Financial Crises and Exchange Rate Policy

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Abstract

This paper develops a dynamic small open economy model highlighting a trade-off between financial and price stability. The key element of the analysis is a pecuniary externality arising from frictions in the international credit markets. The goal is to study the performance of alternative exchange rate policies in sudden stop-prone economies. The main result is that the presence of pecuniary externalities in the credit markets makes a narrow focus on price stability sub-optimal.

Keywords: Financial crises, Monetary Policy, Sudden Stops, Exchange Rate Regime, Nominal Wage Rigidities, Pecuniary Externalities.
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1 Introduction

Since the financial liberalization wave of the 1980s, several countries have experienced financial crises characterized by sudden arrests of international capital inflows and sharp drops in output, consumption and asset prices.[1] These episodes, known as sudden stops, have sparked great interest in the design of monetary and exchange rate policies in financially fragile economies. Should these economies let their exchange rate float or rather anchor it to a foreign currency? Should monetary policy be concerned only with its traditional objective of granting price stability or should it also care about financial stability?

In this paper, I address these questions focusing on a pecuniary externality originating from frictions on the international credit markets. I present a theoretical framework that shows how the combination of financial frictions and nominal rigidities gives rise to a trade-off between financial and price stability. My main result is that a narrow focus on price stability can lead to a sub-optimal monetary policy in sudden stop-prone economies.

I study a small open economy with imperfect access to the international financial markets. Domestic agents borrow from foreign investors against collateral. Collateral consists in a physical asset used in production, land, valued at market price. When the collateral constraint binds a financial accelerator mechanism akin to Fisher's debt deflation arises: aggregate demand for land falls, the price of land drops and collateral declines. Since domestic agents are atomistic, they do not take into account the general equilibrium effect of their actions on the price of land and on the value of their collateral. This is the pecuniary externality that creates scope for policy interventions in the financial markets.

Wages are nominally rigid.[2] During a financial crisis nominal wages fail to adjust

[1]Diaz-Alejandro (1985) is the classic reference on the link between financial liberalization and financial crises in emerging economies. Calvo et al. (2004) provide an overview of the facts characterizing sudden stop events.

[2]A growing body of evidence emphasizes how nominal wage rigidities represent a key transmission channel through which monetary policy affects the real economy. For instance, this conclusion is reached by Christiano et al. (2005) using an estimated medium-scale DSGE model of the US economy. Moreover, Olivei and Tenreyro (2007) show that monetary policy shocks in the US have a bigger impact on output if they occur during the first or second quarter of the year. They argue that this finding can be explained with the fact that most US firms adjust wages during the fourth quarter, and hence wages tend to be more rigid during the first half of the year. There is also evidence describing the role of nominal wage rigidities in exacerbating the downturn during financial crises, especially if coupled with fixed exchange rates. This point is made by Eichengreen and Sachs (1985) and Bernanke and Carey (1996) in the context of the Great Depression, while Schmitt-Grohé and Uribe (2011) document the importance of wage rigidities for the 2001 Argentine crisis and for the 2008-2009 recession in the Eurozone periphery. Micro-level evidence on the importance of nominal wage rigidities is provided by Fehr and Goette (2005),

downward, potentially worsening the impact of financial turmoil on the real economy. The central bank can mitigate the downturn associated with a financial crisis by engineering an exchange rate depreciation that increases the competitiveness of the economy. Importantly, the stimulus provided by an exchange rate depreciation has a positive effect on the aggregate demand for land and on the value of collateral. Through this channel, exchange rate policy affects domestic agents' access to the international credit markets during crisis events.

Many narratives of financial crisis episodes have given a central role to the interaction between capital flows, asset prices and wage rigidities. Consider the recent events in the Eurozone periphery. Prior to 2008, several European countries underwent a period characterized by fast build-up of foreign debt. Rising real estate prices likely contributed to the credit boom, since housing represents an important source of collateral. Conversely, the crisis that followed has been characterized by a vicious cycle of falling capital inflows and plummeting asset prices.[3] In addition, many commentators have argued that the combination of rigidities in wage setting and fixed exchange rates has exacerbated the severity of the crisis.[4] This is the kind of episodes that the model is meant to capture.

I use the model to compare the performance of three alternative monetary rules: a fixed exchange rate rule and two types of floating exchange rate regimes. The first type of float considered is a policy of strict wage inflation targeting. This rule eliminates all the distortions arising from nominal wage stickiness and corresponds to the price stability rule of closed-economy sticky price models. The second type of float is a policy of flexible exchange rate targeting in which the central bank intervenes to smooth out deviations of the exchange rate from a target. This rule parallels flexible price level targeting rules in closed-economy models and represents a simple alternative to wage inflation targeting. In addition, this rule is interesting because it implies a more expansionary monetary policy stance during crisis events compared to the strict wage inflation targeting rule.

The main result of the paper concerns the role of financial frictions in determining the welfare ranking between strict wage inflation targeting and the flexible exchange rate targeting rule. I show that in a version of the model in which the collateral constraint is

Gottschalk (2005), Barattieri et al. (2010) and Fabiani et al. (2010).

[3]McKinsey (2010) and Merler and Pisani-Ferry (2012) describe the accumulation of debt, especially foreign debt, in countries at the Eurozone periphery during the run up to the 2008 financial crisis and the subsequent sudden stop in capital inflows, giving rise to deleveraging by the private sector.

[4]This point is forcefully made by Feldstein (2010) and Krugman (2010).

replaced by a fixed borrowing limit, and hence in which Fisher's debt deflation channel is shut down and financial crises are not present, the strict wage inflation targeting rule delivers higher welfare gains than the flexible exchange rate targeting rule for any initial state of the world. This finding is in line with the well known result that, in models in which the only distortions come from monopolistic competition and from nominal rigidities, a policy that corrects for nominal rigidities approximates well the optimal policy.[5]

I then show that the pecuniary externality implied by the Fisherian deflation mechanism has the potential to change the welfare ranking among the policy rules considered. In fact, once the Fisherian deflation mechanism is introduced the initial stock of foreign assets owned by domestic households becomes a key determinant of the welfare ranking. For high levels of net foreign assets the probability of a future crisis is small and a policy of targeting wage inflation is preferred, due to its good performance in managing normal business cycle fluctuations. For low levels of net foreign assets the risk of a crisis is high and flexible exchange rate targeting becomes the preferred regime, since it does a better job in mitigating the fall in the price of land and in capital inflows during crisis events compared to the wage inflation targeting rule. In contrast, the peg is always welfare dominated by the other two rules. This happens because during tranquil times the peg does not remove the distortions due to wage stickiness, while during crisis times pegging the exchange rate amplifies the fall in the price of land and in capital inflows compared to the other two regimes.

A second set of results concerns the impact of the monetary regime on precautionary savings and crisis probability. The currency peg is the regime that stimulates more the accumulation of precautionary savings, followed by the policy of targeting wage inflation and by the flexible exchange rate targeting rule. The intuition is simple: the more crises disrupt economic activity, the more agents accumulate precautionary savings to reduce the risk of experiencing a sudden stop. Since the peg is the regime under which crises have the strongest impact on output and consumption, the peg is also the regime under which the accumulation of precautionary savings is stronger. Moreover, since crises are milder when the central bank adopts a flexible exchange rate targeting rule, agents accumulate

[5] Kollmann (2002) and Schmitt-Grohé and Uribe (2007) derive this result using models with monopolistic competition in the product market and nominal price rigidities. However, a similar logic should apply to models with monopolistic competition in the labor market and in which the presence of sticky wages is the only source of nominal rigidities.

less precautionary savings under flexible exchange rate targeting than under a policy of strict wage inflation targeting. The outcome is that the currency peg is the regime featuring the lowest crisis probability, while the probability of experiencing a sudden stop is highest under a policy of flexible exchange rate targeting.

This paper is related to two strands of the literature. The first one focuses on the design of monetary policy in financially fragile small open economies. Cespedes et al. (2004), Moron and Winkelried (2005) and Devereux et al. (2006) compare the performance of different monetary regimes in small open economies featuring financial market imperfections. Contrary to this paper, their models focus on business cycle fluctuations and are not suited to study economies occasionally subject to financial crises. Christiano et al. (2004), Cook (2004), Gertler et al. (2007), Braggion et al. (2007) and Curdia (2007) all use quantitative models to analyze the impact of monetary policy interventions during crisis times. In their frameworks crises are unexpected one-shot events, while this paper presents a model in which crises alternate with tranquil times and crisis probabilities are rationally anticipated by agents. This allows the analysis of the impact of monetary policy on the probability of entering a crisis, an issue on which the existing literature is silent. Moreover, this literature typically finds that the presence of financial frictions does not alter the welfare ranking among monetary policy rules, while the key insight of this paper is that financial frictions are a key determinant of which policy rule delivers higher welfare. Aghion et al. (2004), Caballero and Krishnamurthy (2003), Bordo and Jeanne (2002) and Benigno et al. (2011b) consider monetary economies featuring both tranquil periods and crises. However their focus is on static models, while the dynamics of debt accumulation play a key role in the model presented in this paper.[6] Finally, this paper shares with Schmitt-Grohé and Uribe (2011) the focus on the performance of different exchange rate regimes in economies subject to the risk of experiencing a deep recession. However, in their model recessions are exogenous events and there is no financial amplification, while in this model the probability of entering a crisis is endogenous and the interaction between the exchange rate regime and Fisher's debt deflation is key.

The second strand of related literature employs dynamic real business cycle models featuring occasionally binding credit constraints and financial accelerator mechanisms to describe economies prone to sudden stops and to draw implications about policy conduct

[6] I refer to these frameworks as static because they consider economies that last two or three periods, in which the stock of external debt at the onset of a crisis is essentially taken as an exogenous variable.

in small open economies. Examples are Mendoza (2010), Bianchi (2011), Benigno et al. (2011a), Jeanne and Korinek (2010) and Bianchi and Mendoza (2010). The novelty of this paper with respect to this literature resides in the focus on monetary policy and on the interplay between Fisher's debt deflation and nominal wage rigidities.

The rest of the paper is structured as follows. Section 2 describes the analytical framework. Section 3 presents the results using numerical simulations. Section 4 concludes.

2 Model

Consider an infinite-horizon small open economy. Time is discrete and indexed by t. The economy is populated by a continuum of mass 1 of households that consume a single tradable good and engage in financial transactions with foreign investors. There is also a large number of competitive firms that produce the consumption good using factors of production supplied by the households and a central bank that uses the interest rate on domestic bonds as its policy instrument.

2.1 Firms and production

Firms are owned by the households. They are competitive, take all prices as given and produce the tradable consumption good according to the production function

$$Y_t = z_t F(L_t, M_t, K_t), \tag{1}$$

where Y_t denotes output, $F(\cdot)$ is a decreasing-returns-to-scale production function and z_t is a total factor productivity (TFP) shock.[7] The productivity shock follows a finite-state, stationary Markov process and represents the only source of uncertainty in the model. Firms produce using labor L_t, an intermediate input M_t and land K_t. All the factors of production are purchased or rented from domestic households.

As in Obstfeld and Rogoff (2000), each household supplies a differentiated labor input. L_t is a CES aggregate of the differentiated labor services

$$L_t = \left[\int_0^1 L_t^{i\frac{\sigma-1}{\sigma}} di \right]^{\frac{\sigma}{\sigma-1}},$$

[7]Decreasing returns to scale in production can derive from the assumption that production also requires the input of managerial capital, of which each firm has a fixed supply normalized to 1.

where L_t^i denotes the labor input purchased from household i and $\sigma > 1$.

Purchasing power parity holds so $P_t = S_t P_t^*$. P_t and P_t^* are respectively the domestic and foreign currency price of the consumption good. S_t denotes the nominal exchange rate, defined as the units of domestic currency needed to buy one unit of the foreign currency. For simplicity, I assume that P_t^* is constant and normalize it to 1. Hence, the domestic currency price of the consumption good is equal to the nominal exchange rate $P_t = S_t$.

In every period, the representative firm maximizes profits

$$\Pi_t = S_t Y_t - \int_0^1 W_t^i L_t^i di - R_t^M M_t - R_t^K K_t, \tag{2}$$

where W_t^i is the wage rate of household i, R_t^M is the price of the intermediate input and R_t^K is the rental rate of land, all expressed in units of the domestic currency.

The minimum cost of a unit of aggregate labor L_t is given by

$$W_t = \left[\int_0^1 W_t^{i1-\sigma} di \right]^{\frac{1}{1-\sigma}},$$

which can be taken as the aggregate wage. Using this definition, profit maximization implies equality between factor prices and marginal productivities:

$$W_t = S_t z_t F_L(L_t, M_t, K_t) \tag{3}$$

$$R_t^M = S_t z_t F_M(L_t, M_t, K_t) \tag{4}$$

$$R_t^K = S_t z_t F_K(L_t, M_t, K_t), \tag{5}$$

where F_L, F_M and F_K are the derivatives of the production function respectively in L_t, M_t and K_t. Finally, cost minimization gives the demand for household's i labor

$$L_t^i = \left(\frac{W_t}{W_t^i} \right)^{\sigma} L_t. \tag{6}$$

2.2 Households

Households are the main actors in the economy. Each household derives utility from consumption C_t^i and experiences disutility from labor effort L_t^i. The lifetime utility of a generic household i is given by

$$E_0\left[\sum_{t=0}^{\infty}\beta^t U\left(C_t^i, L_t^i\right)\right]. \tag{7}$$

In this expression, $E_t[\cdot]$ is the expectation operator conditional on information available at time t and β is the subjective discount factor. The period utility function $U(\cdot)$ is assumed to be increasing in the first argument, decreasing in the second argument, strictly concave and twice continuously differentiable.

Each household can trade in one period, non-state contingent foreign and domestic bonds. The foreign bond is traded with foreign investors, it is denominated in units of the foreign currency and pays a fixed gross interest rate R^*, determined exogenously in the world market. The domestic bond is denominated in units of the domestic currency, pays the gross interest rate R_t and is traded only among domestic agents.[8] Moreover, households can purchase and sell units of land.

The budget constraint of household i in terms of the domestic currency can be written as

$$\begin{aligned} S_t C_t^i + S_t B_{t+1}^{*i} + B_{t+1}^i + Q_t(K_{t+1}^i - K_t^i) =& W_t^i L_t^i + R_t^K K_t^i + S_t R^* B_t^{*i} + R_{t-1} B_t^i + \\ & \Pi_t + \left(R_t^M - S_t P^M\right) M_t^i. \end{aligned} \tag{8}$$

The left-hand side of this expression represents the household's expenditure. This is given by the sum of consumption expenditure $S_t C_t^i$, investment in foreign bonds $S_t B_{t+1}^{*i}$, investment in domestic bonds B_{t+1}^i and net purchases of land $Q_t(K_{t+1}^i - K_t^i)$. Q_t is the price of land at time t in units of the domestic currency, while K_t^i denotes the household's holdings of land at the beginning of period t.

The right-hand side captures the household's income. $W_t^i L_t^i$ is the household's labor income, $R_t^K K_t^i$ is the income derived from renting land to firms, while $S_t R^* B_t^{*i}$ and $R_{t-1} B_t^i$ denote respectively the gross return on investment in foreign and domestic bonds made at time $t-1$. Π_t are the profits received from firms. Finally, the household imports from foreigners the intermediate input M_t^i and sells it to domestic firms. The world price of the intermediate input expressed in the foreign currency is constant and denoted by P^M.

[8] This assumption is meant to capture the fact that in small open economies loans from foreign investors are most often denominated in a foreign currency.

Hence, $R_t^M - S_t P^M$ is the return in units of the domestic currency that the household receives from purchasing one unit of the imported input from foreign producers and selling it to domestic firms.

A fraction ϕ of the intermediate input has to be paid at the start of the period and requires working capital financing. To finance the purchase of the imported input the household obtains a working capital loan from foreign investors at the start of the period and repays it at the end of the same period. I assume that the interest rate on these intra-period loans is zero.[9]

Foreign investors restrict loans so that total foreign debt, including both inter-temporal debt in one-period bonds and intra-period loans, does not exceed a fraction κ of the foreign currency value of the household's end of period land holdings

$$\phi P^M M_t^i - B_{t+1}^{*i} \leq \kappa \frac{Q_t}{S_t} K_{t+1}^i. \tag{9}$$

This constraint ensures that the loan-to-value ratio of domestic households does not exceed the limit κ.[10] This international collateral constraint is meant to capture in reduced form an environment in which informational and institutional frictions affect the credit relationship between domestic and foreign agents. A constraint of this form arises if land can be used as collateral to mitigate the frictions on the international credit markets. Domestic bonds are not subject to the collateral constraint since they are not traded by foreign investors.[11]

I introduce nominal rigidities by assuming that each household has to set its nominal wage W_t^i at the very start of the period, before the realization of the productivity shock z_t is known.[12] Each household acts as a monopolistic supplier of its labor input and sets its wage to maximize the expected present discounted value of utility (7), subject to the

[9]One could assume that intra-period loans pay an interest rate equal to R^*. This alternative formulation would not change in any way the key results of the paper.

[10]Similar collateral constraints are widely used in the literature on sudden stops. Mendoza (2010) shows that models featuring this form of financing constraints can reproduce quantitatively well both business cycles and sudden stop episodes in emerging economies.

[11]The implications of segmented international and domestic financial markets is also explored, for example, in Caballero and Krishnamurthy (2001). For simplicity, here I abstract from frictions in the domestic credit market.

[12]The assumption that wages are set at the start of the period, rather than one period in advance, reduces significantly the computational costs involved by the global solution method used to solve the model numerically.

budget constraint (8) and firms' demand for its labor (6). The optimal wage satisfies

$$-E_{t-1}\left[U_L(C_t^i, L_t^i)L_t^i\right] = \frac{\sigma - 1}{\sigma} W_t^i E_{t-1}\left[\frac{U_C(C_t^i, L_t^i)}{S_t} L_t^i\right], \tag{10}$$

where $U_C(\cdot)$ and $U_L(\cdot)$ denote the derivative of the period utility function with respect to consumption and labor. At the margin, the expected disutility from an increase in labor effort, the left-hand side, is equal to the expected utility from higher revenue, the right-hand side.

Once wages are set, households are willing to satisfy firms' labor demand as long as the real wage, that is the wage expressed in units of the foreign currency, does not fall below the marginal rate of substitution between consumption and leisure

$$\frac{W_t^i}{S_t} \geq -\frac{U_L(C_t^i, L_t^i)}{U_C(C_t^i, L_t^i)}. \tag{11}$$

Given the pre-set wage and the realization of the productivity shock, each period the household chooses C_t^i, B_{t+1}^{*i}, B_{t+1}^i, K_{t+1}^i and M_t^i to maximize the expected present discounted value of utility (7), subject to the budget constraint (8) and the collateral constraint (9).

The optimality condition for B_{t+1}^i can be written as

$$\frac{U_C(C_t^i, L_t^i)}{S_t} = \beta R_t E_t\left[\frac{U_C(C_{t+1}^i, L_{t+1}^i)}{S_{t+1}}\right]. \tag{12}$$

The optimal investment in domestic bonds is such that the marginal utility from spending one unit of domestic currency in period t consumption is equal to the expected marginal utility from investing one unit of domestic currency in domestic bonds and consuming the return in period $t+1$.

The optimal choice for B_{t+1}^{*i} is given by

$$U_C(C_t^i, L_t^i) = \beta R^* E_t\left[U_C(C_{t+1}^i, L_{t+1}^i)\right] + \mu_t^i, \tag{13}$$

where μ_t^i is the Lagrange multiplier on the collateral constraint, and by the complementary slackness condition

$$\mu_t^i\left(\kappa\frac{Q_t}{S_t}K_{t+1}^i - \phi P^M M_t^i + B_{t+1}^{*i}\right) = 0. \tag{14}$$

The left-hand side of expression (13) is the marginal utility from spending one unit of foreign currency in period t consumption. If the collateral constraint does not bind ($\mu_t^i = 0$) this is equated to the expected utility from investing one unit of foreign currency in foreign bonds and consuming the return in period $t+1$. When the collateral constraint binds ($\mu_t^i > 0$), B_{t+1}^{*i} is determined by the collateral that the household can offer to foreign investors, as stated by condition (14). In this case, the household is not free to borrow as much as it would like from foreign investors and the marginal utility of period t consumption is bigger than the expected marginal utility cost of borrowing on the international credit market.

Combining equations (12) and (13) gives

$$\beta R_t E_t \left[U_C(C_{t+1}^i, L_{t+1}^i) \frac{S_t}{S_{t+1}} \right] = \beta R^* E_t \left[U_C(C_{t+1}^i, L_{t+1}^i) \right] + \mu_t^i. \tag{15}$$

When the collateral constraint is not binding this equation is just the usual uncovered interest parity condition, which rules out arbitrage opportunities between domestic and foreign bonds. However, when $\mu_t^i > 0$ the uncovered interest parity condition breaks down and the expected return in terms of utility from investing in domestic bonds is greater than the expected utility from investing in foreign bonds. The presence of a spread between the cost of borrowing on the domestic market and the world interest rate in states in which the collateral constraint binds is due to the assumption that only foreign loans enter the collateral constraint.[13] Whether the spread materializes through an increase in the domestic interest rate, a movement of the exchange rate or a combination of both depends on the actions of the monetary authority.

The optimality condition for land K_{t+1}^i is

$$\frac{Q_t}{S_t} U_C(C_t^i, L_t^i) = \beta E_t \left[U_C(C_{t+1}^i, L_{t+1}^i) \frac{R_{t+1}^K + Q_{t+1}}{S_{t+1}} \right] + \frac{Q_t}{S_t} \kappa \mu_t^i. \tag{16}$$

The left-hand side is the marginal cost in terms of utility of an extra unit of land investment. The right-hand side captures the marginal benefit from increasing the household's land holdings. The first term is the marginal return in terms of utility of renting a unit of land to firms in period $t+1$ and selling it at the end of the period. The second term

[13] Intuitively, when the collateral constraint binds the household cannot borrow as much as it would like on the international credit market. This induces the household to stand ready to pay a higher rate on domestic loans, because they are not subject to the collateral constraint.

is the value that the household gets from relaxing the collateral constraint by increasing its stock of land.

The last first order condition gives the optimal choice of M_t^i:

$$R_t^M = S_t P^M \left(1 + \frac{\mu_t^i}{U_C\left(C_t^i, L_t^i\right)}\right). \tag{17}$$

When the collateral constraint does not bind the price at which the intermediate input is sold to domestic firms is equated to its world price expressed in units of the domestic currency. If the collateral constraint binds the amount of intermediate input that the household can import is limited by the value of its collateral. This shows up in the first order condition as an increase in the price of the imported input.[14]

2.3 Equilibrium

The solution is symmetric across households and in equilibrium individual and aggregate per capita variables are identical. For example aggregate consumption per capita C_t is given by

$$C_t = \int_0^1 C_t^i di = C_t^i, \tag{18}$$

where the last equality comes from the fact that each household makes the same choices in equilibrium. Similarly, in equilibrium the aggregate net foreign asset position of the economy B_t^* is such that

$$B_t^* = B_t^{*i}, \tag{19}$$

and the individual and aggregate wage coincide

$$W_t = W_t^i. \tag{20}$$

To derive the resource constraint of the economy, notice that since the domestic bond is traded only among domestic households its net supply must be equal to zero, i.e. equilibrium on the domestic bond market requires $B_t^i = 0$ for every t. The aggregate stock of land is assumed constant and equal to K, so that in equilibrium the households' net purchases of land must be zero. Using these equilibrium conditions, the expression for

[14] Through this channel an episode of binding collateral constraint is associated with disruptions in trade credit and inefficient use of imported inputs.

firms' profits (2) and the household's budget constraint (8) gives the aggregate resource constraint of the economy

$$C_t + B^*_{t+1} = Y_t - P^M M_t + R^* B^*_t. \tag{21}$$

This expression says that the aggregate expenditure of the economy, the sum of consumption plus investment in foreign bonds, must be equal to aggregate income, which is given by the sum of the gross domestic product $(Y_t - P^M M_t)$ plus the gross return on foreign bonds purchased during the previous period.

Finally, market clearing for the factors of production requires:

$$L_t = L^i_t \tag{22}$$

$$M_t = M^i_t \tag{23}$$

$$K_t = K^i_t = K. \tag{24}$$

We are now ready to define a rational expectations equilibrium as a set of stochastic processes $\left\{C^i_t, C_t, B^{*i}_{t+1}, B^*_{t+1}, L^i_t, L_t, M^i_t, M_t, K^i_{t+1}, K_{t+1}, Y_t, W^i_t, W_t, R^M_t, R^K_t, Q_t, \mu^i_t, S_t\right\}^\infty_{t=0}$ satisfying (1), (3)-(5), (10)-(14) and (16)-(24), given the exogenous process $\{z_t\}^\infty_{t=0}$, the central bank's policy $\{R_t\}^\infty_{t=0}$ and initial conditions B^*_0 and z_{-1}.[15]

2.4 Central bank and exchange rate policy

The central bank uses the interest rate on domestic loans as the monetary policy instrument. I focus the analysis on the case in which the central bank credibly commits to a policy rule at the start of period 0, before period 0 wages are set, and then sticks to that policy forever. The general form of the interest rate rule can be written as

$$R_t = R^* \left(\frac{W_t}{W_{t-1}}\right)^{\xi_W} \left(\frac{S_t}{\bar{S}}\right)^{\xi_S}. \tag{25}$$

The parameter ξ_W allows the central bank to control the wage inflation rate. The parameter ξ_S controls the response of the interest rate to movements of the exchange rate

[15] z_{-1} has to be included among the initial conditions because at the beginning of each period t households use the value of productivity in $t-1$ to form expectations in the wage setting equation (10).

around a target level $\bar{S}$.

I consider three policy rules. First, I consider a policy of strict wage inflation targeting in which $\xi_W \to \infty$. Under this rule the central bank credibly commits to a policy of zero nominal wage inflation. To achieve this goal the central bank acts so as to replicate the flexible wage equilibrium in any date and state. In this way, households lack an incentive to change the nominal wage and keep their wages constant in every period. This rule offsets all the distortions coming from nominal rigidities and captures the traditional price stability objective of central banks.

Second, I consider a policy of flexible exchange rate targeting in which $\xi_S > 0$ and $\xi_W = 0$. By implementing this policy the central bank provides a nominal anchor to the economy, while allowing some flexibility in the exchange rate. This rule corresponds to a policy of flexible price level targeting in closed-economy models and it represents a simple alternative to targeting wage inflation.[16]

The third regime considered is a perfectly credible currency peg in which $\xi_S \to \infty$. This policy is interesting because it captures the case of dollarized countries or of countries belonging to a monetary union. Moreover it will be used to calibrate the model using data from Eurozone peripheral countries.

2.5 The Fisherian deflation mechanism

Before proceeding to the numerical results, it is useful to build some intuition about the financial amplification mechanism at the heart of the model. To this end, in this section I present a brief partial equilibrium analysis that provides insights about the ability of the model to generate crisis events.

Let's start by combining equations (16) and (13) to write the equilibrium real price of land as

$$\frac{Q_t}{S_t} = \frac{\beta E_t \left[U_C(C_{t+1}, L_{t+1}) \frac{R^K_{t+1} + Q_{t+1}}{S_{t+1}} \right]}{(1-\kappa)\, U_C(C_t, L_t) + \kappa \beta R^* E_t \left[U_C(C_{t+1}, L_{t+1}) \right]}.$$

Since $U_C(C_t, L_t)$ is decreasing in C_t, this equation gives a positive relationship between the real price of land and current consumption. This is due to the households' desire to smooth consumption over time, which implies that the rate at which future returns from land holdings are discounted is decreasing in current consumption. I will refer to this

[16] The results would be similar if I assumed that the central bank was targeting a depreciation rate, rather than a level for the exchange rate.

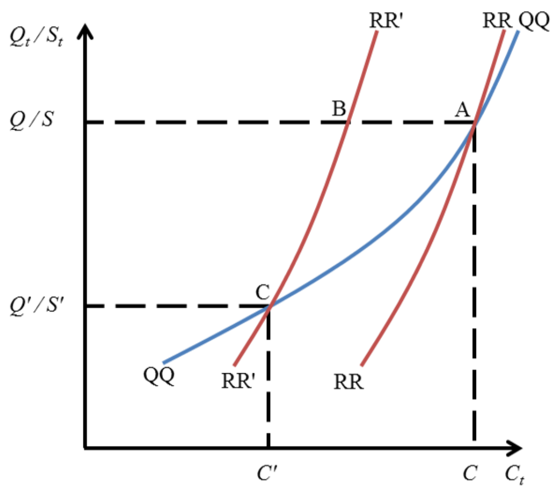

Figure 1: Equilibrium with Fisherian Deflation

relationship as the QQ curve.

In states in which the collateral constraint binds another positive relationship between Q_t/S_t and C_t arises in equilibrium. To see this combine the resource constraint (21) and the binding collateral constraint (9) to obtain

$$C_t = z_t F(L_t, M_t, K_t) - (1+\phi)\, P^M M_t + R^* B_t + \kappa \frac{Q_t}{S_t} K.$$

To gain intuition about this equation, consider that an increase in the price of land corresponds to an increase in the value of collateral that domestic households can offer to foreign investors. If households are borrowing constrained they will respond to the increase in the value of their collateral by borrowing more to finance current consumption. Hence the positive relationship between Q_t/S_t and C_t. I will call this relationship the RR curve.

Figure 1 shows how these two relationships give rise to a financial amplification mechanism based on Fisher's debt deflation. The figure depicts the effects of a negative TFP shock, that is a fall in z_t, in states in which the collateral constraint binds. The initial equilibrium is at point A. The negative TFP shock makes the RR curve shift left to RR'. In absence of financial amplification households would be forced to reduce their consumption, but this would not affect the value of their collateral and the new equilibrium would correspond to point B.

However, the reduction in consumption generates a fall in the demand for land and in its price which tightens the collateral constraint. Households are then forced to decrease their foreign borrowing and further cut their consumption. This gives rise to a vicious cycle of falls in consumption, land price and capital inflows that amplifies the impact of the initial shock. The result is that the Fisherian deflation mechanism moves the economy to the equilibrium depicted by point C, featuring depressed values of consumption and land price.

This simple partial equilibrium analysis shows how the presence of the collateral constraint can be a powerful source of nonlinearity in the response of the economy to exogenous shocks. The numerical results presented in the next section illustrate how the occasionally binding collateral constraint allows the model to reproduce salient features of crisis events in open economies and how it affects the outcome of monetary policy decisions.

3 Parameterization and results

The model cannot be solved analytically and I analyze its properties using numerical simulations. A period in the model corresponds to one year, in accordance with the empirical evidence suggesting that wage contracts are set on average once a year.[17] The values of the parameters are chosen using annual data from five small open economies belonging to the Eurozone periphery: Greece, Ireland, Italy, Portugal and Spain. For each country the period considered starts with the year of adoption of the Euro and ends in 2010.[18] I focus on this sample because it features a homogeneous exchange rate policy and because these countries are currently experiencing a period of financial turmoil. The calibration strategy consists in choosing values for the parameters so that the model with monetary policy characterized by a currency peg matches some key aspects of the countries in the sample.

[17] See Olivei and Tenreyro (2010).

[18] For Ireland, Italy, Portugal and Spain the period considered is 1999-2010, while for Greece it is 2001-2010. Unless otherwise stated, the data come from Eurostat and from the World Development Indicators.

3.1 Functional forms and parameterization

The functional forms for preferences and technology are:

$$U\left(C, L\right) = \frac{\left(C - \frac{L^{\omega}}{\omega}\right)^{1-\gamma} - 1}{1-\gamma},$$

$$F(L, M, K) = L^{\alpha_L} M^{\alpha_M} K^{\alpha_K},$$

with $\omega \geq 1$, $\gamma \geq 1$, $\alpha_L \geq 0$, $\alpha_M \geq 0$, $\alpha_K \geq 0$ and $\alpha_L + \alpha_M + \alpha_K < 1$. The period utility function takes the form introduced by Greenwood et al. (1988). This type of preferences eliminates the wealth effect on labor supply and are widely used in the quantitative literature on small open economies as they are able to reproduce small open economies' business cycles better than separable preferences.[19] The production function is the standard Cobb-Douglas aggregator.

The risk aversion parameter is set at $\gamma = 2$, a standard value in the real business cycle literature. The Frisch elasticity of labor supply $1/(\omega - 1)$ is set equal to 1, in line with evidence by Kimball and Shapiro (2008). The parameter σ is set to 3 as in Smets and Wouters (2003). The world real interest rate is set to $R^* = 1.03$, a reasonable value for the interest rate charged to small open economies during tranquil times. The stock of land K and the price of the intermediate input P^M are both normalized to one without loss of generality.

The measure of gross output (Y) in the data consistent with the one in the model is the sum of GDP plus imported inputs. The average share of imported inputs in gross output in the sample considered is 0.127, hence $\alpha_M = 0.127$. I assume a labor share in GDP of 0.64 and so $\alpha_L = 0.64(1 - \alpha_M) = 0.558$. I set $\alpha_K = 0.044$ following Bianchi and Mendoza (2010). The discount factor β is set to 0.958 to match an average net foreign assets-to-GDP ratio in the model with a currency peg of -0.41.[20] This is the average net foreign assets-to-GDP ratio across the five sample countries during the period since Euro adoption up to 2007, computed using data from Lane and Milesi-Ferretti (2007).

The productivity shock z_t follows a log-normal AR(1) process $log(z_t) = \rho log(z_{t-1}) + \eta_t$. This process is approximated with the quadrature procedure of Tauchen and Hussey

[19] Mendoza (1991) is an early example of a small open economy model using GHH preferences. Correia et al. (1995) compare different utility functions in a small open economy model and show that GHH preferences provide the best fit with the data.

[20] In the model the net foreign assets-to-GDP ratio is $B^*_{t+1}/(Y_t - P^M M_t)$.

Table 1: Parameters

	Value	Source/Target
Risk aversion	$\gamma = 2$	Standard DSGE value
Frisch elasticity of labor supply	$1/(\omega - 1) = 1$	Kimball and Shapiro (2008)
Elasticity of demand for labor	$\sigma = 3$	Smets and Wouters (2003)
World interest rate	$R^* = 1.03$	Standard DSGE value
Stock of land	$K = 1$	Normalization
World price of imported input	$P^M = 1$	Normalization
Imported input share in output	$\alpha_M = 0.127$	Sample average
Labor share in output	$\alpha_L = 0.558$	Labor share in GDP = 64%
Land share in output	$\alpha_K = 0.044$	Bianchi and Mendoza (2010)
Discount factor	$\beta = 0.958$	NFA/GDP = −41%
TFP process	$\sigma_z = 0.0155$, $\rho = 0.9$	Std. dev. and autoc. of GDP
Credit coefficient	$\kappa = 0.38$	Frequency of crises = 5.5%
Working capital coefficient	$\phi = 0.42$	Working capital/GDP = 6%
Coefficient on interest rate rule	$\xi_S = 1.5$	Standard value
Exchange rate target	$\bar{S} = 1$	Normalization

(1991) using 5 nodes. The first order autocorrelation ρ and the standard deviation of the productivity shock σ_z are set so that the model economy under a peg reproduces the average across the five sample countries of the corresponding moments for the cyclical component of GDP per capita (which are respectively 3.1 percent and 0.65).[21] This procedure yields $\rho = 0.9$ and $\sigma_z = 0.0155$.

The parameter κ is set so that the unconditional probability of experiencing a crisis in the currency peg version of the model economy is 5.5 percent, in line with the observed frequency of sudden stops in the cross-country data set of Eichengreen et al. (2006). To be consistent with their definition, a crisis in the model occurs when the credit constraint binds and this leads to an improvement in the current account that exceeds one standard deviation. This calibration results in a value of κ equal to 0.38. The fraction of imported inputs that has to be paid in advance ϕ is set to 0.42 to match an average working capital-to-GDP ratio of 6 percent. This is the same target as in Mendoza and Yue (2011).

The exponent on the exchange rate in the flexible exchange rate targeting rule ξ_S is set to 1.5, a value commonly used in closed-economy sticky price models to capture the response of policy rates to inflation or to deviations of the price level from its target. I

[21] More precisely, for the five countries in the sample I computed the logarithm of per capita GDP during the period 1960-2010 and removed a smooth trend using the Hodrick-Prescott filter with a smoothing parameter of 100. I then computed for each country the standard deviation and the first order autocorrelation of the detrended series, restricting the sample to the years since the adoption of the Euro. The average standard deviation across the countries in the sample is 3.1 percent, while the average first order autocorrelation is 0.65.

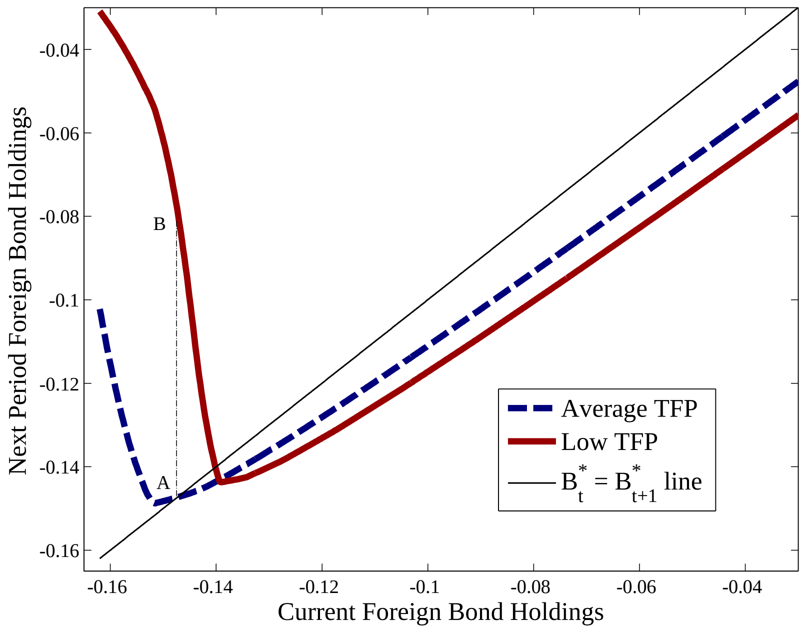

Figure 2: Foreign Debt Dynamics

later show how the main results of the paper hold true for a variety of values for this coefficient. Finally, the exchange rate target $\bar{S}$ is normalized to 1.

3.2 Debt dynamics

The solution is approximated numerically by applying the time iteration method proposed by Coleman (1990) over a discretized state space. This global solution method preserves the nonlinearities induced by the occasionally binding collateral constraint. The state of the economy in period $t \geq 0$ is given by the triplet $\{B_t^*, z_t, z_{t-1}\}$. The previous period productivity shock z_{t-1} must be included among the state variables because it is used by households at the start of the period to form the expectations needed to set their wages. The endogenous state B_t^* is discretized using 700 equally spaced points.

To understand how the model is able to generate both tranquil and crisis times, it is instructive to look at the households' foreign borrowing decision rules. Figure 2 shows the optimal choice of next period foreign bonds as a function of the current holdings of foreign bonds for two different realizations of the TFP shock.[22]

The Fisherian deflation mechanism generates non-monotonic policy functions. The

[22]The decision rule depicted by the solid line is conditional on z_{t-1} being equal to the mean value of TFP and z_t being two standard deviations below mean, while the decision rule represented by the dashed line is conditional on z_{t-1} and z_t being both equal to the mean. Both decision rules refer to agents living under a currency peg. The decision rules for the other two regimes exhibit similar shapes.

point at which the bond decision rules switch slope corresponds to the value of current foreign bond holdings for which the collateral constraint is satisfied with equality but does not bind. To the right of this point the collateral constraint is not binding and the policy function is upward sloped. When the collateral constraint is not binding domestic agents' investment in foreign bonds is increasing in the value of their wealth at the start of the period, as it is standard in models in which the current account is used to smooth consumption over time. To the left of the kink the collateral constraint binds and the policy function becomes downward sloped. This happens because, for a given choice of next period foreign bonds, both consumption and the price of land are increasing in the stock of foreign bonds held by the households at the start of the period. Hence, a decrease in the start-of-period holdings of foreign bonds is associated with a fall in the value of collateral and, if agents are borrowing constrained, with a decline in foreign debt. This gives rise to a negative relationship between current and future bond holdings in states in which the collateral constraint is binding.

Figure 2 also illustrates the process through which the economy enters a crisis. Point A corresponds to a steady state in which the TFP shock is equal to its mean value. At this point, the stock of foreign debt accumulated by domestic agents is big enough to expose the economy to the risk of a sudden stop in the event of a negative TFP shock. Facing a negative TFP shock households try to smooth the impact on consumption by increasing their foreign borrowing. This makes the collateral constraint bind and triggers the Fisherian deflation mechanism which generates a drop in the price of land and in the value of collateral pledgeable to foreign investors. Domestic agents are then forced to cut their foreign borrowing and the economy experiences a sudden stop, that is a drastic decrease in capital inflows. For instance, a negative two-standard-deviations TFP shock causes a fall in foreign borrowing which moves the economy to the equilibrium depicted by point B. After the crisis, domestic agents resume their process of debt accumulation until the economy becomes again vulnerable to the risk of a sudden stop.

Another important feature of the model that can be inferred from the figure is that whether a negative shock makes the collateral constraint bind depends on the stock of foreign assets owned by domestic households at the start of the period. The figure shows that for sufficiently high levels of foreign assets, corresponding to the region to the right of the kink in the 'low TFP' line, a negative two-standard-deviations TFP shock does not make the collateral constraint bind. Conversely, for sufficiently low levels of foreign assets, the region to the left of the kink in the 'low TFP' line, a negative two-standard-deviations TFP shock causes the collateral constraint to bind and triggers the financial amplification mechanism.

3.3 Crisis event analysis

This section describes how the exchange rate regime affects the behavior of the economy during crises. To compare the response of economies with different exchange rate regimes to a typical crisis event I use the following procedure. I simulate the model economy under a currency peg for 100000 periods, drop the first 1000 periods and then collect all the crisis events, that is periods in which the collateral constraint binds and the current account-to-GDP ratio exceeds one standard deviation. Then I construct five year windows centered around each crisis episode and calculate the median productivity shock across all of these event windows in each year $t-2$ to $t+2$, the median holdings of foreign bonds at $t-2$ and the median productivity shock at $t-3$. Finally, I feed this sequence of shocks and initial values for the state variables to the decision rules of each model economy and compute the corresponding endogenous variables.

The results are shown in figure 3. All the variables are in percentage deviations from their ergodic mean except for the current account-to-GDP ratio, the exchange rate and the policy rate. The policy rate corresponds to the interest rate on domestic bonds, deflated by the expected exchange rate depreciation.

Let us start by describing the crisis dynamics under a currency peg, which correspond to the solid lines in figure 3. Initially the economy is on a steady state in which the productivity shock is equal to its mean value, the collateral constraint is not binding, the policy rate is equal to the world interest rate and the net foreign assets are constant. In period t the economy is hit by a negative TFP shock, the collateral constraint becomes binding and the economy enters a crisis.

During the crisis GDP drops by more than 5 percentage points below its ergodic mean. This happens because of three effects. First, the negative TFP shock induces a fall in output for a given amount of factors of production employed. Second, there is an inefficient fall in the imports of the intermediate input because households' access to working capital loans is limited by the collateral constraint. Third, the combination of nominal wage rigidities and fixed exchange rate prevents real wages from adjusting downward to accommodate the fall in firms' labor demand caused by the two previous effects. Because of this, employment falls by nearly 6 percentage points below its ergodic mean.

Consumption falls by more than GDP to almost 8 percentage points below trend. This is due to the fact that the binding collateral constraint prevents households from using the current account to smooth the impact on consumption of the fall in GDP. Indeed, the economy experiences a decrease in capital inflows which translates into a sharp rise in the current account-to-GDP ratio. Moreover, the central bank is forced to raise the policy rate above the world interest rate in order to defend the peg. Finally, the Fisherian deflation mechanism generates a fall in the foreign currency price of land of more than 8 percentage points.

During the fourth period productivity remains below trend, but output and consumption recover because of two effects. First the sudden stop causes a sharp decrease in foreign debt, which relaxes the collateral constraint so that it is no longer binding. This allows households to increase their imports of the intermediate input and of the consumption good, thus having a positive effect on output and aggregate consumption. Second, since the TFP shock is persistent after the first period of productivity below trend households revise downward their expectations of future labor demand and lower their wages accordingly. The drop in wages helps the recovery with his positive impact on employment and GDP.

The dashed lines in figure 3 illustrate the behavior of the economy when the central bank implements a policy of strict wage inflation targeting. The economy with wage inflation targeting and the currency peg exhibit similar dynamics in the two years before the crisis. However, when in period t the crisis hits the behavior of the two economies diverges.

Under wage inflation targeting the central bank lets the exchange rate depreciate during the sudden stop, in order to reduce real wages in response to the fall in firms' demand for labor. This affects the economy through several channels. First, the decrease in the cost of labor pushes firms to increase employment and this has a positive impact on output. Moreover, the increase in output allows households to consume more. This in turn sustains the demand for land and its price and relaxes households' collateral

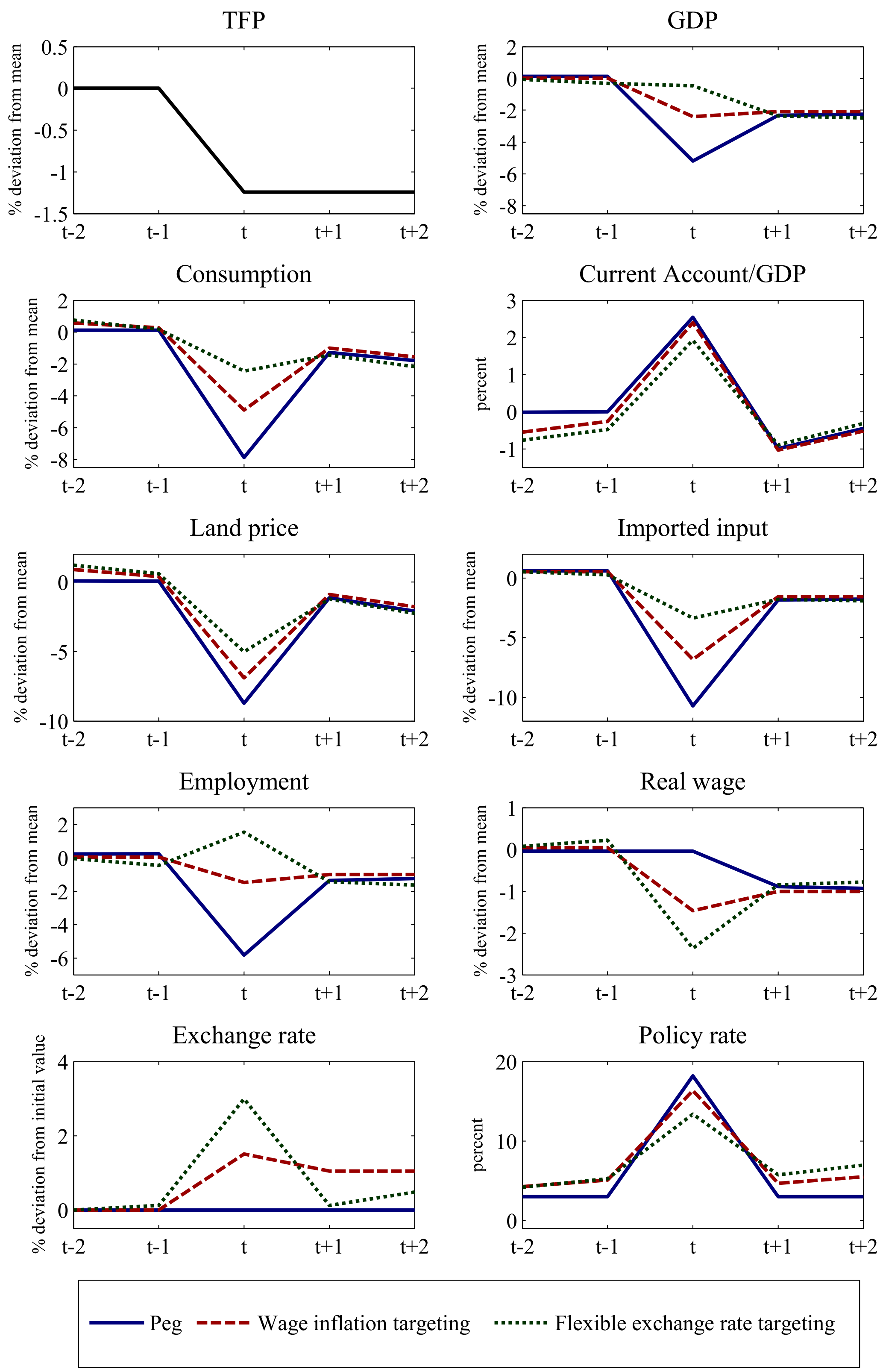

Figure 3: Crisis event analysis

constraints. Finally, due to the assumption of liability dollarization the depreciation reduces the value for foreign investors of a unit of domestic currency and this tightens domestic agents' borrowing limit. In equilibrium the positive impact on the price of land prevails and the depreciation increases the value of the collateral pledgeable to foreign investors. Indeed, the depreciation interacts with the financial amplification mechanism and produces a virtuous cycle of increases in consumption, land price and capital inflows.

The outcome is that under wage inflation targeting the impact of the sudden stop on output, consumption and land price is milder than under the currency peg. GDP falls by only 2 percent below its ergodic mean, consumption falls by 5 percent below its mean and the price of land falls by 7 percentage points below its mean. The policy rate spikes up during the crisis, but the increase is smaller than in the case of the currency peg.

The dotted lines show the behavior of the economy when the monetary authority follows a policy of flexible exchange rate targeting. Under this regime the exchange rate depreciates during the sudden stop by more than under wage inflation targeting, while the policy rate increases by less.[23]

The reduction in the cost of labor is sufficiently big so that employment rises above trend during the crisis and output barely falls below its ergodic mean. Also, flexible exchange rate targeting exhibits the smallest drops in consumption, which falls by just 2 percent below trend, and land price, which falls by nearly 5 percent below its ergodic mean, compared to the other two regimes.

The event analysis suggests that the flexible exchange rate targeting rule fares better than the other two rules in stabilizing output, consumption and the price of land during sudden stops. Figure 4 further illustrates this point by showing the ergodic cumulative probability distribution of the response of consumption and land price to sudden stops

[23] To understand why the exchange rate depreciates under a policy of flexible inflation targeting it is useful to write equation (15) as

$$\beta E_t \left[U_C(C_{t+1}, L_{t+1}) \left(R_t \frac{S_t}{S_{t+1}} - R^* \right) \right] = \mu_t^i.$$

Now suppose that a shock makes the collateral constraint bind and so $\mu_t^i > 0$. Also suppose that the shock does not influence the 'long-run' value of the exchange rate, S_{t+1}, or the future marginal utility from consumption. Then a binding collateral constraint translates either in an increase in the domestic nominal interest rate R_t or in an increase in S_t, that is a nominal exchange rate depreciation. Under a policy of flexible exchange rate targeting the adjustment passes through both margins and so an episode of binding collateral constraint is associated with a nominal depreciation and a rise in the domestic interest rate. Moreover, a weaker response of monetary policy to deviations of the exchange rate from its target, that is a lower value of ξ_s, leads to a larger depreciation.

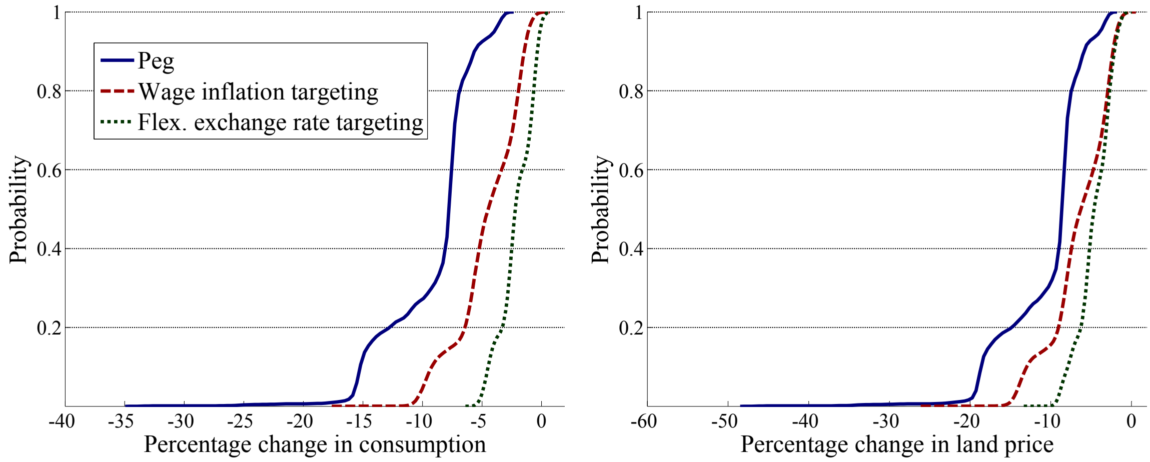

Figure 4: Cumulative distribution of impact effect of crises on consumption (left panel) and land price (right panel)

under the three exchange rate policies, expressed as percentage deviations from their ergodic means.[24] The figure shows that both the economy with wage inflation targeting and the currency peg assign non-trivial probabilities, respectively 20 percent and 90 percent, to consumption drops of more than 6 percent, the maximum fall in consumption experienced by the economy with flexible exchange rate targeting. Similarly, the economy with flexible exchange rate targeting assigns a negligible probability to falls in land price below 10 percent, while this happens with almost a 20 percent probability under wage inflation targeting and with more than a 30 percent probability under a peg.

3.4 Debt accumulation and precautionary savings

The exchange rate regime not only affects the economy during sudden stops, but it also has an impact on debt accumulation during tranquil times and on the probability that the economy slides into a crisis.

Figure 5 displays the ergodic cumulative probability distribution of foreign bond holdings for the three policy rules considered. Both the economy with wage inflation targeting and the one with flexible exchange rate targeting tend to reach higher levels of foreign debt than the peg. For instance, the probability of experiencing levels of foreign debt

[24] To construct this figure I performed for each model economy a 100000-period long simulation, dropped the first 1000 periods and collected all the crisis events. The figure plots for each economy the cumulative probability distribution function of the percentage deviations of consumption and land price from their ergodic means conditional on the economy being in a crisis.

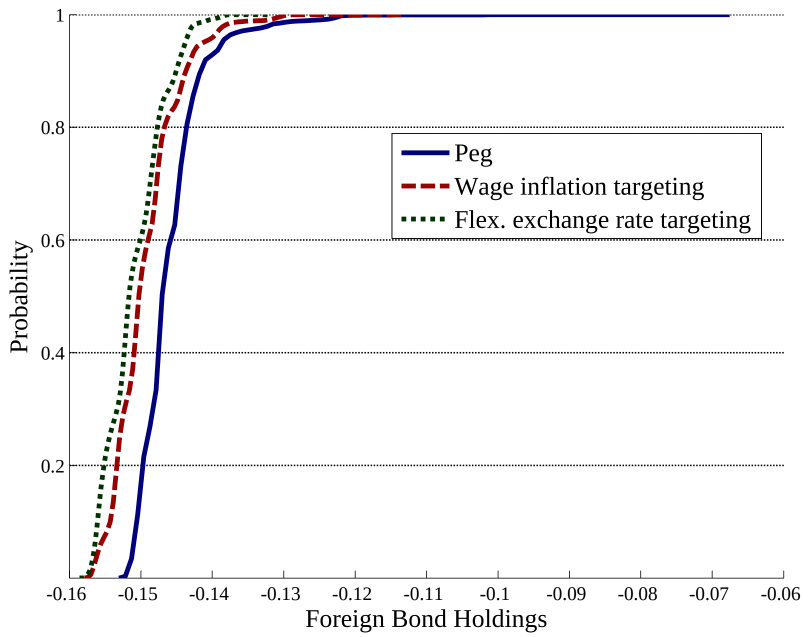

Figure 5: Ergodic cumulative probability distribution of foreign bond holdings

higher than the maximum attained by the currency peg is around 30 percent both for the economy with wage inflation targeting and for the one with flexible exchange rate targeting.

The reluctance of agents living under a currency peg to reach high levels of foreign debt can be explained with the fact that a higher level of foreign debt increases the chances that a negative shock makes the collateral constraint bind. Since episodes of binding collateral constraint are more disruptive under a currency peg than under the two other monetary regimes, households living under a peg take smaller levels of foreign debt to reduce the risk of entering a crisis. Consistent with this, the economy with flexible exchange rate targeting, which is the regime under which crises have the mildest effects, reaches very high levels of foreign debt more often than the economy with wage inflation targeting.

This can also be seen by looking at precautionary savings, defined as the difference between the borrowing limit and foreign debt.[25] Table 2 shows that the peg has the highest average precautionary savings-to-GDP ratio (1.4 percent), followed by the economy with wage inflation targeting (0.7 percent) and by the economy with the flexible exchange rate targeting rule (0.5 percent). This indicates the existence of a positive relationship between the severity of crises and the amount of precautionary savings that

[25] Formally, precautionary savings at time t are defined as $\kappa K Q_t/S_t + B^*_{t+1} - \phi P^M M_t$.

Table 2: **Precautionary savings and crisis probability**

	Wage inflation targeting	Flexible exchange rate targeting	Currency peg
Precautionary savings/GDP	0.7	0.5	1.4
Crisis probability	8.3	9.3	5.5

Note: Precautionary savings are defined as the difference between the collateral value of land and total foreign debt, $\kappa K Q_t / S_t + B^*_{t+1} - \phi P^M M_t$. A crisis event is defined as a period in which the collateral constraint binds and the current account-to-GDP ratio exceeds one standard deviation.

agents accumulate.

By accumulating precautionary savings households influence the probability that the economy enters a crisis. Table 2 shows that the unconditional probability of entering a crisis is 5.5 percent for the economy with a fixed exchange rate, while the crisis probability is 8.3 percent for the economy with wage inflation targeting and 9.3 for the economy with flexible exchange rate targeting.

3.5 Long run moments

This section documents how the monetary policy regime affects the business cycle moments of the economy. Table 3 displays the long-run business cycle moments for the three policies considered, computed using each economy's ergodic distribution. The economy with the currency peg exhibits the highest business cycle variability in GDP, labor and consumption, signaling the role of shock absorber that flexible exchange rates perform in the model.[26] The economy with wage inflation targeting is characterized by lower volatility in GDP and labor than the economy with flexible exchange rate targeting, but by higher volatility in consumption. This can be explained with the fact that the flexible exchange rate targeting rule does a better job in insulating consumption from the effect of crises.

The model produces a higher variability in GDP than in consumption, a typical feature of emerging markets subject to the risk of financial crises highlighted by Neumeyer and Perri (2005). This is due to the fact that the Fisherian deflation mechanism interferes with households' desire to smooth consumption over time. This can be seen by looking at the cyclicality of the trade balance-to-GDP ratio. In absence of frictions in the credit market the trade balance would be procyclical, because households would smooth the

[26]For empirical evidence on the shock-absorbing role of flexible exchange rates see Broda (2004).

Table 3: Long Run Moments

	Standard deviation			Correlation with GDP			Autocorrelation		
	WIT	FERT	PEG	WIT	FERT	PEG	WIT	FERT	PEG
GDP	2.47	2.51	3.14	1.00	1.00	1.00	0.89	0.85	0.65
Consumption	2.80	2.60	3.60	0.94	0.95	0.96	0.64	0.79	0.48
Trade balance/GDP	0.78	0.60	0.89	−0.15	0.04	−0.30	−0.22	−0.27	−0.19
Employment	1.28	1.61	2.62	1.00	0.89	0.94	0.86	0.52	0.32
Leverage	1.48	1.32	2.29	−0.37	−0.56	−0.59	0.30	0.43	0.43
Land price	3.62	3.29	4.11	0.91	0.87	0.94	0.56	0.69	0.51
Exchange rate	1.28	0.96	0.00	−1.00	−0.36	−	0.86	−0.05	−
Policy rate	3.94	2.54	5.36	−0.37	−0.22	−0.49	−0.09	−0.16	−0.04

Note: WIT stands for the economy with strict wage inflation targeting, FERT stands for the flexible exchange rate targeting rule and PEG stands for the currency peg. Autocorrelation refers to the first-order autocorrelation. Leverage is defined as $(-B^*_{t+1} + \phi P^M M_t)S_t/KQ_t$. The policy rate is the domestic nominal interest rate R_t, deflated by the expected exchange rate depreciation.

impact of productivity shocks on consumption by decreasing net exports during periods of low productivity. Instead, the binding collateral constraint forces agents to reduce their foreign borrowing, and hence to increase their net exports, when productivity is low generating a countercyclical trade balance-to-GDP ratio. By looking at the cyclicality of the trade balance we can see that consumption smoothing works worst under the peg, which has the highest negative cyclicality of the trade-balance-to-GDP ratio, while the flexible exchange rate targeting rule is the regime that guarantees better consumption smoothing, since its trade balance-to-GDP ratio is mildly procyclical.

The Fisherian deflation mechanism also affects the business cycle moments of land price and leverage.[27] Land price is much more volatile than GDP and strongly procyclical under the three regimes. The flexible exchange rate targeting is the regime with the lowest land price volatility, while the peg exhibits the highest volatility in land price. Also leverage is most volatile under the peg, while the lowest volatility is attained under the flexible exchange rate targeting rule. Leverage is countercyclical under the three policy regimes, due to the fact that when the collateral constraint binds, and thus when leverage has reached its maximum κ, GDP tends to fall.

The exchange rate is more volatile under the wage inflation targeting regime, compared to the economy with flexible exchange rate targeting. Both regimes exhibit small volatilities in the exchange rate compared to data from small open economies, in accordance with the well known difficulty of DSGE models in accounting for the volatility of

[27] The leverage ratio is given by $(-B^*_{t+1} + \phi P^M M_t)S_t/KQ_t$.

nominal exchange rates (see for example Kollmann (2002) and Gertler et al. (2007)). In both regimes the exchange rate is countercyclical due to the fact that it tends to depreciate following bad productivity shocks. While the first-order autocorrelation of the exchange rate is strongly positive under a policy of wage inflation targeting, it becomes mildly negative when the central bank follows a policy of flexible exchange rate targeting.

The policy rate tends to be more volatile than GDP, and the highest policy rate volatility is attained under the peg. Interestingly, the model generates countercyclical policy rates, because crises are associated with spikes in the domestic interest rate. The flexible exchange rate targeting rule is the regime that guarantees the lowest countercyclicality of the policy rate.

3.6 Welfare

This section compares the welfare performance of the three monetary regimes considered. I compute the welfare gains of moving from the policy regime r to regime s as the proportional increase in consumption for all possible future histories that households living under regime r must receive in order to be indifferent between remaining in regime r and switching to regime s. Formally, the welfare gain η at a state (B_0, z_{-1}) is defined as

$$E_0\left[\sum_{t=0}^{\infty}\beta^t U\left(C_t^r\left(1+\eta(B_0,z_{-1})\right), L_t^r\right)\right] = E_0\left[\sum_{t=0}^{\infty}\beta^t U\left(C_t^s, L_t^s\right)\right],$$

where the superscripts r and s denote allocations in the economy with the corresponding policy regime. Since the central bank commits to a regime at the start of period 0, before wages are set and the TFP shock is known, I compute the welfare compensation η contingent on the initial stock of foreign bonds B_0 and on the past TFP shock z_{-1}. Importantly, this welfare measure takes into account the impact on welfare of the transition to the steady state implied by the new policy.

I start by showing how the presence of the Fisherian deflation mechanism affects the welfare ranking between the strict wage inflation targeting and the flexible exchange rate targeting rule. To this end, I compute the welfare gains of moving from a policy of wage inflation targeting to the flexible exchange rate targeting rule both for the benchmark model, in which the Fisherian deflation channel is present, and for a version of the model

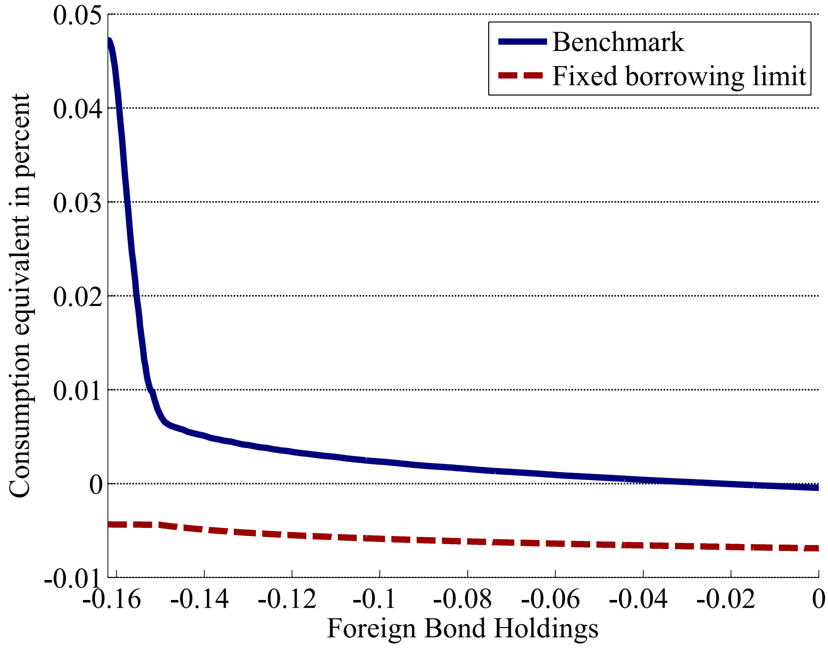

Figure 6: Welfare gains of switching from wage inflation targeting to flexible exchange rate targeting

in which the collateral constraint (9) is replaced by

$$\phi P^M M_t^i - B_{t+1}^{*i} \leq \kappa \bar{Q} K_{t+1}^i,$$

where $\bar{Q}$ is a constant.[28] In this case households are subject to a fixed borrowing limit, there is no financial amplification and the economy never experiences a financial crisis.

Figure 6 plots the welfare gains of moving from wage inflation targeting to the flexible exchange rate targeting rule as a function of B_0^*, conditional on z_{-1} being equal to $E(z)$.[29] The dashed line refers to the economy with a fixed borrowing limit. Absent the Fisherian deflation channel, a policy of wage inflation targeting delivers higher welfare than targeting the exchange rate for any initial state of the world. This happens because with a fixed borrowing limit there are only two sources of inefficiency. First, on average production is inefficiently low due to the presence of monopolistic competition in the labor market. Second, the assumption of nominal wage stickiness may lead to inefficient wedges between the wage rate and the marginal rate of substitution between consumption

[28] In the numerical simulations $\bar{Q}$ is set equal to the average price of land in the benchmark model with a currency peg.

[29] The welfare gains for other values of z_{-1} have similar shapes.

and leisure. These two sources of inefficiency are standard in monetary economics and we know that a policy that corrects for nominal rigidities and replicates the equilibrium with flexible wages is close to the optimal policy in this setting.

The Fisherian deflation mechanism introduces another source of inefficiency, based on a pecuniary externality. Atomistic households do not internalize the effect of their actions on the price of land and thus on the value of their collateral. A benevolent social planner that internalizes the impact of its decisions on prices has an incentive to sustain the price of land in states in which the collateral constraint binds, in order to increase the value of the collateral pledgeable to foreign investors. This creates an incentive for the central bank to deviate from its traditional objective of pursuing price stability and to adopt policies that sustain households' access to the international credit markets during crisis times, by mitigating the fall in the price of land in states in which the collateral constraint binds.

The relevance of this source of inefficiency is highlighted by the solid line in figure 6, which displays the welfare gains of moving from wage inflation targeting to the flexible exchange rate targeting rule for the benchmark economy. The figure shows that once the Fisherian deflation mechanism is introduced the welfare ranking between a policy of wage inflation targeting and a policy of flexible exchange rate targeting crucially depends on the initial stock of foreign assets owned by domestic households. For high levels of initial foreign assets, corresponding to low initial foreign debt, the wage inflation targeting rule delivers higher welfare gains. This happens because a policy of targeting wage inflation does a good job at managing normal business cycle fluctuations. If the economy starts with a high stock of net foreign assets the probability of a future crisis is small and so welfare is mostly affected by business cycle fluctuations.

As the initial stock of net foreign assets decreases the welfare gains of sticking to the wage inflation targeting rule diminish until adopting the flexible exchange rate targeting rule becomes the preferred option. This happens because a policy of flexible exchange rate targeting does a better job at mitigating the fall in the price of land and at granting access to international credit during crisis events, compared to a policy of targeting wage inflation. Lower foreign assets are associated with higher probability of entering a crisis in the future and so households living in an economy with a low stock of net foreign assets attach more value to the good crisis management properties of the flexible exchange rate

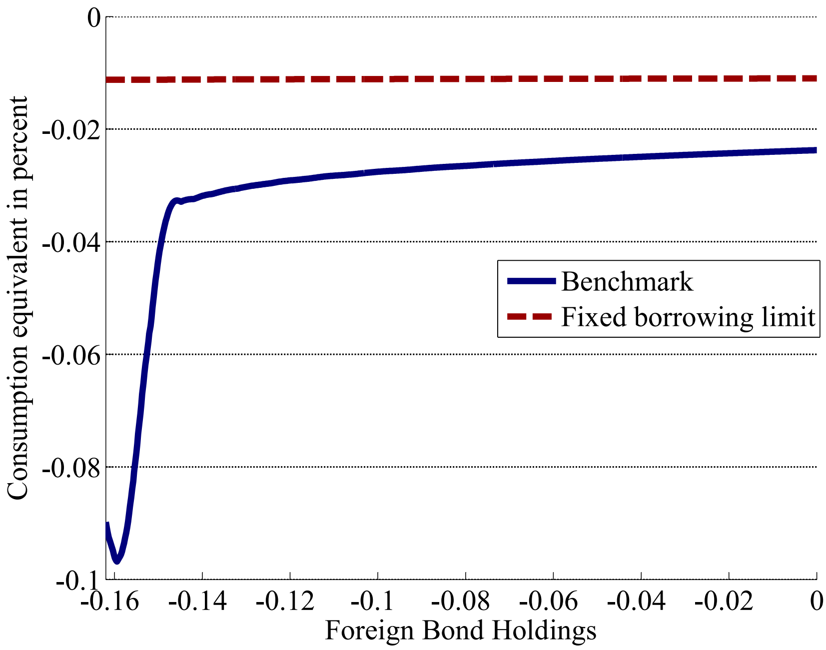

Figure 7: Welfare gains of switching from wage inflation targeting to currency peg

targeting rule. The gains from adopting the flexible exchange rate targeting rule become significantly higher for very low levels of initial net foreign assets, because these are the states of the world in which a negative TFP shock triggers a financial crisis.

In the stochastic steady state, the average welfare gains of moving from a policy of strict wage inflation targeting to the flexible exchange rate targeting rule are positive but small, about 0.007 percentage points of permanent consumption. On the one hand, this can be explained with the fact that the gains of adopting a policy of flexible exchange rate targeting are concentrated in states of the world in which the collateral constraint binds. Due to the accumulation of precautionary savings this happens with a small probability in steady state. On the other hand, this finding is in line with Lucas' result on the small welfare costs of business cycle fluctuations in models with CRRA utility, trend-stationary income and no idiosyncratic uncertainty.[30]

Figure 7 shows the welfare gains of moving from wage inflation targeting to a currency peg, again as a function of B_0^* and conditional on z_{-1} being equal to $E(z)$. The figure indicates that a policy of strict wage inflation targeting is preferred to a currency peg for

[30] Adding an endogenous growth process as in Barlevy (2004) or allowing for heterogenous agents as in Krusell et al. (2009) is likely to increase the welfare differences between the two regimes.

both versions of the model and for any value of initial net foreign assets. This suggests that the peg does a poor job in managing both normal business cycle fluctuations and crisis events. In the benchmark version of the model, lower initial net foreign assets are associated with higher welfare costs from pegging the exchange rate. This is due to the fact that the currency peg amplifies the fall in the price of land and worsens households access to international credit during crises.[31]

Considering the stochastic steady state, the average welfare losses from moving from a policy of strict wage inflation targeting to a peg are small, around 0.041 percentage points of permanent consumption. However, compared to the welfare gains of moving to a policy of flexible exchange rate targeting the welfare costs of adopting a currency peg are significantly larger.

3.7 Robustness checks

This section examines the robustness of the main results of the paper to changes in some key parameters. I start by investigating whether the result that the flexible exchange rate targeting rule welfare dominates the wage inflation targeting rule in the benchmark version of the model is robust to changes in ξ_S, the parameter that governs the response of the central bank to deviations of the exchange rate from its target. To this end, I computed the average welfare gains that agents living in the stochastic steady state of the economy with the wage inflation targeting regime would experience from switching to a flexible exchange rate targeting rule for a variety of values of ξ_S. The results, displayed by figure 8, indicate that the flexible exchange rate targeting rule is preferred to a policy of targeting wage inflation over a whole range of values for ξ_S. Among the values of ξ_S considered, setting ξ_S equal to 1 guarantees the highest average welfare gains from adopting a flexible exchange rate targeting rule.

Table 4 presents the sensitivity of the main results of the paper with respect to several parameters. The qualitative results seems not to be affected by changes in the key parameters of the model. In particular, strict wage inflation targeting is always welfare dominated by the flexible exchange rate targeting rule, and the currency peg is

[31]For very high levels of debt the welfare losses of moving from wage inflation targeting to a peg become decreasing in the initial stock of debt. Presumably this happens because very high initial levels of debt are associated with a high probability of a severe crisis generating a sharp deleveraging that reduces significantly the probability of entering a crisis again in the future.

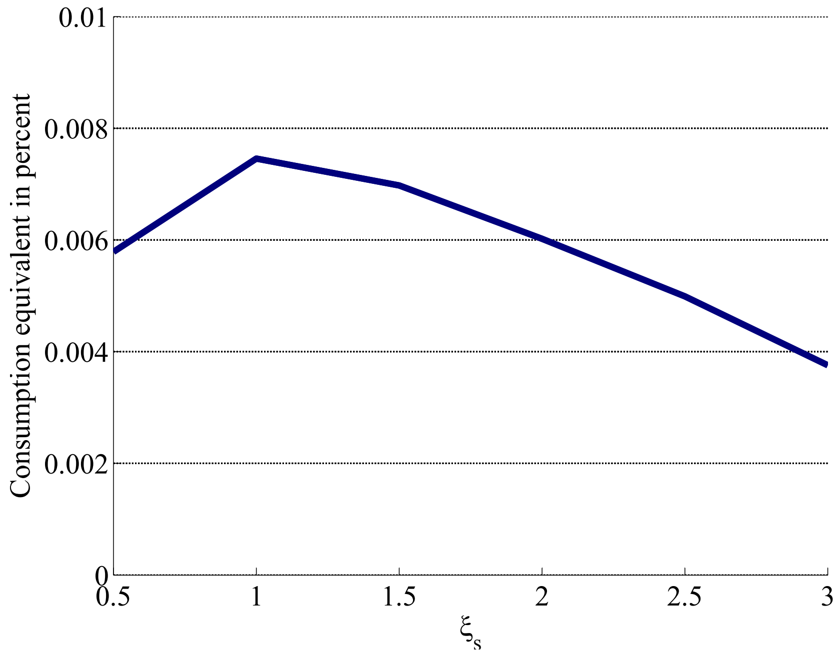

Figure 8: Average welfare gains of switching from wage inflation targeting to flexible exchange rate targeting

always the regime characterized by the worst performance in terms of welfare. Moreover, the flexible exchange rate targeting rule is always the regime under which crises have the mildest impact on the economy, while the currency peg always features the lowest crisis probability.

However, some parameters have a significant effect on the quantitative results. Indeed, the differences in the welfare performance of the three regimes increase significantly if the coefficient of relative risk aversion rises or if the fraction of land holdings that can be offered as collateral increases. This suggests that different calibrations of the model may yield higher welfare gains from adopting an appropriate monetary policy regime.

Table 4: Robustness Checks

	Welfare gains from WIT to		Crisis probability			Mean impact effect of financial crises								
						GDP			Consumption			Land price		
	FERT	PEG	WIT	FERT	PEG	WIT	FERT	PEG	WIT	FERT	PEG	WIT	FERT	PEG
benchmark	0.007	−0.041	8.3	9.3	5.5	−2.0	0.2	−5.9	−4.8	−2.3	−9.5	−3.0	−2.2	−4.7
$\gamma = 1.8$	0.003	−0.031	10.1	10.1	7.4	−1.5	−0.2	−5.0	−3.7	−2.1	−7.9	−2.1	−1.7	−3.5
$\gamma = 2.2$	0.015	−0.090	7.5	9.0	4.5	−2.2	0.2	−6.6	−5.2	−2.0	−10.7	−3.6	−2.4	−5.7
$1/(\omega - 1) = 0.9$	0.005	−0.042	8.5	9.2	5.4	−1.9	−0.2	−6.0	−4.5	−2.2	−9.6	−3.0	−2.2	−4.9
$1/(\omega - 1) = 1.1$	0.009	−0.042	8.3	9.0	5.3	−2.1	0.7	−6.1	−4.9	−2.1	−9.8	−3.0	−2.0	−4.7
$\sigma_z = 0.013$	0.007	−0.034	9.3	10.9	5.4	−1.3	0.8	−5.1	−3.7	−1.6	−8.7	−2.4	−1.6	−4.4
$\sigma_z = 0.018$	0.006	−0.049	7.9	8.7	4.9	−2.4	−0.3	−7.1	−5.3	−2.7	−11.1	−3.4	−2.4	−5.4
$\kappa = 0.36$	0.005	−0.036	8.6	9.1	5.7	−1.9	−0.2	−5.9	−4.5	−2.2	−9.3	−2.9	−2.1	−4.7
$\kappa = 0.4$	0.010	−0.060	7.9	9.0	4.9	−2.4	−0.8	−6.3	−5.1	−2.1	−10.4	−4.2	−2.1	−5.1
$\phi = 0.32$	0.010	−0.038	8.0	9.0	5.3	−2.0	0.1	−5.7	−5.0	−2.0	−9.6	−3.2	−2.1	−4.8
$\phi = 0.52$	0.005	−0.043	8.6	9.0	5.7	−2.0	−0.3	−6.2	−4.5	−2.3	−9.5	−2.8	−2.1	−4.6

Note: WIT stands for the economy with strict wage inflation targeting, FERT stands for the flexible exchange rate targeting rule and PEG stands for the currency peg.

4 Conclusion

This paper has examined the performance of alternative monetary policy rules in a small open economy model with an occasionally binding collateral constraint that limits access to foreign credit and with nominal wage rigidities. The main finding is that the presence of pecuniary externalities in the credit markets introduces a trade-off between price and financial stability. For low levels of external debt the probability of a future crisis is small and a policy that eliminates the distortions coming from nominal rigidities by targeting wage inflation is the best rule. For high levels of external debt the probability of a future crisis is high and targeting wage inflation is dominated by a flexible exchange rate targeting rule, because the latter policy is better at mitigating the fall in output, consumption and capital inflows during crisis events. In contrast, pegging the exchange rate is always welfare dominated by the wage inflation targeting rule. A second key finding is that the exchange rate regime affects both the behavior of the economy during crisis events and the probability that the economy enters a crisis, through its impact on debt accumulation during tranquil times. The more the monetary policy regime mitigates the impact of crises on output and consumption, the more private agents engage in foreign debt accumulation during tranquil times and the higher is the probability of experiencing a crisis.

The paper represents a first step in the analysis of monetary policy in dynamic general equilibrium models featuring tranquil and crisis times. The model is kept voluntarily simple to reduce the computational complexities involved by the derivation of a global numerical solution. An interesting area for future research would be to extend the model in order to make it more suitable to deliver quantitative results. Two possible extensions are the inclusion of endogenous capital accumulation and of a dynamic wage-setting process.

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