Dipartimento di Economia

Working Papers

No. 8 (April 22, 2010)

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Abstract

The paper presents an open-economy macrodynamical growth model with the aim of giving an endogenous characterisation to the process that leads a small country with a currency-board arrangement to accumulate dangerously high levels of external debt and become vulnerable to macroeconomic instability. The macrodynamics of the model results from the combination of the commitment to maintain the peg - that makes liquidity closely dependent on the dynamics of foreign reserves – and the non-linear real and financial interactions that drives the pro-cyclical behaviour of the economy. Within this context, the external finance ease during an economic upswing leads to debt-supported growth and financial fragility; the consequent deterioration of profitability expectations brings about a capital reversal that, in the absence of monetary stabilization tools, makes the currency arrangement unsustainable. A financial crisis may thus turn into a currency crisis.

We run a continuous-time estimation of a non-linear differential equations system for Argentina during the years of the currency-board arrangement. We find that two steady-state solutions exist. The local stability and sensitivity analysis show that both equilibria are unstable and that the qualitative nature of the equilibria depends in particular on lenders' responsiveness to the degree of leverage. On the contrary, when considering a different currency arrangement with an autonomous monetary policy, the system becomes stable.

JEL: G01, C51, C62, F34, E52.

Keywords: Currency Board, Financial Crisis, Monetary policy, Continuous Time Econometrics, Stability, Sensitivity.

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1. *Introduction*

Financial integration into world capital markets represents a crucial factor in the growth process of emerging market economies, where the accumulation process would otherwise be constrained by the limited resources channelled by the domestic financial markets. The increased access to international capital markets relaxes financial bottlenecks and bursts growth, yet it may lead to overborrowing and determine macroeconomic vulnerabilities. This is particularly true in the presence of weak institutions when capital inflows are largely debt-creating (Ranciere *et al*., 2005, Calvo *et al*., 2008).

In fact, the recent literature on currency crises[1] emphasizes the role played by the large imbalances of the private sector in the explanation of the financial distress in the Asian tigers and the Latin-American Countries during the Nineties. Most contributions extend to open economies the Bernanke-Gertler-Gilchrist (1999) "financial acceleration hypothesis": in the presence of highly leveraged balance sheets a currency devaluation impacts negatively on firms' net worth determining capital flights, thus accelerating a financial and currency crisis. The issue is particularly relevant for open emerging economies, which typically face difficulties in attempting to borrow in their own currency.[2]

Yet, tight nominal pegs do not appear a valid protection from a crisis. In the aftermath of the recent financial crisis, that determined a financial distress in international capital markets, some of the European economies that gravitate around the EMU, appear to have be severely affected by huge capital outflows. In a number of these countries, monetary stability has been achieved thanks to the choice of a hard peg regime. Yet, the massive capital inflows fuelled by the integration into world capital markets have led to the building up of large imbalances in the public and private sectors. The absence of policy instruments for stabilization purposes has then determined a financial collapse. In fact, hard pegs require macroeconomic imbalances to be

[1] The so-called "third generation" models of currency crises. Among the others, see Krugman (1999), Céspedes-Chang-Velasco (2000), Aghion-Bacchetta-Banerjee (2001), Hausmann-Velasco (2002).
[2] See Eichengreen-Hausmann-Panizza (2003).

limited in size and in persistence; at the same time wage and price flexibility should be allowed to fully operate in order to ensure the exchange regime sustainability.[3]

Not too different was the experience of Argentina during the currency board years, 1991-2001. As known, after a period of outperforming growth driven by massive capital inflows, Argentina plunged into a severe recession that led to a financial crisis and the abandonment of the currency-board arrangement.

Two different perspectives are at the basis of the various explanations in the literature of the above macrodynamical behaviour: the first considers a currency crisis the result of a "sudden stop" due to the surge of interest rate spreads or other exogenous factors, in the presence of imperfect financial markets. The second views a currency crisis the outcome of an endogenous overborrowing process. In the explanation of the experience of Argentina the sudden-stop hypothesis is emphasised in Calvo *et al*. (2008), whereas Perry-Serven (2003) argue that that crisis should be interpreted more likely as the outcome of an endogenous capital reversal.

In this paper we follow the second interpretation and address the issue of "financial instability" and currency crisis for a country that adopts a super-fixed exchange rate, such as a currency board or a dollarization. We argue that an endogenous overborrowing process was at work, that first fostered growth and eventually made Argentina financially fragile and determined the capital reversal that propelled the currency crisis. In fact, given the wage and price rigidities, the macroeconomic imbalances accumulated during the boom would have required an unsustainable output adjustment. Our analysis is very close to the macrodynamical literature that builds on Minsky's "financial fragility hypothesis" in the explanation of business fluctuations.[4] In particular, in Franke-Semmler (1989) a nonlinear real-financial interaction is at the basis of an endogenous overborrowing process that determines financial instability. The endogenous nature of the model derives from the combination of a certain degree of "inertia" in agents behaviour, together with the "financial acceleration hypothesis". The idea is that firms'

[3] Roubini (1989) and Mulino (2002), among others, has shed light on some of the critical features of currency boards.

[4] Minsky (1982). In such a direction are the works of Foley (1986), Taylor-O'Connell (1989), Franke-Semmler (1989) and Cavallaro (1999), among the others. A general framework for disequilibrium macroeconomic dynamics is proposed in Flaschel-Franke-Semmler (1997).

investment decisions as well as lenders' financing decisions require an assessment of future profitability conditions of the economy. Within the context of limited information, such an evaluation is made on the basis of the *current* economic return on investment, and on the perceived "state of confidence". The latter improves in periods of expanding economic activity, but is negatively affected by high leverage ratios that increase the possibility of default. Increasing leverage ratios also affect negatively lenders' willingness to provide finance for given profitability expectations. The economy thus behaves procyclically, and the macrodynamical behaviour of the economy turns out to depend strongly on the attitude of firms and lenders to incur in an overborrowing process.

We contribute to that literature by extending the analysis to an open-economy framework where an external overborrowing process drives a currency crisis. The focus is on a country that adopts a hard peg. In this case, the strong commitment to maintain the peg makes the money supply closely dependent on the stock of foreign reserves, thus completely endogenous, with no room for stabilization purposes. In our framework the currency arrangement has the effect to amplify the fluctuations of the economy in the upturn and in the downturn: the surge in credibility induced by hard pegs is at the origin of the large capital inflows that initially finance the accumulation process of an emerging economy that integrates itself into international financial markets. Such a process starts a procyclical expansion that improves the "state of confidence" and expands the amount of capital flows to the economy. Yet, when most of the finance accruing is debt-creating, firms' balance sheets deteriorate, and the resulting financial fragility may undermine the "state of confidence" and set up a capital reversal. During the downturn the currency arrangement becomes a binding constraint on the monetary authorities, given that the amount of liquidity which would be necessary to avoid firms' bankruptcy and a financial distress cannot be provided. The perception that the hard peg has become unsustainable accelerates the capital outflows and systemic instability. In this case the only way out is the choice of abandoning the peg.

The analysis emphasises that in a currency-board arrangement the accumulation process and growth totally rest on the inflows of foreign currency generated by balance of payments surpluses. It follows that either a country is able to run persistent trade surpluses, and to attract long-term, non debt-creating capital, or its economic growth is inevitably fragile.

In order to assess the empirical relevance of our theoretical model, we perform an estimation with data for Argentina. We estimate the model as a system of non-linear differential equations from which we derive two unstable equilibria. We then control for the instability by adopting a simple countercyclical monetary rule, thus emphasising that the currency arrangement, with its lack of monetary intervention policies, is the crucial determinant in the crisis. The estimation is in continuous time.

The paper is organised as follows. In section 2 we develop the theoretical model by presenting the dynamical framework for a currency board and analysing the long-run implications of a debt-supported growth. In section 3 we develop the empirical analysis by presenting the data, the methodology and by performing the estimation. In section 4 we analyse the dynamical properties of our empirical model. In section 5 we reformulate the model in order to allow for an anticyclical monetary rule, and analyse the effects on stability. Section 6 concludes.

2. *The theoretical model*

2.1 *The dynamical framework for a currency board*

In this section we present a monetary growth model aiming at describing the macroeconomic behaviour of an economy under a currency board arrangement. Our aim is to explainca financial crisis as the outcome of an endogenous process where foreign finance and profitability expectations interact procyclically: foreign-debt supported expansions lead to the deterioration of firms' net worth, a consequent fall in the state of confidence that makes foreign lenders unwilling to provide additional finance. As a result, shrinking liquidity and dropping output may follow. The analytical framework is similar to the one proposed in Franke-Semmler (1989), but the monetary side of the model differs due to the open-economy setting. To this aim we consider an economy where liquidity is completely created through a country's balance of payments surpluses: in fact, under a currency-board arrangement the growth of liquidity totally rests on the inflows deriving from net current account surpluses and capital inflows, given the monetary authorities' commitment to maintain a fixed proportion between domestic liquidity and the stock of foreign reserves. The consequences is that when accumulation is largely financed with debt-creating capital flows, deteriorated balance sheets may accelerate a capital reversal, and a financial crisis may turn into a currency crisis because of no room for stabilization policies.

We thus consider a small open economy where prices and the exchange rate are fixed and the PPP holds. The model may be represented by the following equations for the six variables: output, the stock of money, the stock of debt, the stock of foreign reserves (all in units of capital), the interest rate and the economy's "state of confidence", which we denote respectively as: y, m, l, fr, i, ρ,:

[2.1] $s-\gamma\left[\pi^{e}-i\right]-nx+il=0$ $\quad\gamma'>0$

[2.2] $m-\lambda(y,i)=0$ $\quad\lambda_1>0,\quad\lambda_2<0$

[2.3] $\dot{l}=\left[\varphi\left(\pi^{e}-i;l\right)-\gamma\left(\pi^{e}-i\right)\right]l$ $\quad\varphi_1>0,\quad\varphi_2<0$

[2.4] $\dot{\rho}=\omega(\pi-i;\ l)$ $\quad\omega_1>0,\quad\omega_2<0$

[2.5] $\dot{fr}=\dot{l}-i\,l+f$

[2.6] $m=m_{t_0}+\int_0^t \dot{fr}\,dv$

Equation [2.1] states the equilibrium condition for the goods market. Its formulation reflects the assumption that in the economy workers spend all their income on domestic goods, whereas capitalists entirely save their income once interest obligations have been met, that is $s=\alpha y\text{-}il$, where α is the share of profits out of income y and il denotes interest payments on outstanding debt - interest payments are assumed to be instantaneous. We assume a Kaleckian investment function $\gamma(.)$ and posit that capitalists make investment decisions on the basis of the difference between the expected net profit rate and the interest rate, $\pi^{e}-i$. The *expected net* profit rate is expressed as $\pi^{e}=\alpha\,y+\rho-i\,l$, that is, the *current* profit rate $\alpha\,y$ and its expected change ρ, net of interest payments. The variable ρ captures the anticipated change in the economy's profitability conditions. It identifies the economy's "state of confidence". The term nx denotes net exports which are positively correlated to the level of output. Net unilateral transfers and inflowing incomes are assumed to be negligible.

Equation [2.2] states the equilibrium condition between the money supply m and the money demand, $\lambda(.)$. The latter is a positive function of output and a negative function of the rate of interest.

Equations [2.3] and [2.4] give the two laws of motion of l and ρ, as suggested in Franke-Semmler (1989). In equation [2.3] the change in the stock of debt per unit of capital l is given by the difference in the growth rate of debt $\varphi(.)$ and the growth rate of capital $\gamma(.)$. We assume that domestic financial markets are unable to finance the excess of firms' investment expenditure over retained profits,[5] so that debt is totally denominated in a foreign currency. The function $\varphi(.)$ explains the behaviour of foreign lenders in supplying finance to firms: given information problems on credit markets, they are assumed to assess firms' worthiness on the basis of two indicators of the likelihood of loans' repayment, that is, the expected net rate of return on investment, $\pi^e - i$, and the degree of leverage, *l*. Whereas the former captures the "economic" value of the project to be financed, the latter provides information on the firms financial situation, and therefore on the financial risk incurred by lenders [6].

Equation [2.4] reflects the way agents assess the evolution of profitability conditions of investment projects. Because of the limited information set, they use a simple forecasting rule.[7] The idea is that when information is incomplete or asymmetric, the value of investment projects is not independent from firms' financial structure, since higher levels of debt signal an increase in the probability of bankruptcy. We thus assume that, in forming expectations of future profitability of investments, agents behave adaptively by looking at *current* profitability, $\pi - i$, that captures the economic return to investment, but adjust their assessment on the basis of the degree of leverage, l, that measures the "financial" robustness. In fact, a deterioration in the "state of confidence" or "market sentiment" due to a fall in the *current* economic return of investment is exacerbated by an increase in firms' financial fragility.

Equation [2.5] defines the evolution of foreign reserves, *fr*, as resulting from the balance of payments, where *f* represents non-debt creating inflows such as net exports and foreign direct investment. Equation [2.6] describes the currency-board arrangement by linking the money

[5] In fact, in a growing economy, liquidity should grow over time at the rate at which firms accumulate the stock of capital. The constraint from the currency-board arrangement implies that the above growth of the monetary base is always matched by the growth of foreign reserves.

[6] The function *φ(.)* captures at a macrodynamical level the essence of credit markets' behaviour, as stressed by the *Economics of Information and Incentives* approach, starting from the pioneering contributions of Stiglitz and Weiss (1981), Bernanke and Gertler (1987), Gertler (1988), among others. Such contributions provide the microeconomic underpinnings to the modern analysis of the real-financial interaction in macroeconomics, based on the "financial acceleration hypothesis" formulated by Bernanke-Gertler-Gilchrist (1999).

[7] The view that agents are limited in their cognitive skills and use heuristics to guide their behaviour in forecasting has become increasingly present in the literature on financial dynamics, since the works of Kirman (1993), Brock and Hommes (1997), Lux and Marchesi (2000). More recent contributions in this field are in De Grauwe and Grimaldi (2006), De Grauwe (2009).

supply to the evolution of the balance of payments. The last two equations jointly give the money supply at each time *t*, given the initial conditions. By integrating equation [2.5] we get $fr_t = m_t = l_t - \int_{v=0}^{t} il_v \, dv + \int_{v=0}^{t} f_v \; dv$, given the simplifying assumption that $fr_{t_0} = m_{t_0}$. Therefore, in line with the hypothesis on the currency arrangement, the money supply consists of the amount of foreign currency available in the economy at a given point in time, and its dynamics is linked to the evolution of the balance of payments.

Given the structure of the model, the uncovered interest parity holds, with a risk premium: as stated in equation [2.2], at each time *t* the interest rate adjusts instantaneously so as to eliminate imbalances between money demand and supply; the resulting interest-rate spread over the international rate closely reflects the credit market conditions, i.e., foreign lenders' willingness to provide finance, according to their assessment of firms' worthiness, on the basis of equation [2.3]

2.2 *Debt financing and growth*

The above equations describe a critical feature of a currency board, that is, the accumulation process and hence growth depend closely on the amount of external liquidity generated by trade surpluses and other nondebt creating flows, as well as foreign lending. As a stylised fact, persistent trade imbalances and the building up of large stocks of external debt characterise the growing process of several emerging small open economies, notwithstanding the relevance of the FDI inflows. Whereas in most countries external finance is strongly procyclical and output growth is matched by the increase in the volumes of debt, there is no clear-cut evidence of a similar pattern for net exports; as a result, the accumulation process of an economy in rapid growth turns out to rest mostly on debt financing. The expectation of blooming future profits and the perceived absence of currency risks may induce foreign lenders to ease the provision of finance. Over time an overborrowing process becomes unavoidable, leading to financial fragility and liquidity collapse. Since a currency board is a rigid institutional setting where monetary stabilization policies are ruled out, systemic instability becomes unavoidable. Hence a currency board may be viewed as a feasible exchange-rate arrangement only if a country is able to run persistent trade surpluses and/or attract non debt-creating flows.

In order to understand the consequences of a similar circumstance we modify the system of equations [2.1]-[2.6] by assuming that, in each period t , non-debt-generating net flows f are just sufficient to meet interest payments on the previous period debt. This amounts to assuming $\int_0^{t-1} il_v \, dv = \int_0^t f_v \, dv$ in equation [2.5], so that money supply at each time t is $m_t = l_t - i\, l_t$. It follows that net foreign currency accrues only through debt-creating flows, and over time, the growth of liquidity is matched by an increase of the stock of debt.[8] Such an assumption emphasises the two-fold nature of finance: it provides the means for economic growth, yet it generates cumulatively debt and undermines macroeconomic stability.

With the above assumption we are able to reduce the size of the system and perform a qualitative analysis of its dynamical behaviour in the long-run. Equations [2.1]-[2.6] are now reformulated as a system of four equations in the four unknowns y, i, l and ρ :

[2.7] $\alpha y - \gamma[(\alpha y + \rho - il) - i] = 0$

[2.8] $l - i\, l - \lambda(y, i) = 0$

[2.9] $\dot{l} = [\varphi((\alpha y + \rho - il) - i,\, l) - \gamma((\alpha y + \rho - il) - i)]\, l$

[2.10] $\dot{\rho} = \omega((\alpha y - il) - i,\ l)$

The two differential equations give us the law of motion of l and ρ with the temporary equilibrium values of y and i given implicitly (equations [2.7] and [2.8]), so as to satisfy instantaneously the goods and money markets equilibrium conditions, for given l and ρ. Accordingly, equations [2.7] – [2.10] generate a sequence of temporary equilibria in continuous time, that reflects the nonlinear real-financial interaction at work: the endogenously generated liquidity feeds back dynamically onto firms' investment, the level of output, the interest rate and the expected rate of return.

The working of the system is analogous to the one described in Franke-Semmler (1989), but here the particular currency arrangement makes the money-supply dynamics completely endogenous, and dependent on the balance of payment surpluses, for a given initial endowment

[8] In the empirical part of the model we shall remove the above hypothesis.

of foreign reserves. Equations [2.8] and [2.9] make clear that in our economy the financing of the accumulation process and hence growth totally rest on debt-creating capital inflows, given that in each period all other sources of external liquidity *f* are assumed to be devoted to the payment of the previous period interest obligations.

2.3 *The long-run dynamics of the model*

In a steady-state equilibrium the stock of debt per unit of capital and profitability expectations are unchanging through time so that, accordingly, output per unit of capital and the interest rate will cease to change. Hence, the amount of foreign reserves and liquidity grow at the rate at which output and the stock of capital are growing. In the long-run equilibrium we thus get

[2.11] $$\dot{l} = \left\{\varphi\left[\alpha\,\Psi\left(l^*,\rho^*\right) - \Theta\left(l^*,\rho^*\right)\left(1+l^*\right) + \rho^*\,;\,l^*\right] - \gamma\left[\alpha\,\Psi\left(l^*,\rho^*\right) - \Theta\left(l^*,\rho^*\right)\left(1+l^*\right) + \rho^*\right]\right\} l^* \equiv F^{\dot{l}}\left(l^*,\rho^*\right) = 0$$

[2.12] $$\dot{\rho} = \omega\left[\alpha\,\Psi\left(l^*,\rho^*\right) - \Theta\left(l^*,\rho^*\right)\left(1+l^*\right);\,l^*\right] \equiv F^{\dot{\rho}}\left(l^*,\rho^*\right) = 0$$

where $y = \Psi(l,\rho)$ and $i = \Theta(l,\rho)$ are the temporary equilibrium solutions of output and the interest rate that solve equations [2.7] and [2.8], which have been substituted into equations [2.9] and [2.10]; and where l^* and ρ^* denote the steady-state values of the stock of debt and the state of confidence, respectively.

The local stability analysis of the model is studied by evaluating the Jacobian matrix:

[2.13] $$J = \begin{bmatrix} F_l^{\dot{l}^*} & F_\rho^{\dot{l}^*} \\ F_l^{\dot{\rho}^*} & F_\rho^{\dot{\rho}^*} \end{bmatrix},$$

where the elements of the Jacobian matrix are the partial derivatives of the functions $F^{\dot{l}}$ and $F^{\dot{\rho}}$, given in equations [2.11]-[2.12], evaluated around the equilibrium point $\left(l^*,\,\rho^*\right)$:

$$F_l^{\dot{l}^*} = \left\{ \left(\varphi_1^* - \gamma'^*\right)\left[\alpha\ \Psi_l^* - \Theta_l^*\left(1 + l^*\right) - \Theta^*\right] + \varphi_2^* \right\} l^*$$

$$F_\rho^{\dot{l}^*} = \left\{ \left(\varphi_1^* - \gamma'^*\right)\left[\alpha\ \Psi_\rho^* + 1 - \Theta_\rho^*\left(1 + l^*\right)\right] \right\} l^*$$

$$F_l^{\dot{\rho}^*} = \omega_1^* \left[\alpha\ \Psi_l^* - \Theta_l^*\left(1 + l^*\right) - \Theta^*\right] + \omega_2^*$$

$$F_\rho^{\dot{\rho}^*} = \omega_1^* \left[\alpha\ \Psi_\rho^* - \Theta_\rho^*\left(1 + l^*\right)\right].$$

By looking at the system of equations [2.11] - [2.12], it appears that the equilibrium levels of l and ρ impact on the law of motion of l and ρ directly, but also indirectly through an effect on the equilibrium level of the profit and interest rates. Hence, the above partial derivatives $\varphi_1 > 0, \varphi_2 < 0$ and $\omega_1 > 0,\ \omega_2 < 0$ capture the direct effects, whereas $\Psi_l^* > 0$, $\Psi_\rho^* > 0$, $\Theta_l^* < 0$, $\Theta_\rho^* > 0$ capture the indirect effects through the impact onto the profit and the interest rates.[9]

It thus follows that the signs of the elements of the Jacobian matrix depend on the combination of the above direct and indirect effects. In particular, $F_l^{\dot{l}^*} < 0$ if the negative effect of leverage on liquidity growth, measured by φ_2, dominates the positive indirect effect of liquidity on net profitability - the term in square brackets. Similarly, $F_\rho^{\dot{l}^*} > 0$ when the positive direct effect of ρ on liquidity growth, measured by $\varphi_1^* - \gamma'^*$, is coupled with a positive feedback effect on net profitability. Analogously, $F_l^{\dot{\rho}^*} < 0$ if $\left|\omega_2^*\right|$ is sufficiently high, so that the negative impact of leverage on the state of confidence offsets the indirect positive effect of liquidity on net profitability, whereas $F_\rho^{\dot{l}^*} < 0$ when the indirect impact is negative and dominates. Finally, the sign of $F_\rho^{\dot{\rho}^*}$ depends on the relative influence of ρ on the profit rate and the interest rate, respectively.

[9] The sign of Θ_l^* depends on the interest rate elasticity of money demand with respect to the interest rate elasticity of money supply, given the endogeneity of money supply. The negative sign follows from the assumption that an increase in the interest rate brings about a reduction in the demand for money greater than the reduction in the money supply. The latter is due to the reduction in foreign reserves determined by the increase in the debt service.

As usual the Routh-Hurwitz conditions for stability are

1 [2.14] $$tr\ J = F_l^{\dot{l}^*} + F_\rho^{\dot{\rho}^*} < 0$$

[2.15]

$$det\ J = F_l^{\dot{l}^*} F_\rho^{\dot{\rho}^*} - F_\rho^{\dot{l}^*} F_l^{\dot{\rho}^*} > 0$$

Given the above signs of the elements in the Jacobian matrix, it appears that a negative trace may result for a relatively strong sensitivity of lenders to leverage that accounts for $F_l^{\dot{l}^*} < 0$, coupled with a weak indirect response of *y* and *i* to expectations, that implies that $F_\rho^{\dot{\rho}^*} > 0$.

As to the determinant, the sign depends on the resulting effect of stabilizing and destabilizing forces at work in the nonlinear interaction. In particular, if improving expectations burst capital inflows, meanwhile the increase in firms' leverage does not curb the state of confidence, the economy may move along a destabilizing path. In such a case we have $F_\rho^{\dot{l}^*} > 0$ $F_l^{\dot{\rho}^*} > 0$. Instability may yet be ruled out if $F_l^{\dot{l}^*} F_\rho^{\dot{\rho}^*} > 0$ and sufficiently high, that is, if lenders' willingness to provide finance responds adequately to a high leverage, and over time the evolution of expectations is not explosive.

The macrodynamical behaviour of the model is the result of the nonmarket-clearing feature of the model that stems from the assumptions on the credit market behaviour in its interaction with the formation of profitability expectations. In fact, equations [2.9] and [2.10] imply that lenders resort to non-price screening of borrowers in order to assess their worthiness, whereas the formation of expectations reflects the limited-information environment. Because of the feed-back effects at work, the model displays an out-of-equilibrium dynamics, albeit the assumption that imbalances in the goods and the money market adjust instantaneously through the changes in quantities and prices.

In conclusion, the model exhibits different behaviours, depending on the assumptions regarding the various reaction functions, which basically reflect the attitude of the economy to incur into external overborrowing. This may happen in periods of expanding economic activity when the perception of financial risk is low. Over time, the building up of debt in firms' balance sheets determines financial fragility. When increased interest rates start reducing profitability conditions, and lenders become less willing to provide finance, then a downward swing may start. The loss of confidence in the currency arrangement may then exacerbate the perception of financial fragility, and the lower levels of debt in firms' balance sheets may not be sufficient to restore profitability expectations. The economy may thus be exposed to a capital flight. Since in the model money is completely endogenous a financial collapse may cause macroeconomic instability with no other way out than abandoning the currency arrangement.

In order to enrich the above qualitative analysis in the following section we consider the experience of Argentina during the currency board.

3. *Continuous-time estimation*

3.1 *The empirical model*

We now reformulate the theoretical model [2.1]-[2.6] in view of its estimation for Argentina. In order to emphasise the out-of-equilibrium dynamical feature of the model, we abandon the instantaneous adjustment hypothesis previously made for the goods and money markets, while we retain the assumptions on the macrodynamic adjustment mechanisms that govern the two markets: a quantity adjustment process for the goods market and a price adjustment mechanism for the money market. The idea is that the goods market behave in a rather "Keynesian" fashion, with output adjusting to discrepancies between desired and actual expenditure, given price stickiness; on the other hand the money market behaves in a "traditional" fashion, i.e., according to a "cross-dual dynamics" so that interest rates adjustments are a sign-preserving function of excess demand.[10] The above feature is in line with the observed volatility in the money-market short-term interest rates; this fact, implies that interest rate spreads reflect the "state of liquidity" of the economy. All other dynamical equations of the empirical model are in line with the theoretical framework outlined in the previous section.The model thus consists of the following five differential equations:

[3.1] $$\dot{y} = \left[k_1 d_1 + k_0 \left(1 - d_1\right)\right] \left(\gamma[\pi^e - i] - s + nx - il\right)$$

[10] The two adjustment mechanisms are also referred to as "dual dynamics" and "cross-dual dynamics", in the case of the Keynesian and the classical mechanisms, respectively (Morishima, 1976).

[3.2] $\dot{i} = k_2 \left(m^d - m\right)$

[3.3] $\dot{l} = \left[\left(k_3\left(\pi^e - i\right) - AVED\right) + p_1\left(l - AVL\right) - \gamma[\pi^e - i]\right]l$

[3.4] $\dot{\rho} = \left[\left(k_4\left(\pi - i\right) - AVD\right) + o_1\left(l - AVL\right)\right]$

[3.5] $\dot{fr} = \dot{l} - il + nx$

[3.6] $\dot{m} = \dot{fr}$, with $fr_{t_0} = m_{t_0}$

where:

[3.7] $\gamma[\pi^e - i] = \gamma_0 + \gamma_1\left(\pi^e - i\right)$, with $\pi^e = \alpha y + \rho - il$, $\pi = \pi^e - \rho$

[3.8] $m^d = h_0 y + h_1 i$

[3.9] $nx = m_0 + m_1 y_w + m_2 y + m_3 tcm$

Equation [3.1] states that output adjusts to discrepancies between desired and actual expenditure. A dummy d_1 is considered for the initial period (1991.1 – 1991.3) and the final period (1998.3 – 2001.2), as well as for the period of the Mexican crisis (1994.4 – 1995.2). This is to take into account that in such periods monetary policy was not strictly adherent to the currency board arrangement.[11] Equation [3.2] posits that interest-rate changes overtime are driven by discrepancies between money demand and supply. Equation [3.3] explains the behaviour of credit markets, by stating that capital inflows depend positively on the deviations of the expected net profitability from its average value *AVED*, and negatively on the difference between the stock of debt and its average value *AVL*. Equation [3.4] formulates profit expectations formations as a positive function of the discrepancy between current profitability and its average value *AVD* and a negative function of the difference between the stock of debt and its average value *AVL*.

[11] Note that, for the empirical investigation, savings are drawn directly from the database, in accordance with the theoretical model where the accumulation process drives the dynamical process.

Equations [3.5] states that the dynamics of foreign reserves is the outcome of debt-creating capital flows, net of interest payments, and of the balance of trade.[12] Equation [3.5] and [3.6] jointly describe the currency-board arrangement, where money is completely endogenous being exclusively dependent on the balance of payments, so that, at each point *t*, $m \equiv fr$ when the initial stock of money is exactly equal to the initial stock of foreign reserves. Equations [3.7]-[3.9] provide the functional forms for aggregate investment expenditure, the money demand and the trade balance, where the expected net profit is defined as in the theoretical part, y_w is world output and tcm is the multilateral real exchange rate.

Equations [3.1] – [3.4] include error terms, which are omitted to simplify the notation. Such residuals are assumed to possess the standard proprieties for the solution of systems of stochastic differential equations.[13]

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[12] All other terms of the balance of payments, having resulted negligible, are included in the estimation of the constant m_0.

[13] The following are the properties of the error term u_t

(I) $\boldsymbol{u}(t) = d\boldsymbol{\phi}(t)/dt$

and

(II) $$\begin{cases} E[\boldsymbol{\phi}(t)] = \boldsymbol{0} \\ E[\boldsymbol{\phi}(t_1) - \boldsymbol{\phi}(t_2)][\boldsymbol{\phi}(t_3) - \boldsymbol{\phi}(t_4)]' = \boldsymbol{0}, \forall t_1 > t_2 \geq t_3 > t_4. \\ E[\boldsymbol{\phi}(t+h) - \boldsymbol{\phi}(t)][\boldsymbol{\phi}(t+h) - \boldsymbol{\phi}(t)]' = \boldsymbol{\Omega}(h) \end{cases}$$

where $u(t)$ is a white noise residual and $\Omega(h)$ is a matrix of constants.

The first property is required to perform the integration necessary to solve the system of stochastic differential equations. The second property is needed to obtain a solution where residuals, obtained after having performed the necessary double integration for the variables to be measurable in presence of stocks and flows, are uncorrelated (Gandolfo, 1981). We underline also that the continuous-time estimator may be obtained under the assumption that the integral of the white noise innovation process is a Gaussian process although the innovations themselves are not assumed to have that property.

1.1.1.1

1.1.1.2 3.2 Methodology and data

The adjustment-form specification of the differential equation system proves to be useful because it allows an immediate check on the convergence of the system, directly from the estimation of the *speed-of-adjustment* coefficient. In fact, the reciprocal of the speed of adjustment is proved (Gandolfo (1981)) to be the mean time lag, i.e. the time required in order to cover the 63% of the gap between the actual and the target (desired or benchmark) value. As known, the value of a single coefficient provides only a *partial* characterization of the dynamical behaviour of the system. Indeed, in order to study the overall dynamical behaviour of the model, we need to first estimate equations [3.1]-[3.4] and then proceed with the calculation of the fixed points and the eigenvalues, after suitable linearisations have been made.

The continuous time estimation represents the most straightforward method for the stability analysis, due to the following advantages: 1) a strict adherence to the theoretical scheme proposed, which is in continuous time as well; 2) an estimation that accounts for the solution of the dynamic system under consideration 3) the possibility to study the stability of the steady state starting from a set of *disequilibrium* relationships, as given in the system [3.1]-[3.4], instead of imposing the steady-state condition *a priori*, as often happens in general equilibrium models (Bee-Espa-Gabriele-Maggi-Piras (2008)); 4) the possibility to perform a sensitivity analysis by exploring the effect on eigenvalues of a change in the parameters of the model. This allows to derive implications on dynamics and stability of the model; 5) the FIML estimator of continuous-time models is super-efficient in that the estimator of parameters and their asymptotic standard errors converge at a rate of $O(T^{-1})$ where T is the sample size, whereas FIML estimators of discrete models converge at a rate of $O(T^{-1/2})$ as $T \rightarrow +\infty$ (Wymer (1997)).

In the analysis we opt for the FIML method in the class of non-linear continuous time estimators. Estimations are performed by means of C. Wymer "Escona" (2005) programme. The choice of the mentioned programme is in that it allows us to use the technique named *exact discrete analogue* for non-linear models. Such a technique consists in solving *exactly* the system [3.1]-[3.5] from which the likelihood derives, instead of *approximating* it. In this way we skip the critique made by Phillips (1991) on the equivalence between continuous time estimation and cointegration, as argued in Maggi et al. (2009).

As to data, the following are the variables considered: output, savings, investments, interest rate, profits, state of confidence, foreign reserves, trade balance, liquidity, capital, debt, multilateral real exchange rate, and world output. Output is GDP, savings is private and public. Profits amount to around the 30% of output as from the micro data on income distribution in the "Encuesta Permanente de Hogares" elaborated by Gasparini (2007). The interest rate is the money market rate. The stock of liquidity is generated over time through the accumulation of net capital inflows and hence it is identified with the stock of foreign reserves in accordance with the currency-board hypothesis. The state of confidence is calculated as a four terms moving average of the difference between output and potential output in percentage terms. Stocks and flows are expressed in units of capital; all variables are expressed in real terms, with data deflated at 2000 prices. We use quarterly (own calculations) data based on the EIU country dataset for the period 1991-2001 for all the variables, but for the multilateral real exchange rate, savings and world output, which are drawn from Central Bank of Argentina, Penn World Tables 6.1 and IMF sources, respectively.

3.3 *The estimation*

The FIML parameter estimates, standard errors and t-values are given in Table 1. The point estimates there reported have an asymptotic normal distribution that gives significant coefficients above 1% level for all the coefficients. All parameters' estimates have plausible values and theoretically correct signs confirming that the behavioural assumptions of the theoretical model are empirically supported by Argentina's data. As to the speed-of-adjustment coefficients, they all are positive and below unity. In particular, the dynamics of the stock of debt responds positively to the deviations of expected net profitability of firms (k_3) and negatively to the deviations of the level of debt (p_1), whereas the dynamics of the state of confidence depends positively on the deviations of the current net profit rate (k_4) and negatively on the deviations of the level of debt (o_2). Table 1 also shows that the export and import propensities (m_1 and m_2, respectively) have the correct signs, with a rather higher value for the latter, underlining the structural weakness of Argentina's trade structure. Such a feature points to the relevant imbalance of the external sector that was financed by debt-creating liquidity.

Table 1 – Continuous time parameters estimates

Parameter	Point FIML Estimates	Asymptotic Standard Error	t-values
γ_0	0.072	0.002	7.2
γ_1	0.30	0.087	174.41
h_0	1.20	0.022	3.34
h_1	-5.70	0.105	4.11
k_1	0.60	0.0002	5.08
k_2	0.705	0.226	4.93
k_3	0.404	0.205	34.26
p_1	-0.49	0.241	3.93
k_4	0.15	0.075	7.11
o_1	-0.69	0.239	3.11
k_0	0.61	0.004	5.08
m_0	0.046	0.002	72.39
m_1	0.075	0.004	5.06
m_2	-0.315	0.104	67.95
m_3	0.039	0.001	3.05
Constants: α= 0.3, *AVED* = 0.095, *AVD* = 0.035, *AVL* = 0.04			

Log-likelihood value = 0.7202188E+03, F_{Pvalue}= 0.000, R_c^2 = 0.85

As far as the interest rate is concerned, equation [3.2] may be easily expressed in terms of its actual value instead of the excess demand function:

[3.2'] $$\dot{i} = |h_1| k_2 \left(\frac{h_0}{|h_1|} y - \frac{m}{|h_1|} - i \right)$$

where the new - implicit - speed of adjustment denotes a super convergence ($|h_1| k_2$ >1) of the interest rate. This is an expected result coherent with the rapid reaction of the money market to disequilibrium that confirms the validity of the money-market adjustment specification, as given in equation [3.2].

However, with reference to simultaneous continuous-time differential equations, in a dynamical setting the well-behaving of a single parameter is not sufficient *per se* to ensure stability. Thus, we now turn to the study of the stability of the model.

4. *The long-run behaviour of the economy*

4.1 *Steady-state solution*

On the basis of the estimations of the previous section, we are able to study the long-run behaviour of the model. Hence, fixed points are obtained by imposing that y, i, l, ρ, fr be constant over time. We can thus use the estimated parameters to derive the steady-state solutions of the above variables as functions of the constant terms and the exogenous variables of the empirical model, i.e., world output per unit of capital and the multilateral real exchange rate.

Then, by positing $\dot{y}=0$ in eq. [3.1] and rearranging terms, we get:[14]

$$[4.1] \qquad \pi^e - i = \alpha y + \rho - il \text{ - } i = \frac{1}{\gamma_1}\left(-\gamma_0 + \alpha y - nx\right).$$

We first use the above expression in equation [3.3] to get rid of the interest rate, and then impose $\dot{l}=0$ to get an expression of the stock of debt as a function of output and the exogenous variables:

$$[4.2] \qquad y = \frac{Z}{\zeta} - \frac{p_2}{\zeta} y$$

where

$$\left[k_3\frac{\alpha}{\gamma_1} - k_3\frac{m_2}{\gamma_1} - \alpha + m_2\right] = \zeta;$$

$$\begin{bmatrix} +k_3\dfrac{\gamma_0}{\gamma_1} + k_3\dfrac{m_0 + m_1 y_w + m_3\, tcm}{\gamma_1} \\ +k_3 AVED + p_2 AVL - m_0 - m_1 y_w - m_3\, tcm \end{bmatrix} = Z$$

We then plug [4.2] in [3.4], and use the conditions $\dot{\rho}=0$ and $\dot{fr}=0$. The latter has the consequence that the flow of interest repayment on outstanding debt is exactly matched by a corresponding trade surplus, given that $\dot{l}=0$, i.e. $nx = il$. With the above rearrangements we get the stock of debt as a function of the exogenous variables and the interest rate:

$$[4.3] \qquad l = \frac{1}{\beta}k_4 i + \frac{1}{\beta}B,$$

where

[14] Note that, in order to find the steady state, we are here using the saving function defined in the theoretical section.

$$\left(o_2 - k_4(\alpha - m_2)\frac{p_2}{\zeta}\right) = \beta;$$

$$-k_4(\alpha - m_2)\frac{Z}{\zeta} + k_4 AVD + o_2 AVL + k_4(m_0 + m_1 y_w + m_3 tcm) = B$$

We finally implement the condition $\dot{fr} = 0$, that is:

[4.4] $nx = il$

and use [4.2] and [4.3] in [4.4] to derive the parabolic equation for the interest rate:

[4.5] $$\left(\frac{1}{\beta}k_4\right)i^2 + \left(\frac{1}{\beta}B + \frac{p_2 k_3}{\zeta}\frac{m_2}{\beta}k_4\right)i + \left(-m_0 - m_1 y_w - m_2\frac{Z}{\zeta} + \frac{p_2}{\zeta}\frac{m_2}{\beta}B - m_3 tcm\right) = 0.$$

From [4.5] we derive two steady-state solutions for the interest rate that allow to find the corresponding equilibrium values for debt, output, the state of confidence and foreign reserves by exploiting respectively [4.3], [4.2], [4.1] and [3.2].

The first steady-state solution corresponds to a *low interest-rate equilibrium*, the second to a *high interest-rate equilibrium*.

The values obtained are reported in the following Table 2.

Table 2. Equilibrium values of the endogenous variables (percentage values)

Equilibria	i^*	l^*	y^*	ρ*	fr*

low interest-rate equilibrium	0.014	15.60	22.380	1.623	26.776
high interest-rate equilibrium	30.35	3.89	18.706	0.021	5.148

The first equilibrium is associated to relatively high values of liquidity, output and foreign reserves while the second equilibrium is associated to low levels of output and liquidity. This is in line with the underlying reasoning of the model that, for a given profit rate, low interest rates imply high economic returns and, hence, capital inflows whereas the opposite holds in case of high interest rates.

The full characterization of the dynamical behaviour of the model calls for a sensitivity analysis.

4.2 *Stability and sensitivity analysis*

In this section we study the local stability of the two equilibria and perform the sensitivity analysis by means of C. Wymer (2005) "Contines" programme for continuous time estimations. To this aim, we proceed to a linearisation around each steady-state equilibrium of the non-linear model [3.1]–[3.6] calculated on the basis of the estimated coefficients given in Table 1. Such a procedure is here applicable in accordance with the Poincarè-Liapunov-Perron theorem for autonomous systems.[15]

Tables 3 and 4 report eigenvalues corresponding to each distinct equilibrium.

By comparing the two tables, it emerges that the characteristic equation associated to low interest-rate equilibrium has one root with positive real part, and all remaining roots with negative real part, whereas in the case of the high-interest rate equilibrium there are two roots

[15] As argued in Gandolfo (1981, 1993), the re-estimation of the linearized model could lead to strongly different results; for this reason we opt for the linearization of the non-linear estimated model in order to study the local stability.

with positive real part and all others with negative real part. Moreover the former equilibrium is characterised by a lower number of complex and conjugated roots and smoother oscillations, as indicated by the smaller period of the cycle.

Table 3. Stability analysis. Eigenvalues for the low interest-rate equilibrium

Eigenv alues	Real part	Imagina ry part	Mo dulus	Damping period	Period of cycle
1	0.076031 1		0.07 603		
2	- 0.44596488		0.44 596	2.242	
3	- 4.10892392		4.10 892	0.243	
4	- 0.12804115	0.23071	0.26 386	7.810	27.235
5	- 0.12804115	- 0.23071	0.26 386	7.810	27.235

Table 4. Stability analysis. Eigenvalues for the high interest-rate equilibrium

Eigenv alues	Real part	Imagina ry part	Mod ulus	Damping period	Period of cycle
1	- 4.11063092		4.11 063	0.243	

2	0.02492971	0.03438	0.04247		182.752
3	0.02492971	-0.03438	0.04247		182.752
4	-0.33708425	0.23362	0.41013	2.967	26.895
5	-0.33708425	-0.23362	0.41013	2.967	26.895

Therefore, although at a different degree, both equilibria are unstable, given that the presence of one unstable root violates the Lyapunov exponential stability criterion (Khalil (2002)).

Hence, neither the correct signs of the speed-of-adjustment coefficients nor the high sensitivity of the money market are sufficient for stability.

Indeed, the linearised systems, associated to Tables 3 and 4, are characterized by indecomposable matrices and, by virtue of Frobenious theorem, correspondingly strictly positive eigenvectors associated to the dominant eigenvalues. This ensures the effectiveness of the dominance of such eigenvalues in achieving the two equilibria, and given that the aforementioned eigenvectors refer to the money market equation, we draw the conclusion that stability is driven by the adjustment on the money market. Yet, the above property is scarcely appealing as it applies only at infinity and till that time the contribution of the unstable eigenvalues are at work. Moreover, initial conditions always exist that are able to annihilate the stabilizing effect of the negative – dominant included - eigenvalues. A convergence path may exists, given the presence of at least one stable root in both solutions, but the system could still be characterised by an oscillatory behaviour that would impose considerable costs to the economy.

Therefore, the money supply shortage, deriving from balance of payments problems, may actually leads to a *not wholly stable* dynamic system.

In order to highlight the contribution of each coefficient to the dynamics of the model, we perform a sensitivity analysis consisting in the calculation of the change in the eigenvalues resulting from a change in the values of the estimated parameters. Table 5 and Table 6 refer, respectively, to the case of low and high interest-rate equilibrium.

Table 5. Sensitivity matrix with respect to the parameters of the system. Low interest-rate equilibrium.

		Eigenvalues				
		1	2	3	4	
		Real	Real	Real	Real	Imaginary
	Parameter Value	0.076	-0.446	-4.1089	-0.128	0.2307
a_0	0.072	0	0	0	0	0
a_1	0.3	-0.3848	-1.3102	0.5627	0.6597	-1.0214
h_0	1.2	-0.006	0.0025	0.0306	-0.0136	0.0062
h_1	-5.7	0.0108	0.0014	0.6888	0.002	0.0055
k_1	0.6	-0.018	-0.3618	0.18	-0.0888	0.122
k_2	0.705	0.0016	-0.0013	-5.6942	-0.0031	-0.0005
k_3	0.4	0.2342	0.8439	-0.2256	-0.4263	1.4358
p_2	-0.49	0.05	0.545	0.00	0.19	0.378

		14	8	61	84	7
k_4	0.15	-0.4106	-0.0162	-0.0197	0.2233	-0.1218
o_2	-0.69	-0.092	-0.0293	0.0005	0.0604	-0.2416
m_0	0.046	0	0	0	0	0
m_1	0.075	0	0	0	0	0
m_2	-0.315	-0.0067	0.2977	-0.0083	0.1587	-0.0084
m_3	0.039	0	0	0	0	0

Table 6. Sensitivity matrix with respect to the parameters of the system. High interest-rate equilibrium.

	Eigenvalues	1	2		4	
		Real	Real	Imaginary	Real	Imaginary
	Parameter Value	-4.1106	0.0249	0.0344	-0.3371	0.2336
a_0	0.072	0	0	0	0	0
a	0.3	0.556	0.79	2.476	-	-0.6467

1		1	38	9	0.9782	
h_0	1.2	0.0306	-0.0082	0.0046	-0.0071	0.0111
h_1	-5.7	0.6881	0.0061	-0.0003	0.0024	0.0067
k_1	0.6	0.1767	-0.0359	0.0385	-0.2411	0.0964
k_2	0.705	-5.6911	0.0003	0.0004	-0.0048	-0.0034
k_3	0.4	-0.2294	-0.6115	-1.5005	0.7261	1.0935
p_2	-0.49	0.0065	-0.0599	-0.164	0.5566	0.2058
k_4	0.15	-0.0193	-0.0146	10.223	0.0242	-0.1374
o_2	-0.69	0.0005	0.0242	0.1742	-0.0244	-0.2065
m_0	0.046	0	0	0	0	0
m_1	0.075	0	0	0	0	0
m_2	-0.315	-0.008	0.1116	0.2189	0.1924	0.0635
m	0.039	0	0	0	0	0

3						

In accordance with the reasoning of the theoretical model, we find p_2 and h_1 as the parameters that mostly influence the dynamics. More specifically, an increase in p_2 leads to positive changes in the (real part) of the eigenvalues in the low-interest rate equilibrium, thus indicating an increase in the degree of instability. The parameter p_2 measures the effect on capital inflows of an increase in the degree of leverage above its average value. Given the negative sign of the parameter, the sensitivity results imply that a reduction in lenders' responsiveness to the deterioration of firms' balance sheets (increase in p_2) raises the degree of instability. As regards h_1, the analysis shows that a reduction in the sensibility of the money market to the interest rate, i.e., an increase in h_1 since $h_1 < 0$, augments the degree of instability. Following the theoretical analysis of section 2, this is explainable in terms of the higher interest rates required to adjust the money market in the presence of an excess demand for money. Higher interest rates exert a negative feedback effect on investment and output, as well as on the money supply, the latter due to the fall in reserves owing to the increase in the burden of debt.

It is worth-noticing the relevance of contribution to stability induced by a slight change in the money market adjustment parameter (k_2) in line with the arguments put forward above.

From this evidence we conclude that the nonlinear real-financial interactions at work in the system are hardly compatible with the rigidity of the currency-board arrangement.

2 5. *Stabilizing an unstable economy: the role of a countercyclical monetary policy*

5.1 *Modelling a countercyclical monetary policy*

In a currency board, money supply strictly matches foreign reserves and there is no room for an autonomous monetary policy. As a matter of fact, monetary authorities in Argentina departed from a strict implementation of the rules by loosening the proportionality coefficient between foreign reserves and domestic liquidity during the periods of consistent reduction in capital inflows, in particular in the aftermath of the Mexican crisis of 1994-95. Yet, the abandon of the currency board was, at the end, unavoidable due to the impressive shrink in liquidity brought about by the capital outflows, the consequent fall of output and rise in unemployment. The estimations obtained for Argentina clearly underline the intrinsic instability of such a currency arrangement that makes the stock of money completely endogenous and totally dependent on the external balance, when a relevant share of capital inflows are debt-creating.

With the aim of further supporting our argument, we run a comparative dynamics exercise to highlight that an active monetary policy would have prevented the unstable dynamics. By so doing we support the argument that hard pegs do not protect from a currency crisis, inasmuch as financial fragility makes the commitment to maintain the peg unsustainable.

We thus modify the system [3.1]–[3.6] in order to allow for an independent monetary policy, as described by the following simple monetary rule:

$$[5.1] \qquad \dot{m}/m = \dot{fr}/fr + \eta(i - \bar{i}) \qquad \text{with} \quad \eta > 0$$

The above equation is used instead of equation [3.6]. According to the rule, when the interest rate goes above its "normal" level $\bar{i}$, the money supply growth exceeds the rate at which foreign reserves are accumulated. From a dynamical point of view, we are adding an additional nonlinearity to an otherwise unstable system, in order to induce stability.

5.2 *Monetary rule and stability*

We run again the stability analysis of the modified model by taking the steady-state interest rates calculated above as the "normal" levels in equation [5.1]. We find that, for both the high and the low-interest rate equilibrium, there exists a value of the elasticity η that makes the system stable. The values are $\eta_H = 0.32$ and $\eta_L = 0.6$ respectively, meaning that the monetary policy effort to gain stability amounts to 32% and 60%, respectively, of the interest rate difference. Tables 7 and 8 below show the eigenvalues matrixes for the stabilizing monetary policy.

Table 7. Stabilizing monetary policy: eigenvalues for the low interest-rate equilibrium. η_L =0.60

Eigenvalues	Real part	Imaginary part	Modulus	Damping period	Period of cycle
1	-0.00345114		0.00345	289.759	
2	-0.44355844		0.44356	2.254	
3	-4.00582152		4.00582	0.25	
4	-0.14105445	0.239683	0.27811	7.089	26.215
5	-0.14105445	-0.23968	0.27811	7.089	26.215

Table 8. Stabilizing monetary policy: eigenvalues for the high interest-rate equilibrium. η_L =0.32

Eigenvalues	Real part	Imaginary part	Modulus	Damping period	Period of cycle
1	-	405.637	0.24		

	4.05636511		7		
2	-0.0002399	0.056071	0.05607	4168.412	112.058
3	-0.0002399	-0.05607	0.05607	4168.412	112.058
4	-0.33904754	0.239434	0.41507	2.949	26.242
5	-0.33904754	-0.23943	0.41507	2.949	26.242

According to our calculations, the higher the equilibrium interest rate the lower the intensity of the monetary intervention required with respect to the interest-rate gap in the high- and low-interest rate equilibrium, respectively.

In fact, when the system moves around the low-interest rate equilibrium, the gap $\left(i-\bar{i}\right)$ is likely to be smaller than in the higher case, due to the lower degree of instability. Consequently, given the proximity to zero of the low interest rate, a higher effort of the monetary policy is necessary in order to reduce the gap.

Overall, the conclusion we draw from the empirical analysis is that the unstable dynamics of the system is hardly compatible with the intrinsic rigidity of a currency board where a relevant stabilization policy tool is not available.

6. *Concluding remarks*

In the paper we address the issue of financial instability for a country with a super-fixed exchange rate.

The theoretical model represents an economy where the liquidity creation process is fundamentally endogenous and based on net capital inflows: the evolution of external finance, and hence debt accumulation, are closely linked to the economy's macroeconomic performance; the latter, in turn, is strongly influenced by the availability of liquidity. The intrinsic dynamical interrelation between the real and financial variables is such that the expanding process of the economy creates itself the conditions for the reversal of the process. In fact, in accordance with the "financial fragility hypothesis", in the course of an upswing an accentuated growth of financial aggregates takes place, and the stock of outstanding debt becomes dangerously high. The resulting financial fragility drives an economic downswing, that brings about a capital reversal and the consequent drop of output.

In the presence of a currency-board arrangement, financial instability is amplified by the absence of monetary policy tools for stabilization purposes: the liquidity which would be necessary to avoid a financial distress cannot be provided. The consequent macroeconomic turmoil may call into question the currency arrangement and lead to a currency crisis.

The continuous-time empirical investigation shows that the theoretical analysis portrayed in the paper well represents the experience of Argentina during the years of the currency-board arrangement. The estimations validate the "financial fragility hypothesis" for a small open economy that adopts a hard peg, within the context of liberalized financial markets. In the above setting, the increased access to international finance is at the basis of an external overborrowing process that boosts growth, at the expense of strong imbalances in the private as well as the public sector. Within this context, the lack of monetary policy tools makes the economy vulnerable to the financial markets' sentiment, thus making the macroeconomic distress unavoidable.

In fact, the dynamical behaviour of the system is characterised by the existence of two unstable steady-state equilibria with the sensitivity analysis showing that the degree of instability increases in the presence of a reduction in lenders' responsiveness to the deterioration of firms' balance sheets, as well as of a reduction in the interest-rate sensitivity of money demand. The stability of the system resulting from a deviation from a currency arrangement, with the monetary authority implementing an autonomous monetary policy, sheds light on the critical role of the currency arrangement rigidity in determining the crisis.

Acknowledgments

The authors wish to thank C. Wymer for suggestions and helpful comments on the empirical analysis. We also wish to thank participants to 11th Workshop of the Research Network Macroeconomic Policies on *Finance-led capitalism? Macroeconomic Effects of Changes in the Financial Sector*, Berlin October 2007, where a preliminary version of the paper was presented. B. Maggi wishes to thank for financial support from "Ricerca di Ateneo Federato anno 2007-prot. C26F078JZR". Although the present research has been conducted with the joint contribution of all the authors, paragraphs 3.2, 3.3, 4.1, 4.2, 5.2 are attributed to B. Maggi, paragraphs 1, 2.1, 2.3, 3.1 to E. Cavallaro, paragraphs 2.2, 5.1, 6 to M. Mulino.

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2.1 Heading 2

2.1.1 Heading 3