

"Std. Dev. (Aggregate)" refers to the standard deviation of aggregate wage growth in each country sample periods shown in row 1. In this computation, aggregate wages refers to whole economy compensation of employees reported in the EU Commission's AMECO databank.

Table 2.3: GMM Results: Asymmetric Calvo Model

	US(a)	US(b)	Ger	Por	Bel
c^+	0.047 (0.242)	0.051 (0.244)	0.079 (1.312)	-0.012 (0.010)	0.010 (-)
ω	0.372 (0.113)	0.710 (0.123)	0.078 (0.256)	0.731 (0.029)	0.000 (0.000)
σ	0.108 (0.007)	0.095 (0.016)	0.054 (0.012)	0.122 (0.013)	0.012 (0.005)
J-stat	2.296	0.380	0.076	4.372	161.115
pval	0.130	0.538	0.783	0.037	0.000

(Standard errors in parentheses.)

Table 2.4: GMM Results: Kim Ruge-Murcia Model

	US(a)	US(b)	Ger	Por	Bel
ϕ	327.259 (0.033)	179.590 (1.286)	0.006 (180.344)	575.331 (0.171)	403.625 (0.642)
ψ	125.803 (0.559)	452.255 (0.487)	147.945 (60.967)	157.673 (0.702)	4.416 (1.926)
σ	0.158 (0.080)	0.129 (0.097)	0.055 (0.202)	0.106 (0.280)	0.152 (1.077)
J-stat	47.645	30.736	0.667	35.529	63.556
pval	0.000	0.000	0.414	0.000	0.000

(Standard errors in parentheses.)

Table 2.5: Data versus Model Moments: Asymmetric Calvo Model

	US(a)	US(b)	Ger	Por	Bel
% zero	0.157 (0.183)	0.267 (0.286)	0.076 (0.070)	0.151 (0.266)	0.007 (0.001)
% negative	0.158 (0.186)	0.066 (0.075)	0.141 (0.124)	0.053 (0.088)	0.102 (0.000)
% 1-2%	0.071 (0.073)	0.039 (0.038)	0.160 (0.139)	0.048 (0.099)	0.168 (0.016)
Std. Dev.	0.090 (0.088)	0.074 (0.072)	0.046 (0.047)	0.076 (0.087)	0.063 (0.011)

Table 2.6: Data versus Model Moments: Kim Ruge-Murcia Model

	US(a)	US(b)	Ger	Por	Bel
% zero	0.157 (0.272)	0.267 (0.438)	0.076 (0.049)	0.151 (0.363)	0.007 (0.005)
% negative	0.158 (0.269)	0.066 (0.086)	0.141 (0.141)	0.053 (0.065)	0.102 (0.000)
% 1-2%	0.071 (0.094)	0.039 (0.084)	0.160 (0.151)	0.048 (0.144)	0.168 (0.260)
Std. Dev.	0.090 (0.076)	0.074 (0.067)	0.046 (0.047)	0.076 (0.060)	0.063 (0.035)

The numbers in parentheses are the moments predicted by the model. The numbers without parentheses are the data moments which are identical to those shown in Table 2.

Chapter 3

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

(co-authored with Paul McNelis, Fordham
University)

3.1 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 **E**xpress **T**ransfer system)¹⁹.

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.

¹⁹The details of the mechanism are discussed more fully below. In addition, it is notable 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.

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 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 (2011b)). 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 country-specific interest rate spreads. 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 3.2, 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 3.3 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 3.4 we present the model we employ while Section 3.5 deals with calibration and the solution methodology. Section 3.6 presents the results, including an analysis of the welfare implications of TARGET financing. Section 3.7 concludes.

3.2 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 puts 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 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. (2004)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 net 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 3.1. 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 years²⁰. The year in which the sudden stop starts is denoted $t = 0$, with the level

²⁰With the exception of capital flow and net export ratios, all variables in the Figure are computed using deviations with a Hodrick-Prescott filter.

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 well as for the Tequila, Asian and Euro Area crises.

Figure 3.1 shows that the most severe drops took place in Asia. In terms of GDP, consumption and investment, the collapse in the Euro zone countries 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 in Europe.

Overall, these results suggest 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.

3.3 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 economy²¹. 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 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.²²

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 3.3 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 3.1. Then

²¹This 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.

²²In 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.

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 3.1. 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 3.1. 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.

In this example, the withdrawal of the Deutsche deposit has created a TARGET liability for the Central Bank of Ireland and a TARGET asset for the Bundesbank of 100²³. 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 identity²⁴:

$$\textit{Current account deficit} = \textit{Capital inflows}$$

We can further decompose this identity by separately identifying TARGET flows, official financing and the remaining flows:

$$\textit{Current account deficit} = \textit{Private capital inflows} \tag{3.1}$$

$$\Delta \textit{TARGET liabilities} + \textit{Official inflows}$$

Official flows relate to receipts/payments in connection with European Union and

²³In 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.

²⁴In 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.

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 (3.1).

Figure 3.2 shows monthly data on the ratio of TARGET balances to GDP over the period 2008 to 2012²⁵. 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 concerns about the survival of the euro, TARGET liabilities reached substantial levels as a percent of GDP²⁶.

Figures 3.3 and 3.4 present the decomposition of the right hand side of (3.1) 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.

²⁵The 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 to the sharp falls in nominal GDP in some of the countries concerned.

²⁶Subsequently, 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.

In the case of Italy and Spain (countries not on EU/IMF programs during the period under consideration²⁷) 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)²⁸. Triggered by a set of contributions by Hans-Werner Sinn²⁹, recent research 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

²⁷In 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.

²⁸An incomplete list of the relevant papers includes: Auer (2013); Bindseil and Koenig (2011); Bindseil and Winkler (2012); Buiters and Rahbari (2012); Cecchetti et al. (2012); Cour-Thimann (2013); Mody and Bornhorst (2012); Sinn and Wollmershaeuser (2012) and Whelan (2012)

²⁹The 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”.

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:

$$\frac{TARGET\ Balance}{GDP} = \alpha_0 + \alpha_1 Spread \quad (3.2)$$

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 3.5 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 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 website³⁰. 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

³⁰The 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.

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 3.2 and 3.3. Table 3.2 reports panel estimates (with and without country and time fixed-effects) of equation (3.2) while Table 3.4 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.

Looking now at the individual country equations reported in Table 3.3, 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 conditionality³¹. There are essentially no lags between private capital outflows and the TARGET inflows and the volume of TARGET 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 TAR-

³¹Although 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) and the central bank’s collateral policy.

GET balances reflect the supportive role played by the Eurosystem in relation to the banking system and its intermediation role on the money markets during the ongoing financial market tensions. To some extent, TARGET balances thus constitute a substitute provided by the public (central bank) sector for what would normally be private claims among commercial 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 character 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 presumably different prices, marking the end of monetary union” (Bindseil and Winkler (2012), p. 37).

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

3.4 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.

3.4.1 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 in 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.

It should be noted that Chari et al. (2005) express scepticism about the sudden stop paradigm. They argue that, in standard real business cycle models, the imposition of a borrowing constraint on the economy, leading to capital flow reversals, will lead to an increase in output rather than the sharp decline observed in the data. This is due to wealth effects on labour supply. Instead they argue that sudden stops are simply a consequence of expected future negative shocks (“news 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 (1997). 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. At the same time, the model incorporates features which imply that hitting the borrowing constraint will lead to falls in output, thus addressing 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.

Since the model we use 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.

3.4.2 Benchmark Model

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

In order to ensure stationarity of net foreign assets the welfare function embodies an endogenous discount factor D_t

$$V_t = U[c_t - N(L_t)] + D_t V_{t+1} \quad (3.3)$$

$$U(\cdot) = \frac{1}{1 - \sigma_c} [c_t - N(L_t)]^{1 - \sigma_c} \quad (3.4)$$

$$N(L_t) = \frac{1}{\omega} L_t^\omega \quad (3.5)$$

The parameters σ_c and ω represent the relative relative risk version coefficient and the Frisch elasticity of labour supply in the labour 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:³²

$$D_t = \rho(c_t - N(L_t)) \quad (3.6)$$

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

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

$$c_t + i_t + g_t = y_t - p_t \nu_t - \phi(R_t - 1)(w_t L_t + p_t \nu_t) - q_t^b b_{t+1} + b_t \quad (3.7)$$

³²Schmitt-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.

where y_t represents total domestic output at time t , c_t consumption, i_t investment, g_t government spending, b_t foreign assets in the form of 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 $q_t^b = 1/R_t$.

The model does not include an explicit banking sector³³. Instead, financial frictions are introduced by means of an occasionally binding collateral constraint which foreign lenders impose on domestic borrowers. The following collateral constraint applies to international borrowing:

$$q_t^b b_{t+1} - \phi R_t (w_t L_t + p_t \nu_t) + \kappa q_t k_t \geq 0 \quad (3.8)$$

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 (1997)

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

$$i_t = \delta k_t + (k_{t+1} - k_t) \left[1 + \Psi \left(\frac{k_{t+1} - k_t}{k_t} \right) \right] \quad (3.9)$$

The parameter δ is the rate of depreciation and Ψ is the adjustment cost function.

³³Under 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 model will generate the same outcomes as the model without an explicit banking sector.

The adjustment cost function in turn is quadratic:

$$\Psi \left(\frac{z_t}{k_t} \right) = \frac{a}{2} \left(\frac{z_t}{k_t} \right)^2 \quad (3.10)$$

$$a > 0$$

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

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:

$$z_t = i_t - \delta k_t - \Psi \left(\frac{z_t}{k_t} \right) z_t \quad (3.11)$$

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 :

$$y_t = \exp(\epsilon_t^A) A k_t^\beta L_t^\alpha v_t^\eta \quad (3.12)$$

$$0 < \alpha, \beta, \eta < 1$$

$$\alpha + \beta + \eta = 1$$

$$A > 0$$

3.4.3 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 3.7, the law of motion of capital, in equation 3.9, and the borrowing constraint, in equation 3.8, with respect to c_t, L_t, k_{t+1}, v_t and b_{t+1} .

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

$$\lambda_t = u_c(c_t - N(L_t)) + \rho_c(c_t - N(L_t))\mathbf{E}_t[V_{t+1}] \quad (3.13)$$

$$-\lambda_t w_t = -u_c(c_t - N(L_t))N_L(L_t) - \rho_c(c_t - N(L_t))N_L(L_t)\mathbf{E}_t[V_{t+1}] \quad (3.14)$$

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:

$$\rho_c(c_t - N(L_t)) = \left(\frac{-\gamma}{1 + c_t - \frac{L_t^\omega}{\omega}} \right) \exp \left[-\gamma \ln \left(1 + c_t - \frac{L_t^\omega}{\omega} \right) \right] \quad (3.15)$$

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

$$N_L(L_t) = w_t \quad (3.16)$$

The first order condition for labour is:

$$\lambda_t \left(\exp(\epsilon_t^A) F_L(k_t, L_t, v_t) - w_t(1 + \phi(R - 1)) \right) - \mu_t \phi R_t w_t = 0 \quad (3.17)$$

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

$$\lambda_t \left(\exp(\epsilon_t^A) F_\nu(k_t, L_t, v_t) - p_t(1 + \phi(R - 1)) \right) - \mu_t \phi R_t p_t = 0 \quad (3.18)$$

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 labour 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:

$$\lambda_t q_t^b = \mu_t q_t^b + D_t \lambda_{t+1} \quad (3.19)$$

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

$$\lambda_t = \mu_t + D_t R_t \lambda_{t+1} \quad (3.20)$$

The gross real interest rate on a one-period riskless domestic bond (R_t^h) satisfies the usual condition which links it to the expected value of 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 $\mu_t > 0$), a spread between the two rates emerges:

$$R_t^h - R_t = \frac{\mu_t}{\mathbf{E}_t \lambda_{t+1}} \quad (3.21)$$

Thus periods in which the borrowing constraint binds will be associated with spreads between domestic and international interest rates.

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

$$\begin{aligned}
D_t \lambda_t \exp(\epsilon_{t+1}^A) F_k(k_{t+1}, L_{t+1}, v_{t+1}) + q_t \left\{ - \left[1 + \Psi \left(\frac{z_t}{k_t} \right) \right] - z_t \Psi_z \left(\frac{z_t}{k_t} \right) \frac{1}{k_t} \right\} + \\
q_{t+1} \left\{ -\delta + \left[1 - \Psi \left(\frac{z_{t+1}}{k_{t+1}} \right) \right] + z_{t+1} \Psi_z \left(\frac{z_{t+1}}{k_{t+1}} \right) \left(1 + \frac{z_{t+1}}{k_{t+1}} \right) \frac{1}{k_{t+1}} \right\} \\
+ \mu_{t+1} \kappa q_{t+1} = 0
\end{aligned} \tag{3.22}$$

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:

$$d_{t+1} = \exp(\epsilon_{t+1}^A) F_1(k_{t+1}, L_{t+1}, v_{t+1}) - \delta + \left(\frac{z_{t+1}}{k_{t+1}} \right)^2 \Psi_z \left(\frac{z_{t+1}}{k_{t+1}} \right) \tag{3.23}$$

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

$$q_t = \mathbf{E}_t \left[\sum_{j=0}^{\infty} \left(\prod_{i=0}^j \left(\frac{1}{\tilde{R}_{t+i+1}^{t+1}} \right) \right) d_{t+1+j} \right] \tag{3.24}$$

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

$$\tilde{R}_{t+i+1}^{t+1} = \frac{\lambda_{t+i} - \mu_{t+i} \kappa}{\lambda_{t+i+1}} \tag{3.25}$$

As equations (3.24) and (3.25) 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.

3.4.4 Downward Nominal Wage Rigidity

Schmitt-Grohe and Uribe (2011b) 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 related 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) (Chapter 2 of this thesis) 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 (2011b), 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

$$w_t^{num} = (1 + tc) \lambda_t L_t w_t^{\theta_w} L_t^{\omega-1} + \psi_w \frac{D_t \lambda_{t+1}}{\lambda_t} w_{t+1}^{num} (1 + \pi)^{\theta_w} \quad (3.26)$$

and

$$w_t^{den} = L_t w_t^{\theta_w} \lambda_t + (1 + \pi)^{\theta_w} \psi_w \frac{D_t \lambda_{t+1}}{\lambda_t} w_{t+1}^{den} \quad (3.27)$$

In contrast to Schmitt-Grohe and Uribe (2011b), 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)³⁴.

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

$$w_t = \left(\psi_w(s) \left(\frac{w_{t-1}}{1 + \pi} \right)^{1-\theta_w} + (1 - \psi_w(s)) \left(\frac{\theta_w}{\theta_w - 1} \frac{w_t^{num}}{w_t^{den}} \right)^{1-\theta_w} \right)^{\frac{1}{1-\theta_w}} \quad (3.28)$$

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).

3.4.5 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 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

³⁴Specifically, 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).

for b_t^{CB} :

$$b_t = b_t^{PR} + b_t^{CB} \quad (3.29)$$

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

$$q_t^b b_{t+1}^{PR} - \phi R_t (w_t L_t + p_t \nu_t) \geq -\kappa q_t k_t \quad (3.30)$$

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 (3.21):

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

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 3.3 for the model calibration.

The assumption in (3.30) 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 (3.30) 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 operations³⁵ renders crowding out

³⁵See 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.

of private capital flows by TARGET balances implausible. In addition, we are not aware of any evidence supporting a catalytic role for TARGET balances.

3.4.6 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 :

$$\begin{aligned}\epsilon_t^A &= \rho_A \epsilon_{t-1}^A + \eta_t^A \\ \eta_t^A &\sim N(0, \sigma_A^2)\end{aligned}\tag{3.31}$$

The gross real world interest rate has the following process:

$$\begin{aligned}\ln(R_t) &= \rho_R \ln(R_{t-1}) + (1 - \rho_R) \ln(\bar{R}) + \eta_t^R + \rho_{RA} \cdot \eta_t^A \\ \eta_t^R &\sim N(0, \sigma_R^2)\end{aligned}\tag{3.32}$$

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 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.

3.4.7 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 3.3, subject to constraints 3.7, 3.9, and 3.8, 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 (3.16) is replaced by the wage-setting condition (3.28).

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

$$w_t = \frac{\partial N(\bar{L}_t)}{\partial \bar{L}_t} \quad (3.33)$$

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

$$q_t = \frac{\partial i(\bar{k}_{t+1}, \bar{k}_t)}{\partial \bar{k}_{t+1}} \quad (3.34)$$

$$\bar{L}_t = L_t \quad (3.35)$$

$$\bar{k}_t = k_t \quad (3.36)$$

When the collateral constraint binds, ($\mu_t > 0$), a wedge, in the form of an external financing premium on debt, emerges (3.21). There is also an external financing premium on working capital

3.5 Calibration and Solution Method

3.5.1 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 3.4.³⁶ The additional

³⁶See Mendoza (2010), pp. 1951-53 for a fuller discussion of the parameter selections for this model.

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 set to 0.13 based on the estimates reported in Section 3.

3.5.2 Model Solution Method

Solving models with sudden stops is challenging since these models contain important and complicated 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 state³⁷.

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).³⁸ Rendahl

³⁷An extensive review of alternative methods for solving dynamic stochastic general equilibrium models is contained in Judd (1999).

³⁸In 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).

(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.

3.6 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, 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.

3.6.1 Impulse Response Analysis

We present impulse responses to a one standard deviation orthogonalized shock to TFP³⁹. 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 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 space⁴⁰ 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 3.6 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.

³⁹We have also computed IRFs for the interest rate shocks. These results are available from the authors on request.

⁴⁰This 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

Figure 3.7 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 3.6. The most striking difference between the two charts relates to the spread, Tobin's q and investment. Without a TARGET system 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.

3.6.2 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 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 3.5.

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 (2011b), 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 (2011b). Second, in our model the labour supply is more elastic, dampening the volatility of wages. (In the baseline model of Schmitt-Grohe and Uribe (2011b) 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.

3.6.3 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. (2004) 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 3.8. 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.

3.6.4 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 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 3.9 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.

3.6.5 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 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.

Since the model has more variables than shocks we have to choose which variables will match the 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 3.10. This figure 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 period⁴¹. 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 percentage points rather than +2pp 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.

3.6.6 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 hitting the borrowing constraint will lead to lower asset prices through the debt

⁴¹We do not examine how well the model fits the other variables for Spain, an issue which is beyond the scope of this exercise.

deflation mechanism.

In choosing the level of foreign debt, however, agents fail to internalize this 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 (2012a)). 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 (2012a). 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 (3.3). 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 3.11. 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 3.11 shows that the welfare gains vary depending on the state of the economy. To explore this further, we follow Schmitt-Grohe and Uribe (2011b) 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 Figure 3.11. 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”.

3.7 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 com-

mon 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” country⁴². A second useful extension would be to introduce an explicit banking system⁴³, 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.

⁴²A 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.

⁴³Although 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 as pure intermediaries between lenders and borrowers. Such a setup, however, would ignore important aspects such as moral hazard, default and systemic risk.

3.8 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. (2004)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 (2012). 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 behaviour 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 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

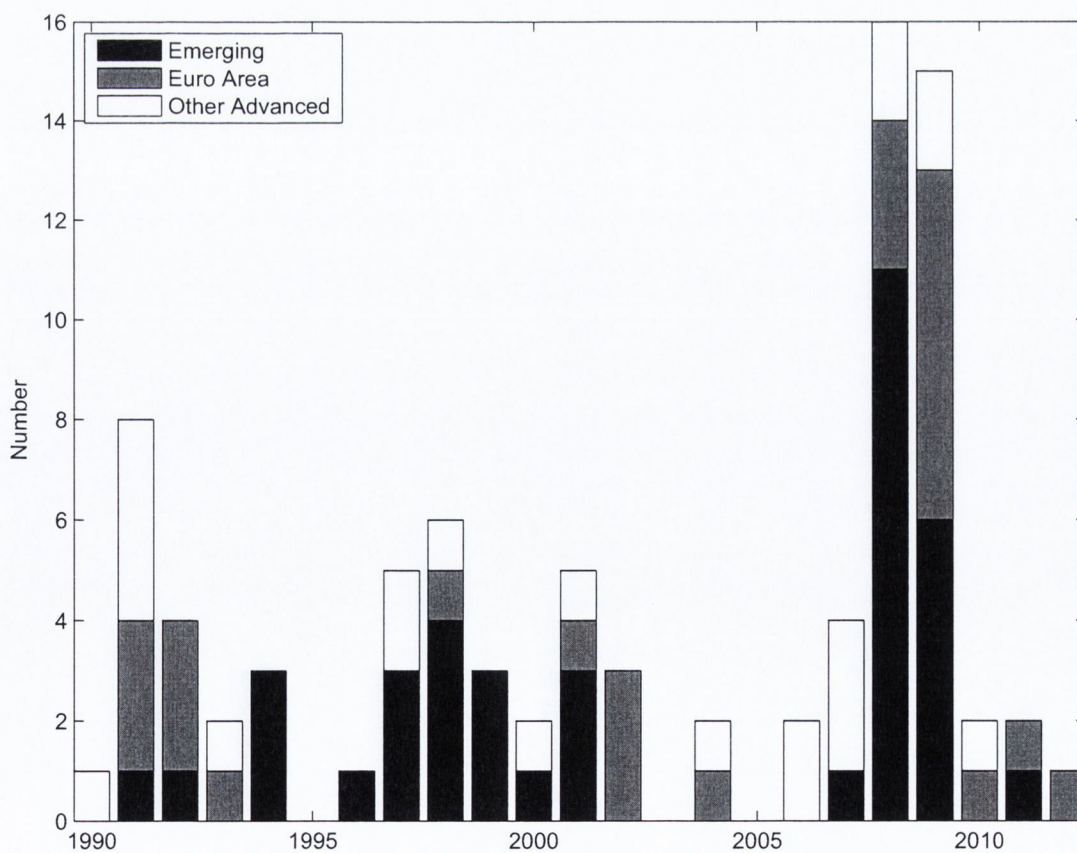
Appendix Table 2: List of identified sudden stop episodes

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



3.9 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:

$$f(s_t, x_t, E_t h(s_{t+1}, x_{t+1})) = 0 \quad (3.37)$$

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:

$$s_{t+1} = g(s_t, x_t, \epsilon_{t+1}) \quad (3.38)$$

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

$$s_t = \{b_{t-1}, k_{t-1}, w_{t-1}, R_t, \eta_t^A\} \quad (3.39)$$

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.

$$x_t = \{b_t, k_t, w_t, c_t, \lambda_t, V_t, y_t, q_t, w_t^{num}, w_t^{den}, \mu_t\} \quad (3.40)$$

The expectation variables entering the model are⁴⁴:

$$h_t = \{\lambda_{t+1}, V_{t+1}, zh_{t+1}, (\lambda_{t+1}w_{t+1}^{num}), (\lambda_{t+1}w_{t+1}^{den})\} \quad (3.41)$$

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

$$E_t h(s_{t+1}, x_{t+1}) = \phi(s_t) \quad (3.42)$$

Once we have obtained this function, we can solve (3.37) 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 (3.37) 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.

⁴⁴Note 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 $zh_t = \lambda_t \left(\delta + \frac{a(k_{t-1}-k_t)}{k_{t-1}} - \frac{a(k_{t-1}-k_t)^2}{2k_{t-1}^2} - 1 - \beta \frac{y_t}{k_{t-1}} \right)$.

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.

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 $i = 1 \dots N$ 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^{nbc}) in the unconstrained case, and b) an initial estimate of the sensitivity of debt to changes in the multiplier ($\psi = \frac{db_t}{d\mu_t}$)⁴⁵:

$$\mu_i = \max\left\{0, \frac{b_i^{bc} - b_i^{nbc}}{\psi}\right\} \quad (3.43)$$

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.

⁴⁵The 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.

Table 3.1: 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 3.2: 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 3.3: Individual Country Estimate of Target Equation

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

Table 3.4: Parameters

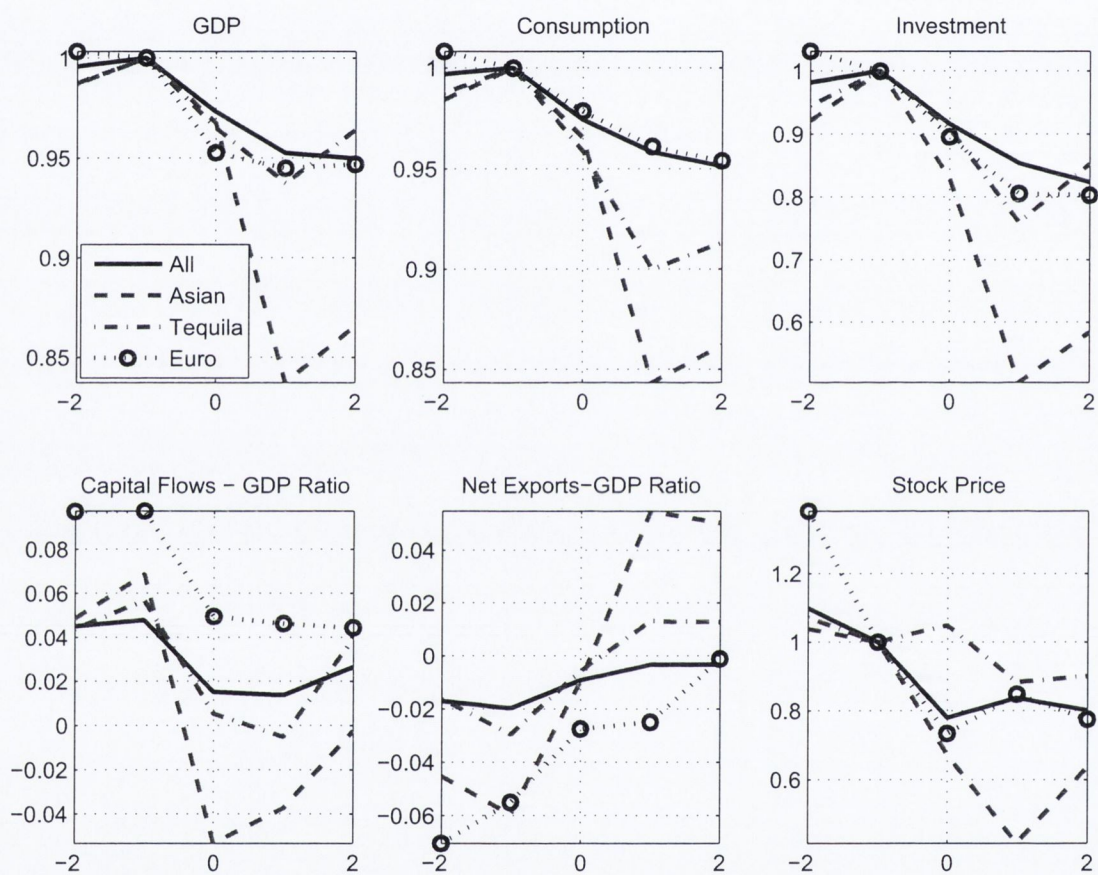
Sector	Definition	Parameter Calibration	
		Value	Source
Utility Function			
σ_c	Risk aversion	2.0	Mendoza, p. 1951
ω	Frisch elasticity	1.846	Mendoza, Tab.1 (p. 1951)
γ	Discounting	0.16	Mendoza, Tab. 1 (p. 1951)
Production Function			
α	Labor	0.592	Mendoza, Tab. 1 (p. 1951)
β	Capital	0.305	Mendoza, Tab. 1 (p. 1951)
η	Intermediate goods	0.102	Implied by Cobb-Douglas
A	Constant	7.389	Implied by steady-state
Investment			
δ	Depreciation	0.088	Mendoza, Tab. 1 (p. 1951)
a	Adjustment costs	2.750	Mendoza, Tab. 1 (p. 1951)
Budget and Borrowing			
κ	Collateral	0.225	Match frequency of borrowing constraint
ϕ	Working capital	0.258	Mendoza, Tab. 1 (p. 1951)
tc	Tax Rate	0.168	Mendoza, Tab. 1 (p. 1951)
Φ	TARGET response	13.00	Estimated from Euro-Area panel
Wage Setting			
ψ_w	Calvo	.60	Fagan (2013)
θ_w	Intratemporal elasticity	6.0	Fagan (2013)
Stochastic Processes			
ρ_A	Productivity lag	.57	Mendoza, p. 1954
ρ_R	Interest lag	.57	Mendoza, p. 1954
ρ_{RA}	Correlation	-.98	Mendoza, p. 1954
σ_A	Productivity volatility	.011	Mendoza, p. 1954
σ_R	Interest volatility	.012	Mendoza, p. 1954

Table 3.5: 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	0.033	1
		BC	392.403	343.654	450.588	0.032	1
		T	392.893	344.089	451.640	0.033	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	0.280	0.300
		BC	.02	-.006	.051	0.283	0.303
		T	.02	-.006	.051	0.280	0.296
Net Ex/GDP	0.047	NBC	0.033	-0.071	0.147	0.795	-0.138
		BC	0.017	-0.082	0.101	0.700	-0.109
		T	0.022	-0.077	0.110	0.721	-0.119
NFA/GDP	-0.378	NBC	-0.213	-1.097	0.452	4.947	-0.134
		BC	-0.016	-0.262	0.496	2.967	-0.368
		T	-0.081	-0.363	0.460	3.200	-0.313
Spread	0.00	BC	0	0	0.025	0.021	0.052
		T	0	0	0.008	0.013	0.096
Target/GDP	0.00	T	0.002	0.00	0.100	0.180	0.096
Pr(BC)	0	BC	0.052				
		T	0.246				

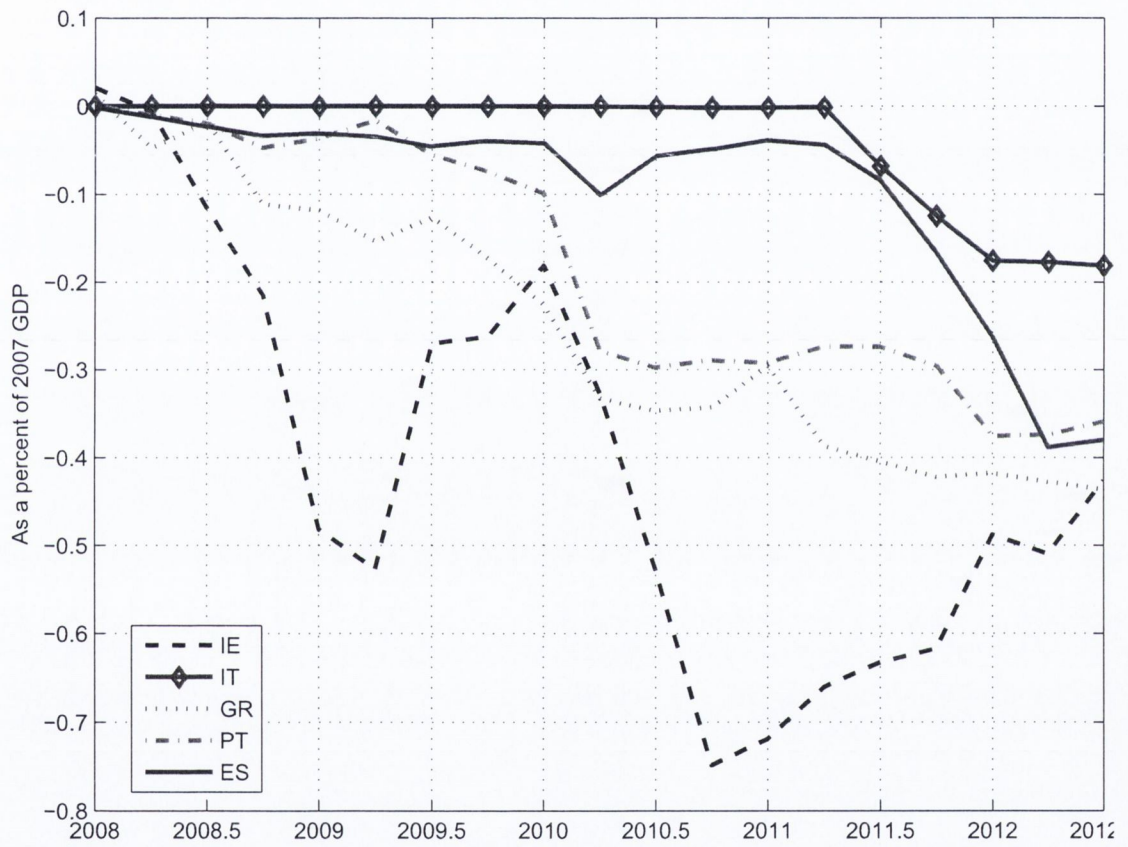
Note: The second last column reports the standard deviation of each variable relative to the standard deviation of GDP except for GDP, where it reports the percentage standard deviation.

Figure 3.1: Macro Dynamics with Sudden Stops (annual)



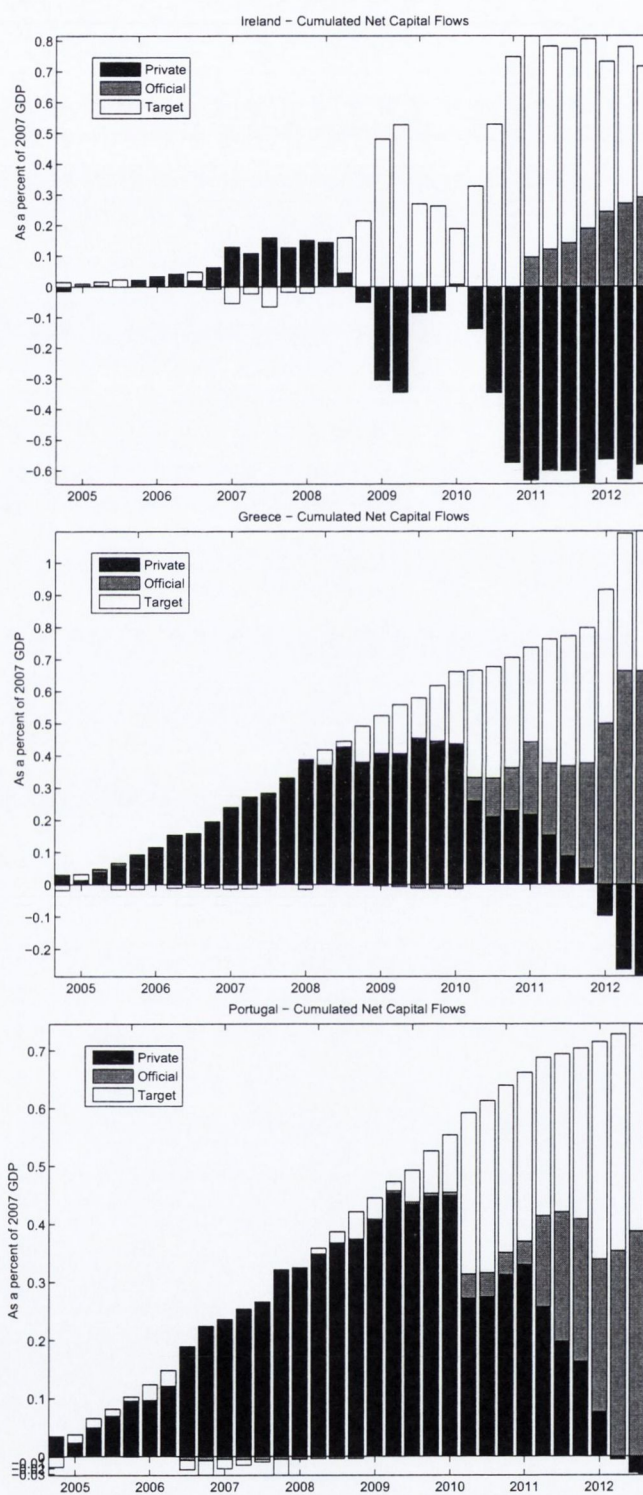
Source: IMF Balance of Payments Statistics, World Development Indicators, AMECO, Bloomberg. The year in which the sudden stop starts is denoted 0. All series except net trade and capital flows are deviations from a Hodrick-Prescott filter indexed to 1 for $t=-1$

Figure 3.2: Target Balances (% GDP): Euro Zone



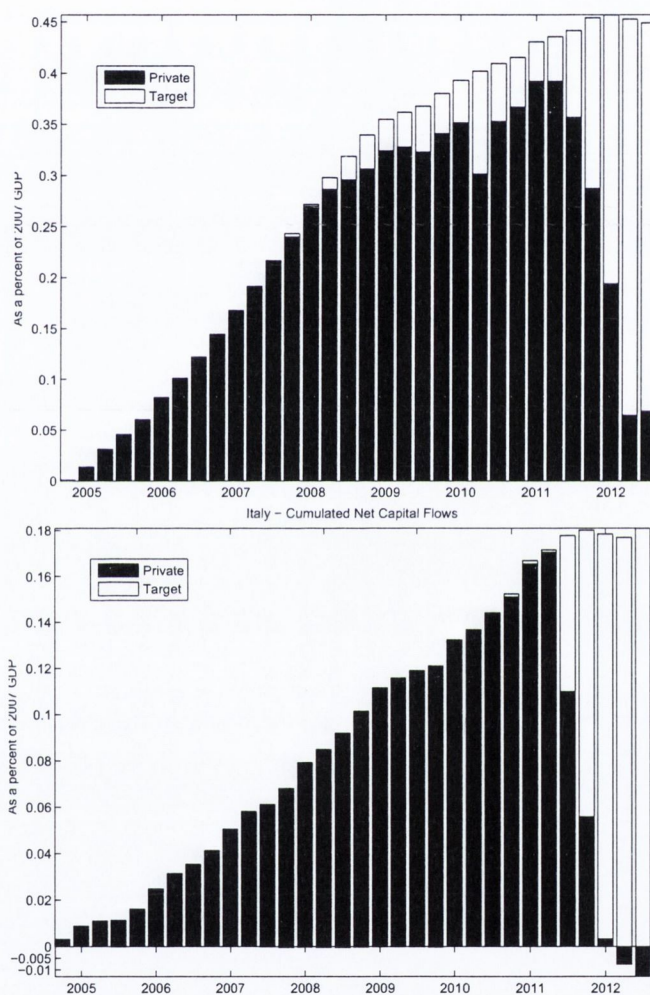
Source: Eurocrisis Monitor website.

Figure 3.3: Cumulative Net Capital Flows: Greece, Ireland and Portugal



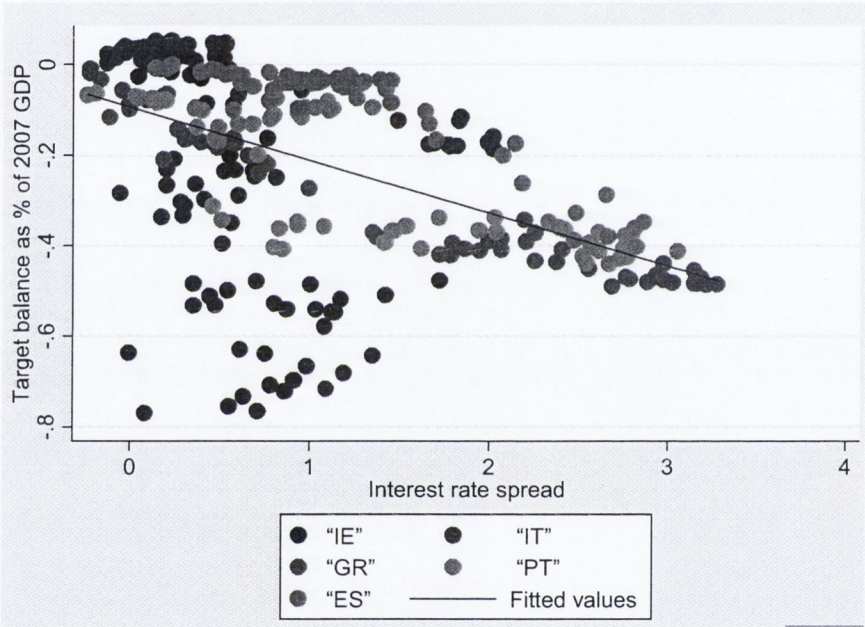
Source: IMF Balance of Payments statistics and World Bank External Debt hub.

Figure 3.4: Cumulative Net Capital Flows - Spain and Italy



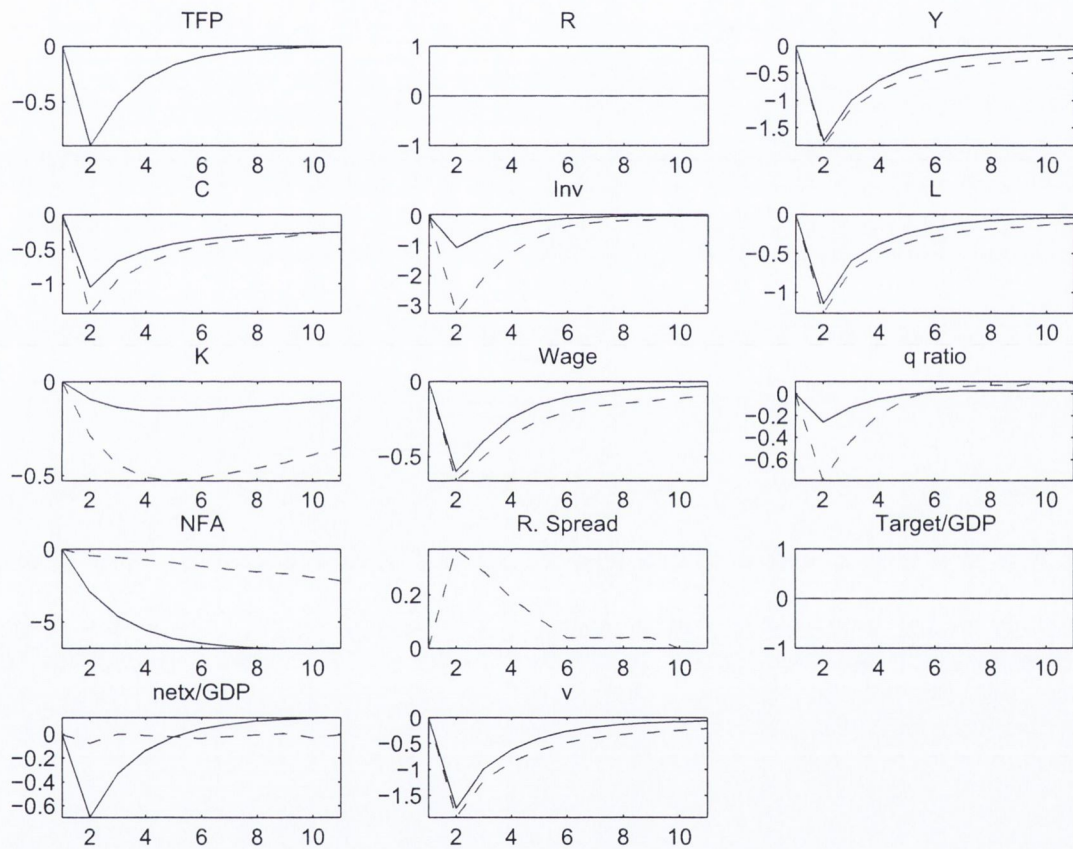
Source: IMF Balance of Payments statistics and World Bank External Debt hub.

Figure 3.5: Target Balances vs. Interest Rate Spreads in Euro Zone



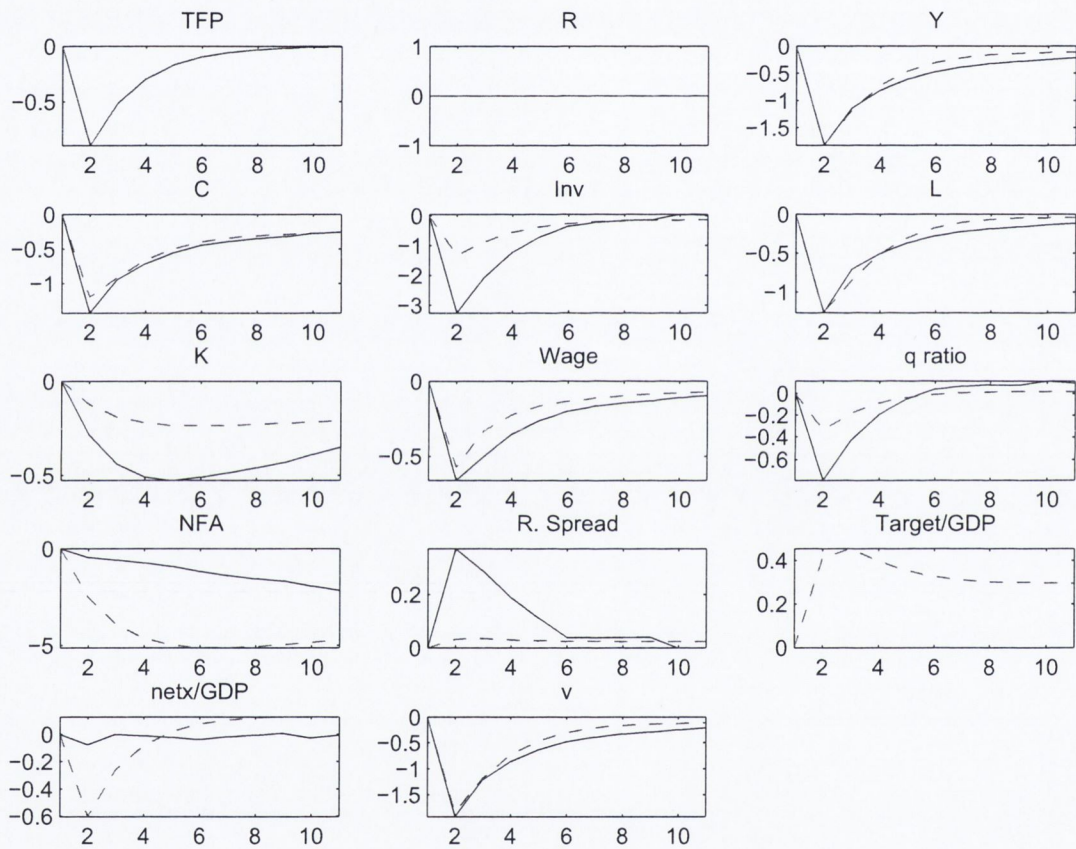
Source: Eurocrisis Monitor website and ECB. The interest rate spread variable relates to the MFI rate on new business loans to non-financial corporations for amounts less than EUR 1 million with a maturity of 3 months to 1 year.

Figure 3.6: IRF to a TFP Shock: Unconstrained vs. Constrained Borrowing



The solid lines refer to the IRFs at the stochastic mean, where the borrowing constraint is not binding. The dashed lines refer to IRFs when the borrowing constraint binds.

Figure 3.7: 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 3.8: Model: Sudden Stop Dynamics: Target vs No Target

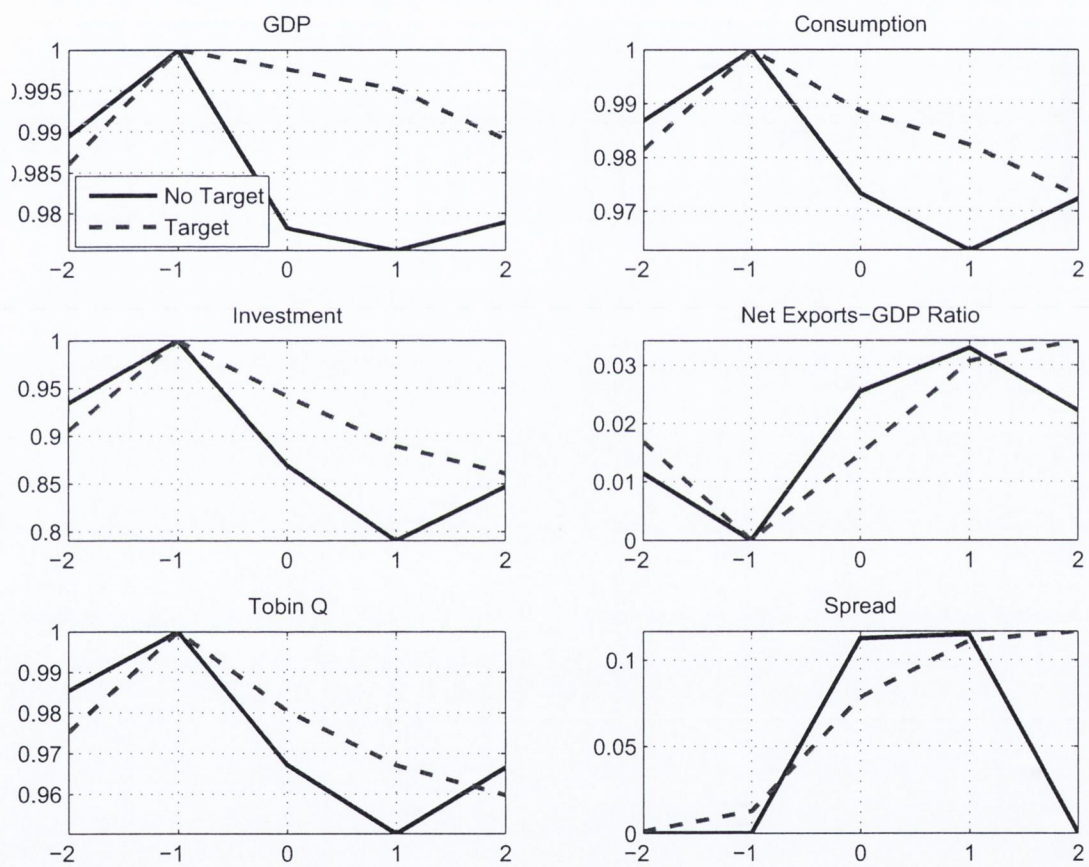


Figure 3.9: Crisis Episode: Target vs No Target

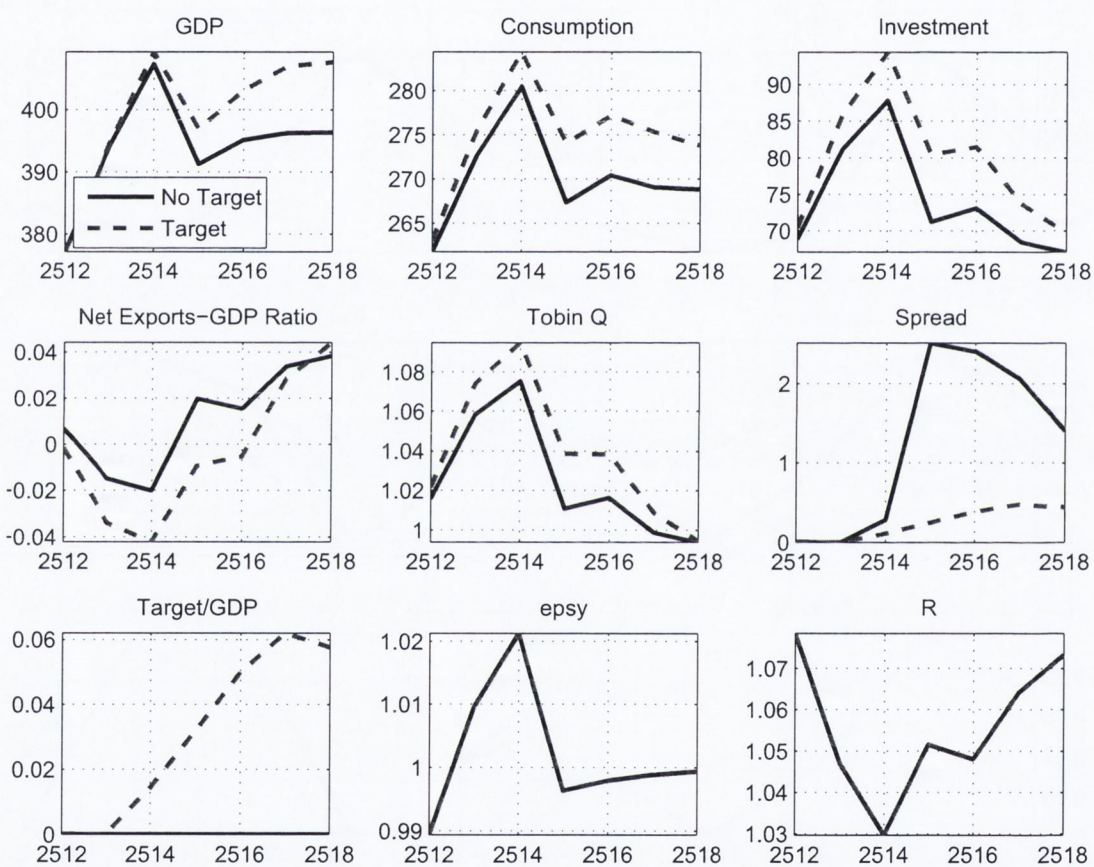


Figure 3.10: Counterfactual Simulation

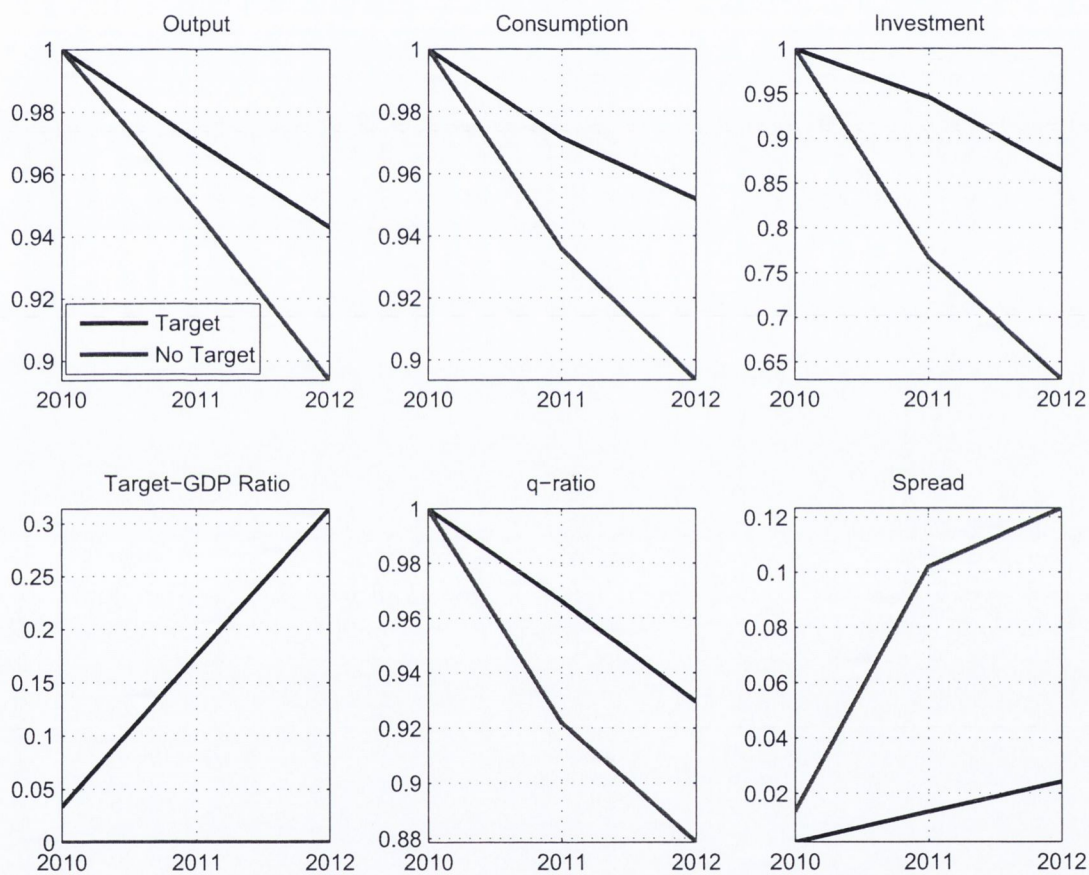
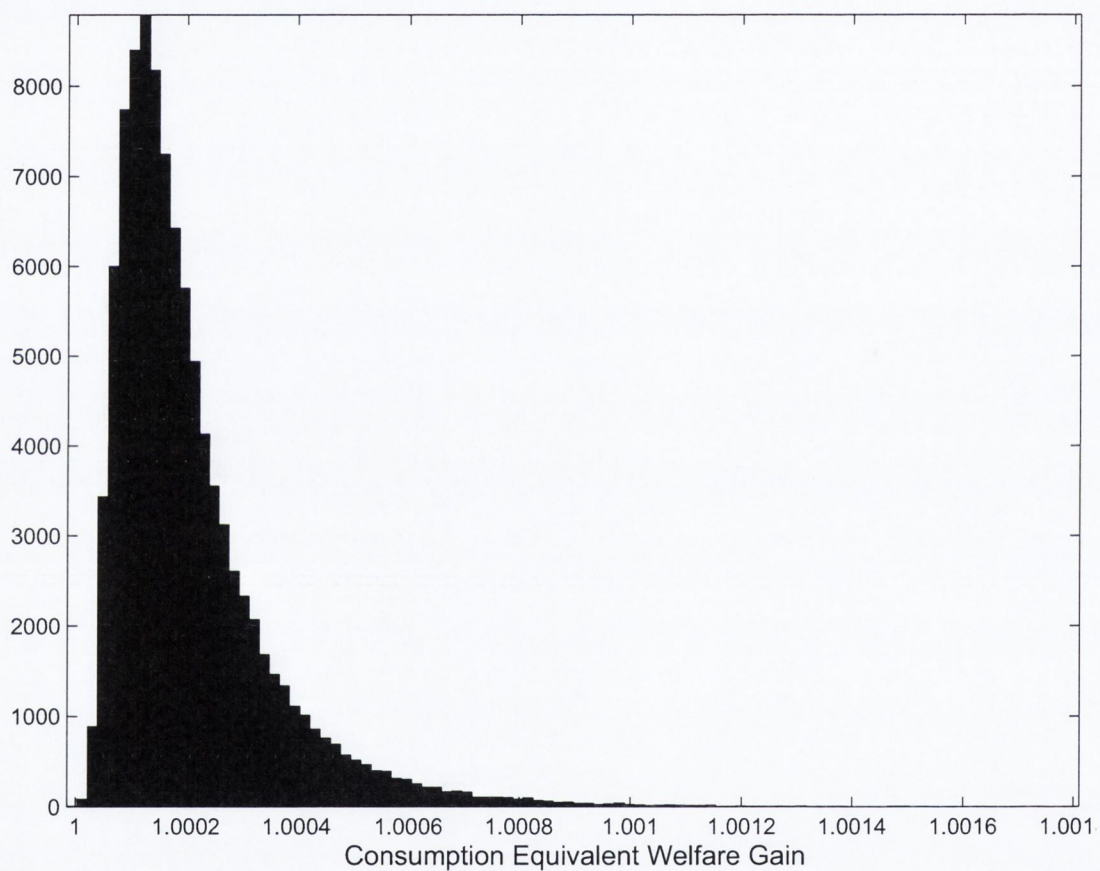
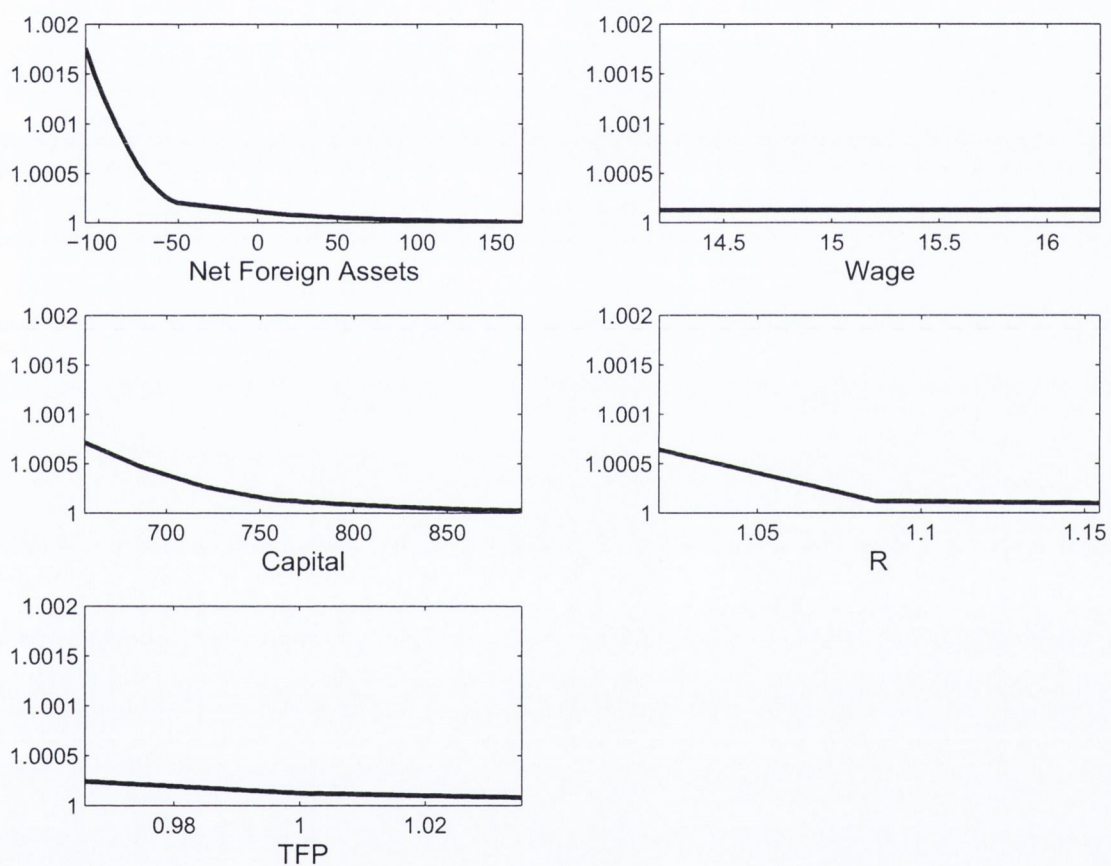


Figure 3.11: Distribution of Welfare Gains (Target vs No Target)



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

Figure 3.12: 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.

Chapter 4

Downward Nominal Wage Rigidity and the Cost of Exchange Rate Pegs Revisited

4.1 Introduction

A well established literature on the costs and benefits of exchange rate regimes suggests that the macroeconomic effects of adopting a currency peg (compared to an optimal policy with a floating exchange rate) are small. There are two strands of this literature. One strand addresses the question using general equilibrium models. Widely cited examples include Kollmann (2002) and Benigno (2004). In the same vein, Devereux et al. (2006) report a maximum consumption equivalent loss from adopting a peg of 0.16 percent of steady-state consumption. The second strand of literature uses panel data econometric analysis to identify the macroeconomic effects of pegging the exchange rate. A recent extensive review of this literature (Tavlas et al. (2008)) concludes that *"we remain a long way from having reliable evidence that can help us choose among alternative systems."* (p. 961). A more recent empirical analysis by Rose (2013) of data for 170 countries for the global financial crisis period

(2007 to 2012) concludes that the estimated macroeconomic effects of alternative exchange rate regimes during this period are “*surprisingly small*”.

In a recent set of papers, Schmitt-Grohe and Uribe (2011, 2012a, 2012b and 2013) present results which are strikingly at variance with these conclusions. By introducing DNWR into a compact SOE model, they show that the *average* unemployment rate over the business cycle can be up to 14 percentage points higher under a peg than under a flexible exchange rate regime. The key mechanism is that under a peg DNWR prevents the adjustment of real wages to adverse shocks. In contrast to standard wage stickiness considered for example by Gali and Monacelli (2008), the effect is asymmetric: in booms employment does not rise above the “full-employment” rate whereas in recessions unemployment prevails. Thus (high) unemployment prevails on average over the business cycle.

These findings lead to a number of policy proposals by the authors. One solution is use taxes and subsidies to neutralise the effect of DNWR. This is in the spirit of “fiscal devaluation” as advocated by Farhi et al. (2011). It is also in line with the earlier analysis by Adao et al. (2009) of the use of fiscal instruments in a peg as an alternative to monetary policy. Alternatively, prudential capital controls may be employed to damp down the volatility of domestic demand and wages, thus reducing the average unemployment rate (Schmitt-Grohe and Uribe (2012a)). Finally, in the case of a monetary union, the common central bank may (temporarily) raise its inflation target to facilitate adjustment in member countries suffering from large adverse shocks (Schmitt-Grohe and Uribe (2013)).

In deriving all of these findings Schmitt-Grohe and Uribe make use of a specific form of DNWR, namely a strict, but occasionally binding, constraint on the economy-wide nominal wage rate (W_t) in period t :

$$W_t \geq \gamma W_{t-1} \tag{4.1}$$

A value of γ equal to unity implies that the no wage cuts are possible. Values of

γ below but close to unity allow for some modest wage cuts. In the calibration of their quarterly model, Schmitt-Grohe and Uribe (2011b) set γ to 0.99, implying that wage cuts cannot be greater than 1% per quarter.

Although analytically convenient, this formulation of DNWR suffers from an important limitation: it is not consistent with the micro evidence on wage changes. For example, in Fagan (2013) (Chapter 2 of this thesis) we used cross-sectional micro data on wage changes for four countries (US, Germany, Portugal and Belgium) to estimate alternative formulations of DNWR. We concluded that specifications such as (4.1) are strongly rejected by the data. Instead, the data is consistent with an asymmetric variant of the Calvo (1983) scheme in which wages are flexible upwards but are subject to a Calvo regime when they need to be adjusted downwards. As we will show below, this formulation of DNWR implies that downward adjustments of aggregate wages can be larger than implied by (4.1) since large wage cuts, though less frequent than in the fully flexible case, are not ruled out. A priori this suggests that the Schmitt-Grohe and Uribe (2011b) model overstates the rate of unemployment in exchange rate pegs.

How much of a difference will this make quantitatively? To address this question, we modify the Schmitt-Grohe and Uribe (2011b) model by replacing the wage setting in (1) by our alternative Calvo scheme and compute average unemployment rates under an exchange rate peg under fully flexible wages and alternative schemes of DNWR. Our main conclusion is that replacing (4.1) by the more data-consistent asymmetric Calvo scheme leads to a substantial reduction in the average unemployment rate. Still, the resulting unemployment rates remain large. Hence, the qualitative and policy conclusions of Schmitt-Grohe and Uribe (2011b) remain intact. A methodological contribution of this paper is that we provide an example of how to incorporate DNWR into a macro model in a way which is consistent with the micro evidence⁴⁶. Of course, the resulting model is highly nonlinear and thus

⁴⁶Daly and Hobijn (2013) is another recent example which integrates an asymmetric Calvo wage setting scheme into a DSGE model. In their case, the focus on a closed economy and address the issue of the impact of DNWR on the slope of the Philips curve.

requires the use of computationally intensive solution methods.

The remainder of this paper is structured as follows. Section 4.2 sets out the model used. Section 3 then presents the alternative wage setting mechanisms we use in the remainder of the paper. The next three sections address the issues of stochastic specification, calibration and model solution method. Section 4.7 presents the results, including a tentative comparison with cross country data on wages and unemployment. Section 4.8 concludes.

4.2 Model

Schmitt-Grohe and Uribe (2011b) present a compact model of a small open economy with competitive markets. There are two goods: traded and nontraded. The economy is a price-taker for traded goods whose price (in foreign currency) is fixed on world markets. In the baseline version of the model, which we use, the supply of traded good is given by an exogenous stochastic endowment process. Nontraded goods are produced by competitive firms using a Cobb-Douglas production function in which labour is the only input. Households inelastically supply one unit of labour. In the presentation which follows, variables in lower case letters denote logs while upper case denotes levels.

4.2.1 Consumers

Household consumption is given by a CES aggregate of the consumption of traded and nontraded goods:

$$C_t = A(C_t^T, C_t^N) = [a(C_t^T)^{\frac{\xi-1}{\xi}} + (1-a)(C_t^N)^{\frac{\xi-1}{\xi}}]^{\frac{\xi}{\xi-1}} \quad (4.2)$$

with ξ being the elasticity of substitution between the two goods. The instantaneous

utility function for the household takes the standard CRRA form:

$$U(C_t) = \frac{C_t^{1-\sigma} - 1}{1-\sigma}$$

With this setup, the maximisation problem of the representative consumer comprises two parts. The first is intertemporal: to choose, subject to the budget constraints, a sequence of consumption which maximises welfare:

$$\text{Max } E_t \sum_{i=0}^{\infty} \beta^i U(C_{t+i})$$

where E_t denotes the expectations operator and β is the discount factor. Second, each period, the consumer chooses the allocation of total consumption between traded and nontraded goods.

Consumers face a sequence of budget constraints of the following form:

$$P_t^T C_t^T + P_t^N C_t^N = P_t^T Y_t^T + W_t H_t + \frac{X_t D_{t+1}}{(1 + R_t)} - X_t D_t + \phi_t \quad (4.3)$$

P_t^T, P_t^N, C_t^T and C_t^N are respectively the prices and quantities consumed of traded and nontraded goods. Y_t^T is the exogenous time-varying endowment of traded goods. X_t is the nominal exchange rate while D_t is foreign debt denoted in foreign currency. ϕ_t are dividends received from the firms. R_t is the world interest rate which is an exogenous stochastic process. In addition to the budget constraint, households are subject to an occasionally binding constraint that the level of foreign debt cannot exceed the natural debt limit (\bar{D}):

$$D_t < \bar{D} \quad (4.4)$$

The first order conditions for the representative yields the Euler equation for consumption:

$$\lambda_t = (1 + R_t) (E_t[\beta\lambda_{t+1}] + \mu_t) \quad (4.5)$$

where λ_t is the marginal utility of traded consumption while $\mu_t \geq 0$ is Kuhn-Tucker multiplier on the borrowing constraint. Optimality also requires that the following slackness condition is fulfilled:

$$\mu_t(D_{t+1} - \bar{D}) = 0$$

The first order conditions for traded and nontraded consumption yield the standard intratemporal condition that the relative price of nontraded goods is equal to the marginal rate of substitution:

$$\frac{P_t^N}{P_t^T} = \frac{A_2(C_t^T, C_t^N)}{A_1(C_t^T, C_t^N)} \quad (4.6)$$

where A_1 and A_2 denote the derivatives of the aggregator function (4.2) with respect to its first and second arguments, respectively.

4.2.2 Production of nontraded goods

Nontraded goods are produced by competitive firms using domestic labour according to the following Cobb-Douglas production function:

$$Y_t^N = H_t^\alpha$$

where H_t denotes labour input. This implies that firms choose the level of employment to solve the following static maximising problem:

$$Max [P_t^N Y_t^N - W_t H_t]$$

This yields the standard first order condition that the real wage (in terms of non-traded prices) is equal to the marginal product of labour:

$$\frac{W_t}{P_t^N} = \alpha H_t^{\alpha-1} \quad (4.7)$$

4.2.3 General equilibrium

Under the assumption of symmetrically flexible wages (or alternatively with an optimal exchange rate policy which neutralises the effect of DNWR), the general equilibrium consists of sequences of nontraded goods prices (P_t^N), wages (W_t), employment (H_t), and consumption of traded and nontraded goods (C_t^T and C_t^N) such that:

1. The optimality conditions for households (4.5) and (4.6) are satisfied;
2. The firms optimality condition (4.7) is satisfied;
3. The budget and borrowing constraints, (4.3) and (4.4), are satisfied;
4. The market for nontraded goods clears, $C_t^N = Y_t^N$;
5. The labour market clears: $H_t = 1$

Schmitt-Grohe and Uribe (2011b) show that in this case of flexible wages the decentralised equilibrium corresponds to the Pareto optimum. When wages are subject to DNWR, however, the labour market no longer clears at all times and unemployment will occur. Specifically condition (5) above is replaced by the following condition:

$$H_t = \text{Min} \left\{ 1, \left(\frac{W_t}{\alpha P_t^N} \right)^{\frac{1}{\alpha-1}} \right\}$$

where the second term in the Min operator comes from the firm's first order condition for labour (4.7). Note that given the assumed inelastic labour supply, employment can never be higher than the full-employment level, which we have normalised to

unity. The decentralised equilibrium in this case is no longer Pareto optimal. We explore this case more fully in the next Section.

4.3 Household Wage Setting under DNWR

In this section, we outline two variants of household wage setting which allow for DNWR. The first variant, which is identical to the formulation used by Schmitt-Grohe and Uribe (2011b), implies that the household is subject to a strict constraint on wage cuts which binds occasionally. We will henceforth refer to this form as SGU wage setting. In the second variant, household wage setters are subject to an asymmetric Calvo scheme which constrains cuts in wages but implies flexibility when wages are rising.

To maintain comparability with the Schmitt-Grohe and Uribe (2011b) model, we continue to assume that labour markets are competitive and that one unit of labour is supplied inelastically by households. In order to incorporate wage setting into a competitive labour market, we employ the “large household” assumption of Merz (1995). She used this assumption to integrate search and matching frictions into an otherwise standard Real Business Cycle model. In this setup, it is assumed that households comprise a continuum of members of measure 1 over the interval $[0,1]$. Household members share consumption and labour market risks among themselves so that each member has the same consumption and each member works the same number of hours. As a result of these assumptions, aggregate household variables (consumption, assets, hours worked) are identical across households. Total hours worked by the household is thus:

$$H_t = \int_0^1 H_t(i) di$$

while the wage rate charged by the household satisfies:

$$W_t H_t = \int_0^1 W_t(i) H_t(i) di$$

Following Erceg et al. (2000), we assume that there is a wage setter in each household which sets the wage for each household member. In order to retain consistency with the competitive setup employed by Schmitt-Grohe and Uribe (2011b), we do not assume that households have market power in setting wages. Instead, we will assume that the household wage setter tries to minimise a quadratic function which depends on the difference between the wage set and the flexible wage.

We then consider two cases. In the first the wage setter is subject to an occasionally binding constraint that wage cuts cannot exceed a predetermined magnitude. This yields conditions on aggregate wages which are identical to those used by SGU (where the economy-wide wage is subject to a DNWR constraint, (4.1)). The second case is an asymmetric Calvo scheme. In contrast to the standard Calvo scheme, the probability of wages being fixed varies over time, depending on the state of the economy. Specifically, if aggregate wage growth is above a certain threshold then wages are flexible and the wage setter sets the wage of household members equal to the wage which clears the labour market and ensures full employment. Otherwise, wages are set using a Calvo scheme⁴⁷.

4.3.1 Schmitt-Grohe Uribe wage setting

In this setting, it is assumed that the household wage setter faces a static optimisation problem of choosing the (log) wage for each household member indexed, by j , in order to minimise:

$$L_t = \frac{1}{2} (w_t(j) - w_t^{flex})^2$$

⁴⁷To maintain comparability of results with SGU wage setting, we use the same threshold that DNWR does not apply for all aggregate wage changes in excess of -1 percent per quarter.

w_t^{flex} is the (log) wage that would prevail under completely flexible wages, thereby ensuring full employment. The wage setter is subject to the following DNWR constraint:

$$w_t(j) - w_{t-1}(j) > \log(\gamma)$$

Throughout we follow the Schmitt-Grohe and Uribe (2011b) calibration that $\gamma = 0.99$. In words, households cannot cut nominal wages by more than 1 percent per quarter (4% per year).

If the constraint binds, the solution to the wage setting problem is:

$$w_t(j) = w_{t-1}(j) + \log(\gamma) > w_t^{flex}$$

Otherwise the optimal wage is given by:

$$w_t(j) = w_t^{flex}$$

That is, when the constraint does not bind, the wage chosen for each individual member of the the household is equal to the flexible wage.

With the SGU form of DNWR, regardless of whether the constraint binds or not, the wage set by the wage setter is the same for each member of the household:

$$w_t(j) = w_t(i), \quad \forall i, j$$

Thus the aggregate household wage (w_t), which by our large household assumption is equal across households, is given by:

$$w_t = w_{t-1} + \log(\gamma) > w_t^{flex}$$

when DNWR binds, and

$$w_t = w_t^{flex}$$

when DNWR does not bind. In this latter case, full employment prevails:

$$h_t = \bar{h} = 0$$

(noting that h_t denotes the log of employment). When wages cannot adjust because of DNWR, however, unemployment prevails:

$$h_t < \bar{h}$$

4.3.2 Asymmetric Calvo wage setting

In this setup, we assume that, when setting the wage of the individual household members, the wage setter is subject to a Calvo scheme in which the probability that the wage remains fixed in period t is given by θ_t . This probability is time-varying, depending on the state of the economy, hence the t subscript. This formulation follows Fagan (2013) and Daly and Hobijn (2013). Specifically, when DNWR does not apply, $\theta_t = 0$, so wages are fully flexible upwards. However, when DNWR does apply we have $\theta_t = \bar{\theta} > 0$.

In this case where DNWR does not apply, we assume, as in the previous subsection, that the household wage is set equal to the flexible wage:

$$w_t = w_t^{flex}$$

This assumption assures that full employment prevails in this case:

$$h_t = \bar{h} = 0$$

and rules out the possibility of the level of employment exceeding the inelastic labour supply and is thus consistent with the assumptions of the original model. Now consider the case when DNWR applies in the current period. Letting Π_{t+k} denote the probability of a wage set in period t will be unchanged in period $t+k$, we have :

$$\Pi_{t+k} = \theta_{t+1}\theta_{t+2}\dots\theta_{t+k}$$

The wage setter now only has the opportunity to set a new wage for a fraction $(1 - \theta_t)$ of the household members. We assume that wage setter chooses the wage for these members to solve the following intertemporal optimisation problem:

$$L_t = \frac{1}{2} \left(\tilde{w}(j) - w_t^{flex} \right)^2 + \frac{1}{2} E_t \sum_{k=1}^{\infty} \beta^k (\Pi)_{t+k} \left(\tilde{w}(j) - w_{t+k}^{flex} \right)^2$$

$\tilde{w}_t(j)$ is the log nominal wage selected by the wage setter for household member j whose wage can be changed in the current period. Loosely speaking, in choosing the adjustable wage, the wage setter tries to pick a level which is as close as possible to the expected flexible wage over the period in which the wage is likely to be fixed. Note that the problem is identical for each household member whose wage can be changed in the current period, so we can dispense with the j index. The first order condition for \tilde{w} then yields:

$$\tilde{w}_t = \frac{V_t}{B_t}$$

with

$$V_t = w_t^{flex} + \beta E_t [\theta_{t+1} V_{t+1}]$$

and

$$B_t = 1 + \beta E_t [\theta_{t+1} B_{t+1}]$$

With the fraction, $(1 - \theta_t)$, of the household members wages changing each period, the aggregate (log) household wage rate evolves according to:

$$w_t = \text{Max} \left\{ w_t^{\text{flex}}, \theta_t w_{t-1} + (1 - \theta_t) \tilde{w}_t \right\}$$

or:

$$w_t = \text{Max} \left\{ w_t^{\text{flex}}, \theta_t w_{t-1} + (1 - \theta_t) \frac{V_t}{B_t} \right\} \quad (4.8)$$

In words, the current wage is the maximum of the flexible wage, which ensures full employment, and the wage implied by the Calvo scheme. It is useful to contrast this with the wage function which applies with the SGU wage setting, namely:

$$w_t = \text{Max} \left\{ w_t^{\text{flex}}, w_{t-1} + \log(\gamma) \right\} \quad (4.9)$$

As we will demonstrate below, a key difference is that the asymmetric Calvo scheme allows for larger wage cuts than the SGU setup, both at the micro and the aggregate level.

4.4 Stochastic Processes

The economy is driven by two exogenous stochastic processes, traded output (y_t^T) and the world real interest rate (r_t). These variables are assumed to follow a structural VAR(1) process which allows for contemporaneous correlation between the shocks:

$$\begin{pmatrix} y_t^T \\ r_t \end{pmatrix} = A \begin{pmatrix} y_{t-1}^T \\ r_{t-1} \end{pmatrix} + e_t \quad (4.10)$$

Schmitt-Grohe and Uribe (2011b) estimated this VAR using quarterly data for Argentina over the period 1983:Q1 to 2001:Q4 (thereby excluding the early 2000s crisis)

and we will use these estimates throughout this paper. The empirical counterpart of traded output is the cyclical component of the sum of output agriculture, manufacturing, mining, forestry and fisheries. The interest rate variable is the sum of the US T-bill rate plus the EMBI+ spread minus a measure of expected dollar inflation. Specifically, the estimates are:

$$A = \begin{bmatrix} 0.79 & -1.36 \\ -0.01 & 0.86 \end{bmatrix}$$

and

$$VCV(e) = \begin{bmatrix} 0.00123 & -0.00008 \\ -0.00008 & 0.00004 \end{bmatrix}$$

Three features of this stochastic process are worth highlighting. First, reflecting the experience of Argentina during the sample period, the unconditional volatilities of traded output and the real interest rate are high: with unconditional standard deviations of 12.2 percent and 1.7 percent per quarter, respectively. Second, there is a high degree of persistence in this system. The estimates imply univariate AR(1) coefficients of 0.95 and 0.93 for output and the interest rate. Third, there is a strong negative correlation between traded output and the interest rate with a contemporaneous correlation coefficient of -0.86. This means that a bad realisation of traded output will typically be accompanied by a high realisation of the interest rate.

4.5 Calibration

The values for the calibrated parameters follow Schmitt-Grohe and Uribe (2011b) and are set out in Table 4.1. The values are standard in the open economy macro literature. The only differences relates to the discount factor where we use a value of 0.957 (as against the value of 0.938 reported in the original paper). The use of

this value enables us to match the results reported by Schmitt-Grohe and Uribe (2011b). Specifically, we match i) the average annual foreign debt to GDP ratio of 0.26 for Argentina obtained from Lane and Milesi-Ferreti (2006); ii) the distribution of net foreign assets under the peg reported in Figure 8 on page 34 of Schmitt-Grohe and Uribe (2011b) and iii) the average unemployment rate under the peg. The differences in the discount rate reflects a different treatment of the stochastic processes in the two solution algorithms. Our solution algorithm uses continuous functions whereas the solution algorithm used by the authors constrains foreign debt to lie in a discretised grid.

In addition to these standard values we need to calibrate the value of $\bar{\theta}$, the Calvo coefficient. Our baseline value is 0.75. This implies that when DNWR applies, only 25% of wages can be changed each quarter. This number is in line with existing DSGE models with wage stickiness such as Erceg et al. (2000) and Smets and Wouters (2007). It is also in line with the GMM estimate for the US based on cross-sectional data on wage changes. reported in Fagan (2013)⁴⁸. As a sensitivity analysis, we look at the implications of a higher value of 0.9. This number corresponds to the highest cross country estimate of DNWR found by Fagan (2013), in the case of Portugal.

4.6 Solution Method

Our model contains two important nonlinearities. First, we have the occasionally binding constraint that foreign debt may not exceed the natural debt limit (4.4). Secondly, under both formulations of DNWR, (4.8) and (4.9), the wage function is highly nonlinear and state-dependent. In view of this we solve the model using a global solution technique, the collocation method. For this we use the Compecon package of Miranda and Fackler (2002). To briefly illustrate our solution algorithm,

⁴⁸Using annual data, Fagan (2013) finds a value of the Calvo coefficient for wages of 0.372 in the case of the US data without correction for measurement error. Converting this to quarterly frequency yields a value of 0.78

note that our model can be expressed in a general form:

$$f(s_t, x_t, E_t h(s_{t+1}, x_{t+1})) = 0 \quad (4.11)$$

$$s_{t+1} = g(s_t, x_t, \epsilon_{t+1}) \quad (4.12)$$

where s_t is the state vector and x_t the vector of current endogenous variables. The challenge in solving this model is to find a suitable approximant for the expectation function:

$$E_t h(s_{t+1}, x_{t+1}) = \phi(s_t) \quad (4.13)$$

Once such an approximation is found, the model can be solved and simulated straightforwardly using standard techniques. Specifically, in the case of our model:

$$s_t = \{w_{t-1}, D_{t-1}, y_t^T, R_t\}$$

$$x_t = \{w_t, h_t, c_t^T, D_t, p_t^N, \lambda_t, (V_t, B_t)\}$$

$$h_t = \{\lambda_{t+1}, (\theta_{t+1} V_{t+1}), (\theta_{t+1}, B_{t+1})\}$$

The variables V and B only appear in the version with Calvo wage setting.

In our solution method, we approximate $\phi(s_t)$ by a flexible functional form, specifically a piecewise linear function. This type of function has been found to be useful for models with occasionally binding constraints (see, for example, Judd (1998) and Miranda and Fackler (2002)). We compute the nodes as follows: for each W_t and D_t we use 40 evenly spaced points. For the two exogenous state variables, which are basically loglinear, we only need to use 3 evenly spaced points. This gives us a total of 14400 collocation nodes. We then iterate on the parameters of the approximating function until the model "fits" exactly at the collocation nodes. In solving the model, we use Gaussian quadrature to compute expectations of future variables.

To deal with the occasionally binding borrowing constraint we follow one approach examined by Christiano and Fisher (2000). This involves iterating on the values of the Kuhn-Tucker multipliers at each collocation node, μ_t , until slackness condition is satisfied at each of the nodes. We follow the same procedure to deal with the Schmitt-Grohe and Uribe (2011b) form of DNWR. For the Calvo version of DNWR, we set the Calvo coefficient to zero for nodes where DNWR does not apply, otherwise we set it to a value of 0.75 (or 0.9).

To simulate the model, we draw 100000 replications from the distribution of the two stochastic shock variables in (4.10). We then feed these shocks into our solution function to derive paths for the endogenous variables.

4.7 Results

Before presenting more detailed results from the alternative models, it is illustrative to look at the implications of different forms of DNWR on the behaviour of wages obtained from the stochastic simulation of the model. Specifically, we present histograms of aggregate nominal wage changes for three variants of our model: symmetrically flexible wages, the SGU wage setting and the asymmetric Calvo scheme with a coefficient of 0.75. The results are presented in Figure 4.1.

The first panel shows the distribution of wage change with flexible wages. Not surprisingly, this is symmetric with wage cuts being as frequent as wage increases. It is notable that, as will be discussed below, that the volatility of wage changes is rather high.

The second panel shows the distribution under SGU wage setting (recall that wages cannot fall by more than 1% per quarter). This leads to a very different distribution of wages. We do not observe wage cuts greater than 1% and there is a very large mass of wage changes in the vicinity of the constraint: almost half the wage changes are at the level of a cut of 1%.

The distribution under the Calvo scheme also differs from the flexible case but less dramatically than in the previous case. We observe a significant frequency of wage cuts greater than 1%. However, in the Calvo case wage cuts are less frequent than in the flexible case and we rarely observe a cut in wages greater than 10% in sharp contrast to the flexible case.

To summarise the main finding, the Calvo scheme allows for more frequent and larger wage cuts than SGU wage setting. However, compared to flexible case, large wage cuts are much less common. Overall, this suggests that in the Calvo scheme, wages are less inflexible downwards than with SGU wage setting. As we shall see below, this has important implications for the behaviour of the economy under an exchange rate peg, particularly for the behaviour of the unemployment rate.

4.7.1 Impulse response functions

To illustrate the impact of alternative wage setting arrangements on the properties of the model, we first present impulse response functions. Specifically, we consider a negative shock to the innovation in the traded output equation in the VAR for the exogenous variables. To adequately illustrate the nonlinearity of the model we need to choose a large shock. Specifically, the shock has been calibrated to deliver a 10% decline in traded output on impact. Given the correlation between the shocks in the two VAR equations, this shock also implies a small rise in the interest rate (peaking at about 25 basis points). We consider three variants of the model: symmetrically flexible nominal wages, the SGU wage setting scheme and the version with asymmetric Calvo wage setting with a Calvo parameter of 0.75. The shock is sufficiently large to trigger DNWR in both of these cases.

Given the highly non-linear nature of the model, impulse response functions depend not just on the size of the shock but also on the state of the economy. Since our purpose here is mainly illustrative, we compute impulse responses at one representative state, namely the stochastic mean of the state vector in the Calvo case. The

results of the exercise are reported in Figure 4.2.

In the flexible wage case (shown in the dotted red line), the shock leads to an immediate decline in nominal wages of around 14%. Unemployment remains unchanged since the labour market clears continuously. In line with standard SOE models, traded consumption falls by about 6 % on impact, less than the decline in traded output due to consumption smoothing on the part of agents. Reflecting this smoothing behaviour, foreign debt rises before gradually returning to base.

In the case of SGU wage setting, the responses to this adverse shock are quite different. The decline in wages is much more muted initially, since wages are not able to adjust fully to the shock. The difference between the decline in wages under SGU wage setting (solid blue line) and under the Calvo scheme (dashed green line) is also striking. Since wages cannot fall by more than 1% per quarter under SGU wage setting (solid blue line) the decline in wages is very muted compared to the Calvo case. The stickiness of wages in response to the negative shock implies an increase in unemployment which rises by over 4 percentage points on impact. Under Calvo wage setting unemployment returns to base whereas the slow adjustment in wages in the SGU case implies high and protracted level of unemployment. Indeed, in this latter case it takes nearly 80 quarters before unemployment returns to base. Under both variants of DNWR, the adverse shock implies a much smaller fall in the price of nontraded goods (not shown⁴⁹). Hence the “rebalancing” of the economy between traded and nontraded consumption is less rapid than under flexible wages. In consequence, there is a larger rise in foreign debt in both cases of DNWR, with rise in being more marked in the case of SGU wage setting.

4.7.2 Stochastic simulations

While the impulse response functions provide useful insights into the implications of different schemes of wage setting on the properties of the model, the overall

⁴⁹Further details are available on request.

importance (in terms of effects on the means and volatilities of the macroeconomic variables) can only be assessed by stochastic simulation the model. For this purpose, as mentioned in Section 4.6, we simulate the model using 100000 replications and compute the relevant statistics for key model variables in the various versions of the model. The results of this exercise are presented in Table 4.2.

Looking first at the flexible wage case, the unemployment rate is always zero since the labour market clears continuously: thus the mean and standard deviation of this variables is zero. The assumption of inelastic labour supply together with the calibrated shock volatilities result in the nominal wages being highly volatile in this case. The standard deviation of the log wages being is 0.24 while quarterly wage *growth* has a standard deviation of 0.14. Both traded consumption and foreign debt are also highly volatile.

Using SGU wage setting, in contrast, we find a mean unemployment rate of 13 percent, thereby replicating the key finding of Schmitt-Grohe and Uribe (2011b) that under a peg, DNWR leads to a very substantial level of unemployment. Moreover, the unemployment rate is also highly volatile, with a standard deviation of 0.18. Since DNWR mutes the downward adjustment of wages to shocks, it is not surprising that wages and wage growth are less volatile: the standard deviation of wage growth is now 2% as against 14% in the flexible case. The mean level of debt is lower than under flexible wages. This reflects the need for increased precautionary behaviour by households faced with a more volatile debt in the face of an occasionally binding constraint on foreign debt.

As shown in the previous section, the Calvo version of DNWR allows for greater adjustment of nominal wages in response to negative shocks than the SGU model. Thus it is not surprising that the results for the Calvo scheme, with a Calvo coefficient of 0.75, lie between the flexible case and SGU wage setting. The average unemployment rate, at 7.8%, is almost half the level under SGU wage setting. Though still high, this key result highlights the sensitivity of the conclusions of the effects of pegs on unemployment on the assumptions regarding the nature of DNWR.

Setting the Calvo coefficient to 0.9, implying less downward nominal wage flexibility, results in a higher average unemployment rate of 10.3 per cent (see Table 4.3) and moves the results closer to the SGU case. This is not surprising. As shown by Fagan (2013), the Calvo scheme collapses to a binding constraint on wage cuts when this coefficient tends to unity.

4.7.3 Comparisons with data across counties

Schmitt-Grohe and Uribe (2011b) calibrate the stochastic processes in the model (traded output and the interest rate) to match data for Argentina. However, they do not systematically report statistics regarding how well the moments for a range of macroeconomic variables match the respective data moments. We briefly address this issue in this subsection. Specifically, we focus on labour market variables and ask how do the predictions of the various versions of the model regarding wage growth and unemployment rates compare with the data from a range of countries. Since average wage growth and the average unemployment rate depend on a range of factors beyond the scope of this paper (such as labour market distortions or the inflation targets of central banks) we focus on the volatility of two key labour market variables: nominal wage growth and the unemployment rate.

Comparable measures of wages across countries are difficult to obtain. However, the Bureau of Labor Statistics (BLS) in the US has expended a considerable effort to produce a consistent and comparable dataset on hourly wage rates (and other labour cost variables) across countries. The BLS provides annual data on hourly wage rates in 34 countries covering the period 1996 to 2012.⁵⁰ While comparability problems also exist for unemployment rate data, these problems mainly relate to the level of the unemployment rate rather than its volatility. For the unemployment rate, therefore, we use data from the IMF World Economic Outlook database (version

⁵⁰The data may be obtained at www.bls.gov/fls/ichccaesuppall.xls. Our wage rate variable refers to the average hourly direct pay in national currency in the manufacturing sector. It thus excludes nonwage costs such as social insurance charges and other labour related taxes. See www.bls.gov/fls/ichcctn.pdf for more details of the definition of the hourly wage variable.

October 2013) covering the same countries and time period. Of the 34 countries we examine, the “coarse” classification of Iztzki et al. (2010) indicates that 12 of these countries⁵¹ pursued a pegged exchange rate regime during the period, where the definition of a peg ranges from having no separate legal tender to having a de facto peg. For completeness, however, we will present data for all 34 countries.

Since the data we are using is annual while our model is quarterly, we convert the simulated model variables to annual data by taking four period non-overlapping averages.

In this exercise, we consider four variants of the model. The first variant is the case of an exchange rate peg with flexible wages (denoted “No DNWR”). The second variant relates to a floating regime in which the policymaker adjusts the exchange rate to neutralise the effect of DNWR while at the same time minimising the volatility of the exchange rate (denoted “Opt. XR”)⁵². This policy is denoted by Schmitt-Grohe and Uribe (2011b) as an “optimal exchange rate policy”. With this policy, the real allocation is identical to the flexible wage allocation under a peg and is thus Pareto optimal, but nominal variables will in general be different. The third variant is a peg with SGU wage setting, denoted “SGU Peg”. Finally, the fourth variant is a peg with asymmetric Calvo wage setting with a Calvo coefficient of 0.75 (denoted “Calvo Peg”). The results are presented in Table 4.3 and Figures 4.3 and 4.4. Table 4.3 presents three statistics: the standard deviation of wage growth; the mean unemployment rate and the standard deviation of the unemployment rate. In addition to our four variants, we also consider two further variants: a Calvo scheme with a higher Calvo coefficient (0.9) and a variant with lower shock volatility (discussed further below).

⁵¹Austria, Belgium, Denmark, Estonia, Finland, France, Greece, Ireland, Italy, Netherlands, Portugal and Spain.

⁵²Specifically, this policy involves setting the exchange rate each period such that $X_t = \text{Max} \left\{ 1, \gamma \frac{W_{t+1}}{\omega_t} \right\}$, where ω_t is the real wage consistent with full employment. Thus when DNWR threatens to bind, the authorities will devalue the exchange rate. Otherwise, they will keep the exchange rate at its long-term target level of unity. Schmitt-Grohe and Uribe (2011b) show that there is a family of exchange rate policies which will yield a Pareto optimal outcome: all that is required is that the exchange rate is adjusted sufficiently so that DNWR never binds.

Looking first at wage growth in Figure 4.3, it is evident that the the volatility of the data is typically well below what is implied by most variants of the model. The best match is with variant of the peg with SGU, where the volatility of wage growth exceeds the model prediction in only 3 countries (Argentina, Estonia and Ireland). In all other cases, this variant leads to a much higher volatility of wages than is found in the data. The variant with optimal exchange rate policy comes close to what is found in the case of Argentinean data but is well above what is found in other countries. The remaining variants - a peg with flexible wages and the peg with Calvo wage setting - yields predictions for wage volatility which are well above what is seen in the data for all countries, regardless of their exchange regime.

In the case of unemployment (Figure 4.4), the differences between the data and the predictions of model are even more marked. Both the flexible wage peg and the peg with optimal exchange rate policy imply zero standard deviations (since the labour market always clears). This is clearly at variance with the data. The variant with SGU wage-setting generates a standard deviation of unemployment which 3 times larger than in the country with the highest volatility (Greece). In the case of the Calvo wage-setting, the differences with the data are less marked. Still, the model implied standard deviation is larger than in the data for all of the countries examined.

These results suggest that the shock volatilities used by Schmitt-Grohe and Uribe (2011b), although matching the data on traded output and interest rates in Argentina, have been calibrated at too high a level. This is not innocuous. Higher shock volatilities imply that the wage cuts (and increases) needed to clear the labour market will typically be larger than otherwise. In this sense, DNWR (whether SGU or Calvo) will be more constraining and have larger effects on unemployment. By lowering the volatility of shocks, therefore, we expect to see a lower mean unemployment rate. To explore this issue further we look at a final variant of the model. We consider the case of Calvo wage-setting with a Calvo coefficient of 0.75 but with the standard deviation of both shocks reduced by 50%. As shown in Table 4.3, this

leads to a reduction of one-third in the volatilities of both wage growth and the unemployment rate, bringing them closer to the data. With this lower volatility calibration, the mean unemployment rate under a peg falls further, to 5.3%.

4.8 Conclusions

In this paper, we revisited the analysis of Schmitt-Grohe and Uribe (2011b) regarding the effects of DNWR on the unemployment rate in countries pursuing an exchange rate peg. We argued that the form of DNWR employed in that paper was problematic, since it is inconsistent with the micro data on wage changes. Replacing their version of DNWR with an asymmetric Calvo scheme consistent with the micro data leads to a reduction in the mean unemployment rate, from 13% to 8%. We also found that the calibration of volatilities used by Schmitt-Grohe and Uribe 2011b yields predictions for wage and unemployment volatilities which are too high relative to the data for 34 countries. Both of these findings suggest that the original paper exaggerates the costs of exchange rate pegs. Despite this, allowing for lower volatility and a more data-consistent form of DNWR results in an unemployment rate which is still very high. Thus the qualitative conclusions of Schmitt-Grohe and Uribe (2011b) remain intact, underpinning their arguments on the need for countries operating under exchange rate pegs to adopt appropriate policy measures to mitigate the impact of DNWR on unemployment.

From a methodological point of view, our paper has shown that it is possible to incorporate a data-consistent form of DNWR into general equilibrium models.

Table 4.1: Calibration of Parameters

Name	Value	Description	Source
β	0.957	Discount factor	match Lane-MF D/Y = 0.26
a	0.26	Share of traded goods in utility function	SGU
ξ	0.44	Substitution elasticity (T/NT)	SGU
α	0.75	Production function exponent	SGU
σ	5	Intertemporal elasticity of subs	SGU
θ	0.75 or 0.9	Calvo coefficient	Fagan (2012) SW and EHL
\bar{H}	1	Labour supply	SGU

Table 4.2: Model Moments under a Peg with Different Wage setting Arrangements (quarterly)

	Mean			Standard Deviation		
	Flexible	SGU	Calvo(0.75)	Flexible	SGU	Calvo(0.75)
Wage	0.240	0.750	0.525	0.435	0.244	0.345
Employment	-0.000	-0.131	-0.078	0.000	0.180	0.095
Traded Consumption	-0.228	-0.197	-0.209	0.191	0.169	0.179
Debt	5.118	4.272	4.648	0.641	0.844	0.590
Nontraded Price	0.527	0.982	0.781	0.435	0.253	0.351
Nontraded Output	-0.000	-0.098	-0.059	0.000	0.135	0.071
ΔWage	0.000	0.000	0.000	0.141	0.021	0.049

Note: all variables except Debt are in logs.

Table 4.3: Moments of Wage Growth and Unemployment under Different Model Variants (annual)

	Wage Growth		Unemployment Rate	
	Std. Dev.	Mean	Std. Dev.	Mean
Peg - Flexible Wages	0.224	-0.000	0.000	0.000
Optimal Exchange Rate Policy	0.082	-0.000	0.000	0.000
Peg - SGU	0.089	0.131	0.162	0.162
Peg - Calvo(0.9)	0.104	0.103	0.117	0.117
Peg - Calvo(0.75)	0.150	0.078	0.077	0.077
Peg - Calvo 0.75, lower volatility	0.079	0.053	0.055	0.055

SGU and Calvo refer to SGU and Calvo wage setting, respectively, the latter with coefficients of 0.75 or 0.9. Calvo 0.75, lower volatility refers to Calvo wage setting with a coefficient of 0.75 and with the volatility of the shocks reduced by 50 percent relative to baseline.

Figure 4.1: Distribution Wage Changes with Alternative Wage Setting

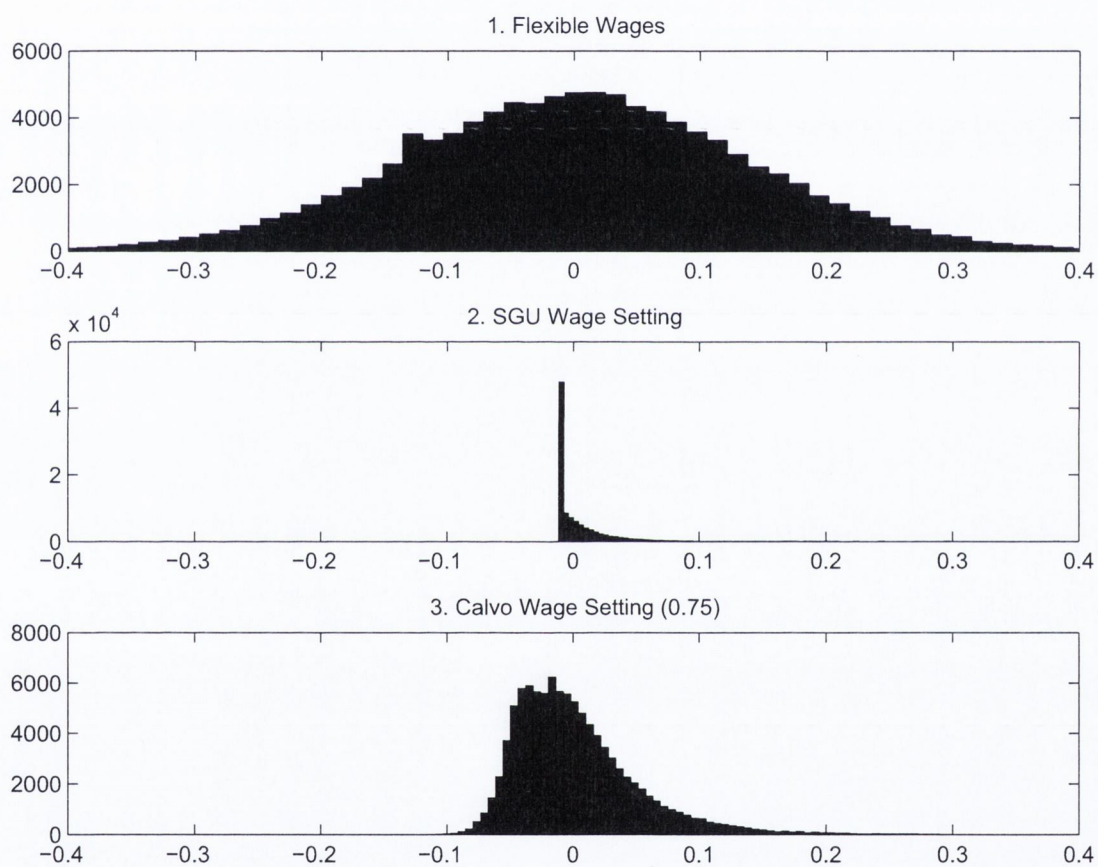
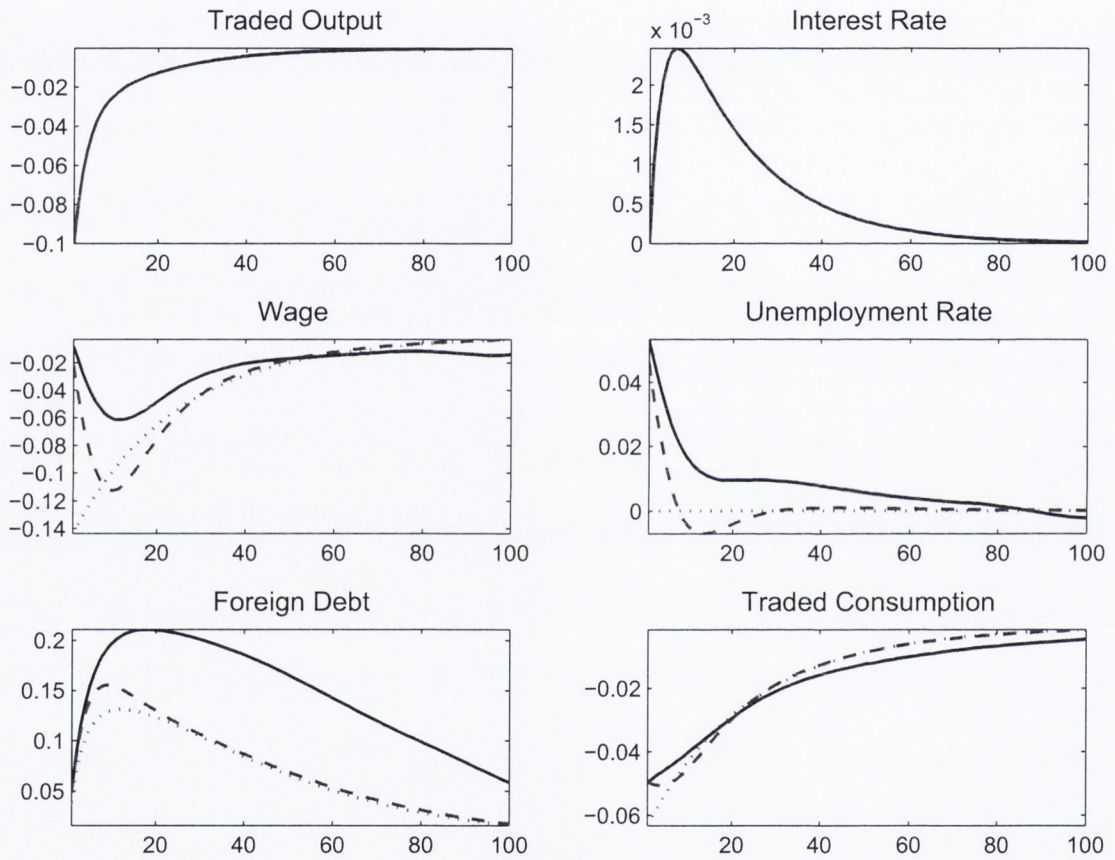


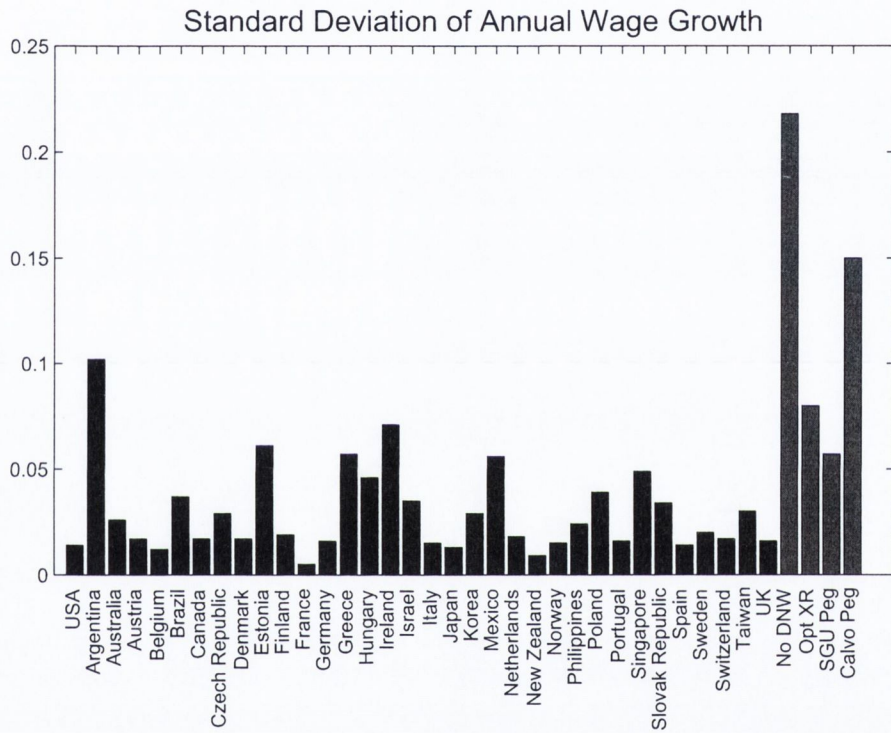
Figure 4.2: Impulse Response Functions



Note: These charts show the impulse responses to a 10 percent fall in traded output under a peg.

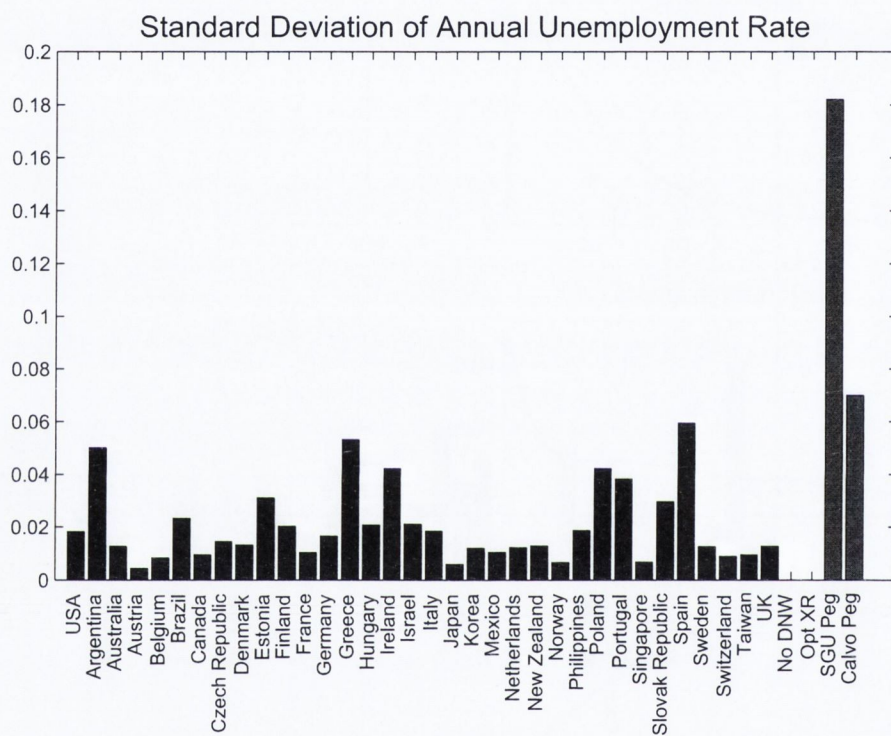
The solid (blue) line shows the response under SGU wage setting, the dotted (red) line the responses under flexible wages and the dashed (green) line the response under Calvo wage setting with a coefficient of 0.75.

Figure 4.3: Data vs. Model: Volatility of Nominal Wage Growth



Note: Blue bars refer to data for the respective country. Source: Bureau of Labor Statistics. Red bars refer to model variants. SGU and Calvo refer to a peg with SGU and Calvo wage setting, respectively. Opt XR refers to optimal exchange rate policy while No DNW refers to a peg with flexible wages.

Figure 4.4: Data vs. Model: Volatility of Unemployment Rate



Note: Blue bars refer to data for the respective country. Source: IMF WEO Database. Red bars refer to model variants. SGU and Calvo refer to a peg with SGU and Calvo wage setting, respectively. Opt XR refers to optimal exchange rate policy while No DNW refers to a peg with flexible wages.

Chapter 5

Conclusions

The three chapters in this thesis addressed three questions. First, looking at micro data on wage changes, is there evidence for DNWR and, if so, what model best fits the data? Second, how does the presence of central bank financing, and the resulting TARGET balances, affect the adjustment of stressed euro area countries to sudden stops in capital flows. Third, what is the impact of including a data-consistent modelling of DNWR on unemployment in an exchange rate peg.

In relation to the first question, the main conclusions are as follows. First, micro data on wage changes in four countries (US, Germany, Belgium and Portugal) do provide strong evidence of DNWR. Second, however, there are notable differences across countries, with wages being symmetrically flexible in Germany and Belgium whereas DNWR is clearly indicated in the case of the US. In terms of modelling DNWR, the data strongly rejects some schemes which have been put forward in the literature such as strictly binding constraints on wage cuts or asymmetric but continuous wage adjustment cost functions. Instead, an asymmetric Calvo scheme is preferred by the data. In this setup, wages are flexible upwards but only a fraction of wage cuts can be implemented in any period.

As regards the second question four main conclusions were derived. First, the evidence provides support for the idea that a number of stressed euro area countries

(Greece, Spain, Ireland, Italy and Portugal) experienced sudden stops in private capital flows and the behaviour of key macroeconomic aggregates is consistent with previous sudden stop episodes. Second, provision of liquidity by the Eurosystem, and the resulting TARGET balances, in part compensated for the reversal of private capital flows. Third, model based analysis suggests that the TARGET system reduces significantly the effects of private capital outflows on domestic demand, output and the current account balance. Finally, despite this, the gains in welfare from introducing a TARGET system are small, since reduced precautionary saving leads to a higher incidence of sudden stops.

On the third question, we found that way in which DNWR is modelled has important implications for the level of unemployment under a fixed exchange rate regime. Using a form of DNWR which is consistent with the micro data implies a significantly lower level of unemployment than has been found in the earlier literature, which used binding downward constraints on wage cuts. Nonetheless, even allowing for this, we find that the level of unemployment is still substantial.

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