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Foreign Exchange Reserves in a Credit Constrained Economy

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Abstract

We discuss the role of foreign exchange reserves as precautionary savings under an imperfect market framework due to the presence of endogenously determined borrowing constraints. We show that cost of holding reserves is higher in borrowing constrained economies than unconstrained ones as a result of the leverage effect of the debt. We also argue that high global reserve holdings can even be welfare reducing for the world economy where financially constrained developing countries are heavy borrowers in international lending markets.

JEL Classification: F32, F34.

Keywords: Foreign Exchange Reserves, Credit Constraints.

1 Introduction

We examine the impact of foreign exchange reserve holdings under an imperfect market framework due to the presence of borrowing constraints. We suggest that cost of reserve holdings is higher in borrowing constrained economies than unconstrained ones as a result of the leverage effect of the debt. We also argue that high global reserve holdings can even be welfare reducing for the world economy where financially constrained developing countries are heavy borrowers in international lending markets.

The last decade witnessed a substantial increase in foreign exchange reserve holdings of central banks. The level of global reserve holdings reached to a peak of USD 7,3 billion at the end of 2008 which is around 12 percent of the world GDP (Figures 1 and 2). This surge in reserves is mainly driven by central banks of developing countries.

Central banks prefer safe and liquid assets while building up their reserve stocks which could cushion the shock in cases where external borrowing is either ceased or limited. Accordingly, Figure 3 reveals that a significant portion of the international reserve stock is accumulated in US dollars or Euros. The sizeable level of reserves points out a substantial flow of capital from developing countries to developed areas. This reverse capital flow can be suggested as an explanation of Lucas Paradox. Standard neoclassical theory implies that capital should move from rich to poor areas until marginal product of capital is equalized in both. However, Lucas (1990) argues that, given the difference in return on capital, this flow is not as strong as predicted by theory. A number of studies point to capital market imperfections as an explanation to Lucas Paradox [1]. Gertler and Rogoff

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[1] See Reinhart and Rogoff (2004) and Alfaro, Özcan and Volosovych (2005) for a review of this literature.

Figure 1: Foreign Exchange Reserves

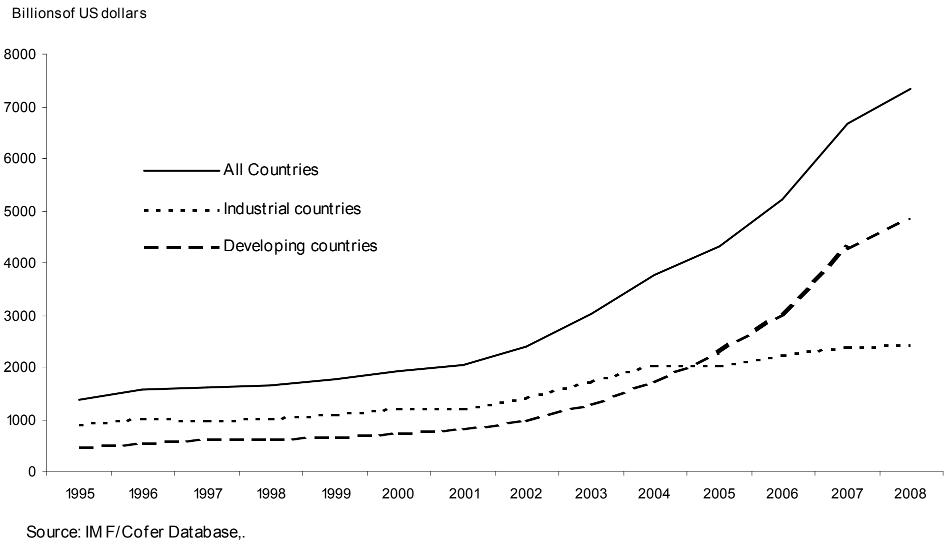


Figure 2: Reserves as a percentage of World GDP

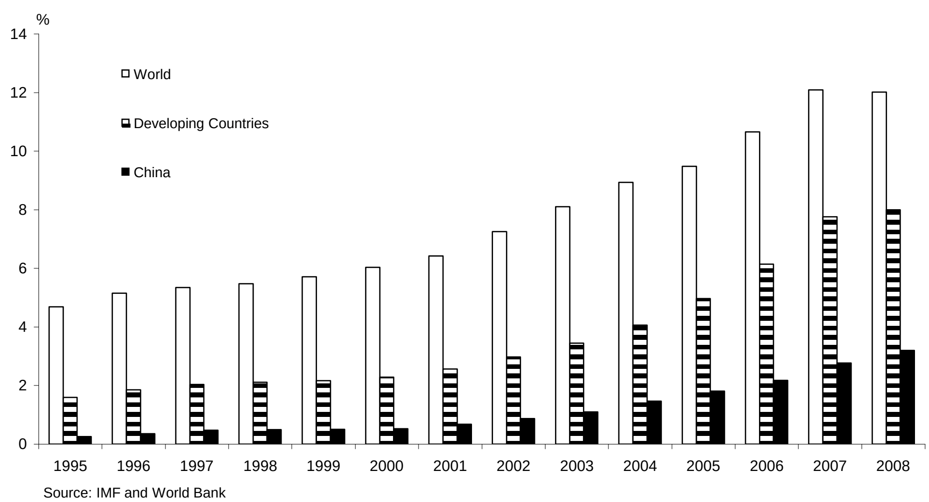
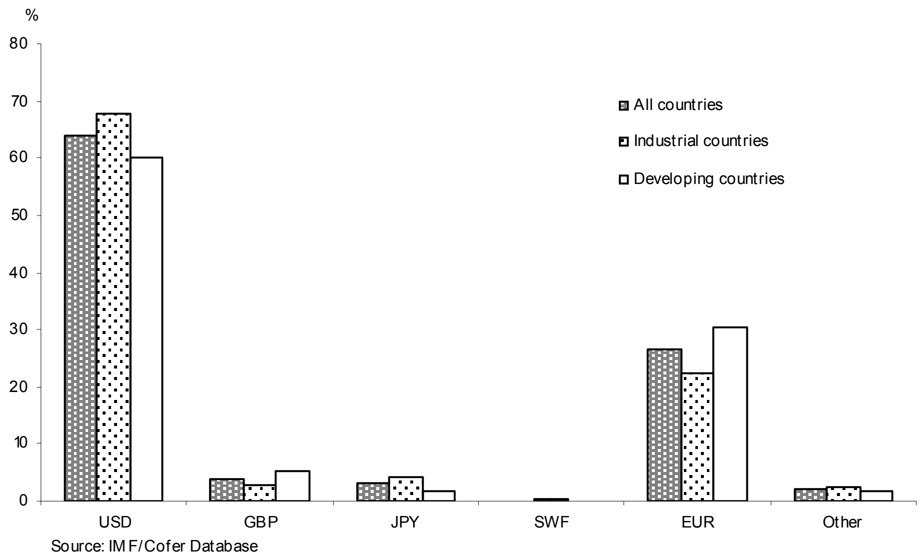


Figure 3: Currency Composition of Foreign Exchange Reserves (End of 2008)



(1990) suggest that the asymmetric information problem between borrowers and lenders diverts the capital from poor to rich countries. Reinhart and Rogoff (2004) present a historical review of countries that declared sovereign default and argue that default has further detrimental effects on the institutional build up of a country, further increasing the credit risk of that country and thereby preventing capital inflows. Similarly, Alfaro, Özcan and Volosovych (2005) emphasize the institutional quality as a factor determining capital flows. Smaghi (2006), a member of executive board of European Central Bank, agrees with this view and adds that:

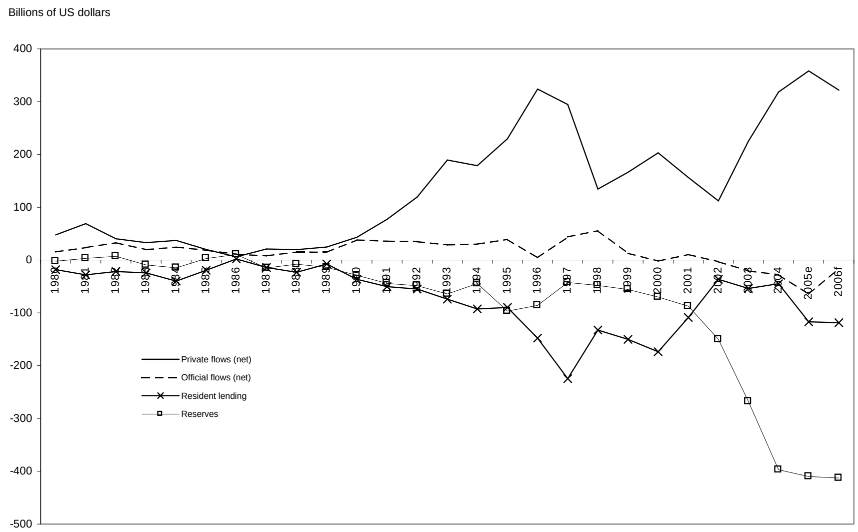
> *"Improving institutions is not easy... This is why several countries have looked for an alternative to the strengthening of institutions, consisting in accumulating large stocks of foreign reserves. Foreign reserve accumulation has been a (partial) substitute for institution building, with a view to increase the country's credibility in the eyes of foreign investors. In contrast to institution building, however, the sizable foreign reserve accumulation has further contributed to the build-up of imbalances. Such a policy has also been very costly to the economy, taking into account efficiency losses, and is not sustainable over time"*

Taylor (2006) goes one step further and suggests that if we subtract reserves from capital inflows to emerging economies, then Lucas paradox disappears (Figure 4).

Reserve accumulation is a costly policy for two reasons. First, reserves could be used for less liquid but more productive investment in developing countries. In addition to this opportunity cost, under the presumption that most emerging markets are heavy borrowers in the international market, the positive spread between borrowing rates and return on reserves is another discouraging factor behind accumulation of reserves. Rodrik (2006) calculates the cost of holding excess reserves as one percent of GDP for developing countries[2]. He argues that the costly reserve accumulation preference of developing countries over reducing their short-term liabilities is puzzling.

[2] Excess reserves are defined as the amount exceeding three-months of imports.

Figure 4: Net Capital Flows to Emerging Economies



Source: Source: Martin Wolf, "Fixing Global Finance". SAIS Lectures, March 2006.

There are numerous empirical studies to find the optimum level of foreign exchange reserves[3], though, less effort is put on theoretical side. The main problem faced is the ad-hoc nature of foreign exchange reserve policies of central banks. Moreover, more often than not, changes in international reserves might be a residual of monetary policy actions, rather than a result of predetermined reserve management policies. A point worth to highlight here is the relation between reserve volatility and the choice of exchange rate regime. Most countries have officially adopted floating exchange rate regimes after epidemic financial crises of late 1990's. This would supposedly lower reserve volatility since reserves were no longer required to support the level of exchange rate. Yet, as Calvo and Reinhart (2002) argues, the pervasive fear of float reveals itself in managed floating practices for many developing countries. Many countries utilize precautionary savings argument as an ex-post justification mechanism for the surge in reserves[4]. As Mishkin (2007) puts it:

> "*However, there are costs associated with such reserve accumulation and there is also a danger that, under the guise of "insurance," countries will engage in activities–including intervention to keep their currencies weak–that are increasingly distorting global capital and trade flows*"

The adherents to this mercantilist view focus on Chinese case and argue that high reserve holdings of China stems from the preference of a depreciated currency to sustain the export-led growth of the country (Dooley et al, 2003)). Aizenman and Lee (2007) conduct an empirical test for the determinants of reserve demand and suggest that only a small part of the reserve accumulation can be explained by the mercantilist motive whereas precautionary saving motive is

[3] See Frenkel and Jovanovic (1981), Flood and Marion (2002), Jeanne and Ranciere (2006), Aizenmann, Lee and Rhee (2005), Bar-Ilan, Marion and Perry (2007).

[4] This kind of a communication policy is apparently a risky one. If central banks do not have full control over reserves, and reserve accumulation is not a result of a precautionary policy but mostly a result of combination of exogenous factors, then a possible reduction in the level of reserves in the future, due to a reversal of these exogenous factors, would be hard to explain under a prudential framework.

still the dominant factor[5].

While the adequate level of reserves is still an issue under scrutiny, many developing countries hold -and advised to hold- more reserves in the last ten years. To fill this gap of indeterminate optimal reserve level, Guidotti (1999), ex-minister of finance of Argentina, comes up with a simple rule for reserve management. According to this external balance rule, countries should hold foreign exchange reserves to meet their foreign liabilities for a year. Later on, Greenspan (1999) favors this rule and adds that such a rule could also "*...limit the size of international rescue packages, since the size of such packages is often related to the size of a countries short-term liabilities less its reserves*". Similarly, three months import rule tells that a certain amount of liquid assets is required for a country in case of a crisis, to sustain compulsory imports (like medicine or oil) for a certain amount of time (three months or more) until the political turbulence come to an end.

In this theoretical study, we first highlight the connection between the traditional precautionary saving role of foreign exchange reserves and their effect in mitigating the credibility problem of developing countries. A popular conjecture nowadays is that reserves can serve as an implicit collateral against borrowing and lower the risk-premium associated with financial vulnerabilities of emerging markets. In a recent study, Levy-Yeyati (2008) argues that one point increase in foreign exchange reserves lowers the borrowing spreads around 0.5 points in emerging markets.

We argue that the credibility enhancing role assigned to reserves is to some extent over-emphasized in presence of endogenously determined borrowing constraints. If reserves play the role of an *implicit* collateral as discussed above, then we start with the presumption that developing countries face borrowing constraints in international lending markets. Provided that these constraints are endogenously determined by the level of net worth, then any choice that affects the evolution of the net worth of the country, such as an ad-hoc reserve policy, might in turn intensify the level of market imperfections in an intertemporal manner.

We develop a model that is similar to Kiyotaki (1998) to examine the impact of reserve holding under an imperfect capital market framework due to the presence of borrowing constraints. Kiyotaki constructs a model with a propagation mechanism where small sectoral shocks amplify, persist and generate larger aggregate shocks. The core of his model includes endogenously determined credit constraints which deteriorates the credit flow from the relatively unproductive agents to the productive ones. As a result of the commitment problem, all borrowing between productive and unproductive agents takes place against collateral which is a part of the future returns from investment. The level of market imperfection (degree of credit constraints) is determined endogenously by two factors: the level of the productive country's share in the world and the difference in productivity level of countries. Productive agents facing a binding constraint provide all of their net worth to finance the gap between the investment and borrowed amount. A higher net worth lowers the severity of the constraints and leads to a higher return in the next period. He shows how a small temporary productivity shock amplifies through the leverage effect and in turn results in lower output and growth for the economy.

Kiyotaki (1998) model fits our framework for three important reasons. First, many emerging market countries are financially constrained in international lending markets, despite their high borrowing requirements. A solution to this friction is to provide collateral against borrowing. Reserves - provided that they are going to be used in a crisis- are a part of the net worth which

[5] Calvo and Talvi (2006) argues that this is even true for China, the largest international reserve holder in the world in the last years. They tell that China will eventually liberalize its banking system in line with World Trade Organization rules. Yet, many banks might face a high ratio of non-performing loans as a result of their significant lending to bankrupt state owned enterprises so far. Therefore, if Bank of China prefers to bailout weak banks in such a case, it is a prudent policy to stock up liquid reserves.

can be used as a collateral[6]. However, foreign exchange reserves are usually low return instruments with high liquidity. Holding excess reserves leaves fewer resources for investment every period for productive country and therefore affects the evolution of the share of its net worth in world economy. This affects borrowing constraints in an endogenous framework and, in turn, might result in lower output and growth rates. We compare cases with and without borrowing constraints and show that the cost of holding reserves is higher in a constrained economy than an unconstrained one, as a result of the leverage effect.

One difference between our approach and existing literature on foreign exchange reserve demand is that we focus on borrowing constraints that a developing country faces at non-sudden stop times. Many studies model sharp capital reversals as tightening of (or binding) borrowing constraints for developing countries[7]. These sudden stops lead to significant reversals in current account, sharp declines in aggregate output and consumption, corrections in asset prices and relative prices of tradable to non-tradable goods (Mendoza, 2006). The countries that experienced sudden stops accumulate reserves as a war chest under consumption smoothing motive under this framework. However, sudden stops are not the only source of binding borrowing constraints. Credit constraints faced by developing countries are an intrinsic characteristic of the international lending market structure at normal (non-sudden stop) times. In a world, where governments of the developing countries have *effectively acted as financial intermediaries, channeling domestic saving away from local uses and into international capital markets* (Bernarke, 2005) through reserve holdings, endogenously determined borrowing constraints exacerbate this reverse north-south lending. In this line, we focus on the role of reserve accumulation in determining the evolution of net worth, and in turn the severity of the constraints, in an endogenous framework, even when there are no sharp capital reversals.

Mendoza (2006) argues that the amplification mechanism due to credit constraints helps to produce sudden stops in real business cycle models. A binding constraint due to a sudden stop results in liquidation of assets, which in turn causes a decline in their prices and further tightens the borrowing constraint. The amplification of this effect is similar to Fisher's (1933) debt-defation mechanism which results in large drops in investment and output. Precautionary savings help to smooth consumption by preventing sharp drops and reducing the probability of these rapid capital reversals. However, probability of sudden stops is still positive in the long-run despite precautionary savings.

Using a similar framework, Durdu et al. (2008) examine impacts of financial globalization, sudden stops and output variability on the demand for foreign exchange reserves under two different preference specifications. Their results suggest a positive impact of financial globalization in addition to sudden stops on reserve demand while the relationship between output variability and reserves is not significant. The effect of credit constraints on producing sudden stops differs under alternative specifications of time preference in their study.

Caballero and Panageas (2008) argue that if a country can identify variables that are correlated with sudden stops, then it can reduce the cost of reserve accumulation through engaging in contingent contracts which provide insurance at rapid reversals of capital flows. They picture reserve

[6]An alternative to using reserves in case of a crisis is default, if the latter one seems less costly at the time of the crisis. We assume that emerging countries are aware of the fact that a default has further detrimental effects for credibility and institutions, as stated in Reinhart and Rogoff (2004). They care about their reputation and are reluctant to be out of international borrowing system. Therefore, instead of assuming an outsider supranational legal authority (as in Gertler and Rogoff (1990) or as discussed in Feldstein (1999)) we assume an implicit enforcement constraint as in Kehoe and Perri (2002), which tells at any period the country always chose his current situation relative to the autarky situation.

[7]See Caballero and Krishnamurthy (2001), Arellano and Mendoza (2002), Calvo, Izquierdo and Mejía (2004), Mendoza (2006), Durdu et al. (2008) or Caballero and Panageas (2008).

accumulation as a costly choice for a financially constrained country that has higher expected future income. However, their focus is on the portfolio decision rather than examining the endogenous effect of reserve accumulation on net worth.

The second motivation for our model choice is that, as we picture in Figure 3, foreign exchange reserves of the developing countries are mostly held in US dollars or Euros. This suggests a capital flow from developing countries with high productivity levels to the relatively unproductive developed countries, corroborating with Lucas paradox (Figure 4). In our model, we have productive and unproductive countries to model this north-south lending behavior. The external finance requirement of productive ones is met by the funds from unproductive ones in equilibrium, which is guaranteed by a Markov-switching assumption on productivity levels. Moreover, we introduce an ad-hoc reserve policy to this framework. We assume that productive ones have to hold bonds of the unproductive ones every period with a certain proportion of their net worths. These bonds work as reserves in our framework. Therefore, in addition to the commitment problem between borrowers and lenders, reserve policy also act as a factor that intensifies borrowing constraints in a dynamic manner.

In our study, we prefer a deterministic framework to capture the effect of an ad-hoc reserve policy rather than determining the optimal level of reserves under a stochastic framework[8]. Our interest lies in the effect of credit constraints to a given reserve policy rather than searching for the optimal level. Our ad-hoc reserve policy choice can be motivated by following suggestions of exogenous external balance rules such as Guidotti-Greenspan rule or three months import rule[9].

Third, as exposed in Figure 2, today's level of international reserves is high enough to affect the world output and is one of the candidates for the determinants of global imbalances in the last years. Therefore, rather than picturing the model with a country and rest of the world (or investors), we assume that the world is populated by two kinds of agents, productive and unproductive ones. Productive ones, which are supposed to be borrowers, are credit constrained, so they hold bonds of unproductive ones, which works as reserves in our framework.

Aizenman et al. (2005) present a two country model where the second country is subject to credit ceilings as a result of the probability of an output shock. Again, similar to our framework, a proportion of assets (excluding reserves) can be seized by lenders. The agent chooses the level of debt and reserves to maximize consumption. Then, after the realization of shock the country decides whether to default or not. They show that reserve demand goes up with the use of reserves in reducing the probability of a crisis and alleviating the credit ceiling that the country faces.

Next section demonstrates the model and results. Third section examines dynamics. Fourth and the last section concludes[10].

[8] See Frenkel and Jovanovic (1981), Flood and Marion (2002), Aizenman and Marion (2003) and Jeanne and Ranciere (2006) for determination of optimal reserves within a stochastic model.

[9] As explained in the paragraph, we take the reserve policy as deterministic and refrain from specifying any relationship between precautionary savings and borrowing constraints. Yet, there is also a literature examining the effects of borrowing constraints on precautionary savings. Technically, precautionary saving behavior in response to uncertainly is captured by the convexity of the marginal utility function or a positive third derivative (Leland (1968), Sandmo (1970)). Moreover, recent studies show that existence of liquidity constraints increase precautionary savings (Deaton (1991), Xu(1995), Caroll and Kimball (2001)). Aiyagari (1994) argues that the existence of borrowing constraints may lead to precautionary savings behavior regardless of a positive third derivative. Caroll (2001) argues that most important factor behind precautionary savings is the average degree of impatience rather borrowing constraints. Impatient consumers prefer current consumption to future consumption. Without any borrowing constraints, they would like to borrow from the future and consume today or use their existing assets. However, introduction of uncertainty and borrowing constraints may lead to precautionary savings for prudent consumers.

[10] A detailed appendix is available from the author upon request.

2 Model

The model is similar to Kiyotaki (1998)[11]. The world economy consists of two countries, country A and country B. There are two goods in each country, a consumption good and a capital good. Capital good can be turned into a consumption good one-to-one. Representative agent of country A chooses a consumption plan $\{c_{t+i}\}_{i=0}^{\infty}$ to maximize:

$$\sum_{i=0}^{\infty} \beta^i \ln(c_{t+i}), \qquad \beta \in (0,1) \tag{1}$$

where c_{t+i} is the consumption at date $t+i$. Similarly, representative agent of country B chooses consumption plan $\left\{c'_{t+i}\right\}_{i=0}^{\infty}$ to maximize:

$$\sum_{i=0}^{\infty} \beta^i \ln(c'_{t+i}) \tag{2}$$

Both agents have constant returns to scale production functions. The productivity level of the agent in country A is higher than that of the country B. The productive agent in country A produces according to:

$$y_{t+1} = \alpha k_t \tag{3}$$

which implies that k_t unit of capital good at period t turns into y_{t+1}unit of output at $t+1$ with productivity rate α. Similarly, production function of the unproductive agent of country B is specified as:

$$y'_{t+1} = \gamma k'_t \tag{4}$$

where $\alpha > \gamma > 1$.

We introduce shifts between productive and unproductive states for both agents into the model. We assume that an agent who is productive this period may become unproductive next period with probability δ whereas an unproductive agent may become productive next period with probability $n\delta$. This assumption helps to differentiate distribution of productive countries from distribution of wealth in the world and guarantees the credit flow from the relatively unproductive countries to the productive ones in steady state equilibrium. The initial ratio of the population of the productive to unproductive agents is assumed to be $n:1$ and constant over time. We also impose the following condition stating that the probability of shifts between states is not too large:

$$\delta + n\delta < 1 \tag{A1}$$

Capital depreciates fully both for productive and unproductive country:

$$k_t = i_t \tag{5}$$

$$k'_t = i'_t \tag{6}$$

where i_t and i'_t are the investment for productive and unproductive countries respectively.

There is a one period credit market where one unit of capital good this period can be exchanged for $r_t = 1 + R_t$ units of goods next period. Agents take the interest rate r_t as given.

[11] We also benefited from the lecture notes of Kiyotaki's Advanced Macroeconomics class in London School of Economics at 2004.

Our interest lies in the effect of an ad-hoc reserve policy of the productive country to the aggregate output in the world economy. To capture this behavior, we separate the total borrowing of productive agents in two parts:

$$b_t = b_t^{hl} - b_t^{lh} \tag{7}$$

where b_t^{hl} denotes the amount productive agent borrows from unproductive agent and b_t^{lh} denotes the amount productive agent lends to unproductive agent[12]. Positive values of b_t^{hl} and b_t^{lh} indicate that both countries borrow and lend from each other at the same period. Unproductive agents insure themselves by holding bonds of unproductive agents. Therefore, b_t^{lh} is interpretable as foreign exchange reserves[13].

Productive agents have labor-specific technology. This results in a commitment problem between borrowers and lenders. If the agent stops working at any point of the production process, lenders can only confiscate θ portion of total returns. This commitment issue puts a limit to the borrowing for the agent. He has to provide full collateral for the amount he borrowed. Yet, only the seizable θ portion of the return works as a collateral while borrowing. Therefore, the credit constraint of the productive agent of country A is given by:

$$b_{t+1}^{hl} - b_{t+1}^{lh} \leq \theta y_{t+1} \tag{8}$$

In equation (8) left hand side is the net debt repayment of the agent next period and θy_{t+1} is the collateralizable part of the investment of the production agent.

Since reserves (b_{t+1}^{lh}) are characterized as guaranteed bonds, they are also taken as collateral in our model. Therefore, for each bond that is hold as reserves, borrowing of the productive agent can increase. This is expressed with rewriting (8):

$$b_{t+1}^{hl} \leq \theta y_{t+1} + b_{t+1}^{lh} \tag{9}$$

To incorporate a deterministic reserve policy choice to the model, we assume that productive agents hold a certain proportion of their net worth as reserves every period:

$$b_{t+1}^{lh} = \Omega a_t \tag{10}$$

where a_t is the net worth which equals output less of debt repayment:

$$a_t = y_t - (b_t^{hl} - b_t^{lh}) \tag{11}$$

As we discuss in the motivational part of the study, we concentrate on the effect of an ad-hoc constant reserve policy on a credit constrained country, rather than searching for an optimal level of reserves. Also, as mentioned before, more often than not central banks of developing countries justify their reserve levels with ad-hoc simple rules, such as three months imports rule or Guidotti-Greenspan rule which tells that reserve level of a country should meet short-term debt for a year. We take these rules as given and compare this reserve policy under capital markets with and without borrowing constraints.

We assume that the part of the return that the productive agent can provide as collateral is lower than unproductive agents productivity level[14]:

$$\theta\alpha < \gamma \tag{A2}$$

[12] h stands for productive (high), l stands for unproductive (low).

[13] We assume exchange rate equal to 1 for simplicity.

[14] This assumption is required when we examine the dynamics of the borrowing constrained economy in the next section. If the interest rate is equal to the unproductive agents productivity rate, then this assumption is required for bounded borrowing level for the productive agent.

The flow of funds constraint of the productive agent is:

$$c_t + k_t + \frac{b^{lh}_{t+1}}{r_t} - b^{lh}_t = y_t + \frac{b^{hl}_{t+1}}{r_t} - b^{hl}_t \tag{12}$$

In (12) left hand side is the total expenditure on consumption, investment or reserves. Right hand side is output plus new borrowing minus debt repayment. Therefore, consumption and investment is financed by income and new borrowing net of debt repayment.

Similar to (12), the flow of funds constraint of the unproductive agent is:

$$c'_t + k'_t + \left\{ \frac{b'^{hl}_{t+1}}{r_t} - b'^{hl}_t \right\} = y'_t + \left\{ \frac{b'^{lh}_{t+1}}{r_t} - b'^{lh}_t \right\} \tag{13}$$

where bond-market clearing requires that:

$$b^{lh}_t = -b'^{lh}_t \text{ and } b^{hl}_t = -b'^{hl}_t \tag{14}$$

At period t, representative agents of country A and country B chooses in between consumption, investment, borrowing or saving (holding reserves), respectively, $\{c_t, k_t, b^{hl}_{t+1}, b^{lh}_{t+1}, y_{t+1}\}$ and $\{c'_t, k'_t, b'^{hl}_{t+1}, b'^{lh}_{t+1}, y'_{t+1}\}$ to maximize the discounted expected utility (1), with respect to production functions (3), (4), flow of funds constraints (12), (13) and borrowing constraint (8).

The equilibrium in the market is satisfied when aggregate levels of consumption and investment (capital) of both types of agents is equal to the total output of the economy. Aggregating sums of (12) and (13) yields:

$$C_t + C'_t + K_t + K'_t = Y_t + Y'_t = W_t \tag{15}$$

where capital letters denote the aggregate levels in the economy. W_t is the aggregate wealth level in the world at time t.

First, we work through the case where there are no borrowing constraints and no reserve policy. Second we add the borrowing constraint (still no reserves) and show that the growth rate of the whole economy is smaller than the unconstrained economy. These two cases are similar to Kiyotaki (1998). Then, we add an ad-hoc reserve policy to this basic model, examine comparative statics and effects of this policy on the evaluation of output and growth rate of the economy.

2.1 Case 1: No borrowing constraint and no reserves

First, we present the economy with no borrowing constraints and no reserve policy. Absent any borrowing constraints, the representative agent maximizes (1) with respect to the flow of constraint (12) and production function (3). In a competitive credit market the rate of interest would be equal to the rate of return on investment of productive agents.

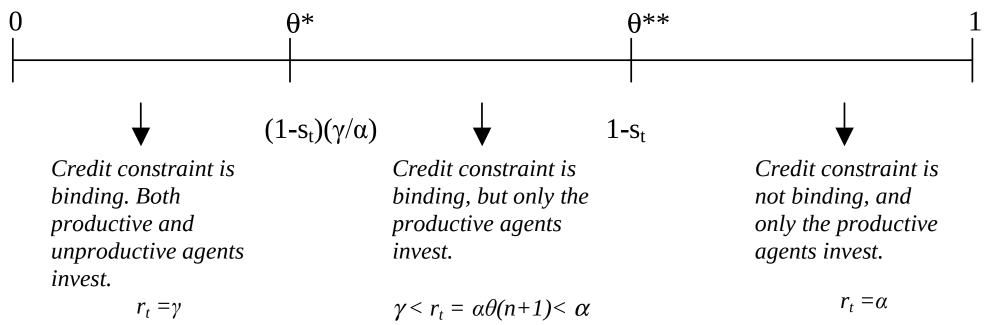
$$r_t = \alpha \tag{16}$$

Unproductive agents prefer to lend all their resources to productive ones since the return is greater than the return of their own investment. As a result, in an economy with no borrowing constraints only productive agents invests.

As a result of log utility specification, both productive and unproductive agents consume a constant $(1-\beta)$ fraction of their net worth:

$$c_t = (1-\beta)a_t \qquad , \qquad c'_t = (1-\beta)a_t \tag{17}$$

Figure 5: A Summary of the Economy with and without Borrowing Constraints



In aggregate level, output and investment are independent of the distribution of wealth between productive and unproductive agents. The growth rate in this unconstrained economy will also be independent of this and be equal to the constant:

$$G_t^{fb} = \frac{W_{t+1}}{W_t} = \frac{K_{t+1}}{K_t} = \beta\alpha \tag{18}$$

2.2 Case 2: Borrowing constrained economy with no reserves

We now present the economy with borrowing constraints. Remember from equation (8) that θ level tells us how tight is the constraint. Accordingly, we can summarize our constrained economy consisting of three regions depending on the magnitude of θ:

a) The constraint (8) may not bind and still only the productive agents invest ($\theta > \theta^{**}$)

b) The constraint binds ($\theta < \theta^{**}$)

i) but still only productive agents invests ($\theta^* < \theta < \theta^{**}$)

ii) unproductive agents also invests. ($\theta < \theta^*$)

Figure 5 displays a summary of the economy. The level of interest rate and critical levels of θ that satisfies these three cases above in the figure are presented along the unit line. We examine each case separately below.

2.2.1 Case 2a: The constraint does not bind ($\theta > \theta^{**}$)

If θ is high enough, then the constraint does not bind, i.e.:

$$b_{t+1}^{hl} - b_{t+1}^{lh} < \theta y_{t+1} \tag{19}$$

The equilibrium will be the same with the unconstrained Case 1 that is discussed above and the interest rate is again given by (16). Let us call this critical θ level as θ^{**}. As can be seen from Figure 5, the critical level in log utility specification is:

$$\theta^{**} = 1 - s_t \tag{20}$$

where:

$$s_t = \frac{A_t}{W_t} \tag{21}$$

is the ratio of productive agents net worth (A_t) in total wealth in the economy (W_t) (Note that (A_t) can be found by aggregating (11)). The higher the ratio of the net worth of productive country in the economy (s_t), the lower is the critical level below which the borrowing constraint is binding. This is intuitive, because the higher is this ratio, the higher net worth they can provide and even a very low θ level will not result in a credibility problem.

2.2.2 Case 2b: The constraint binds ($\theta \leq \theta^{**}$.)

When the constraint binds, two cases are possible. If θ is very low, then the amount that productive agents can borrow at aggregate level is very low. So, unproductive agents will remain with extra goods in their hands. This causes unproductive ones to invest in equilibrium as well. Therefore, we can argue that there exists a low θ^* level under which unproductive agents also invests. However, if $\theta^* < \theta < \theta^{**}$, then the constraint is still binding but unproductive agents do not invest in equilibrium.

We analyze these cases in detail. But, first let's write the borrowing constraint (8) as an equality, namely:

$$b_{t+1}^{hl} - b_{t+1}^{lh} = \theta y_{t+1}. \tag{22}$$

plugging this into the flow of funds constraint (12) yields:

$$k_t = \frac{y_t - \left(b_t^{hl} - b_t^{lh}\right) - c_t}{1 - \frac{\theta\alpha}{r_t}} \tag{23}$$

Equation (23) describes the investment behavior of the productive agent, when the constraint binds. The minus term in the denominator reflects the present value of the return that can be provided as collateral. Then the denominator as a whole is the required down payment for one unit of investment. Numerator is net worth minus consumption. Note that reserves that are carried from last term, b_t^{lh}, is part of the net worth this term. According to equation (23), productive agent provides all its net worth excluding his consumption, to finance the gap between the unit cost of investment and collateralizable return. The higher the net worth, the higher collateral you can provide and the higher you can borrow. Moreover, the lower the interest rate, the higher is the investment of the productive agent. Also, (23) indicates that a positive k_t requires

$$\theta\alpha < r_t \tag{24}$$

which is guaranteed by assumption (A2)[15].

Case 2b-i: θ is so low that unproductive ones also invest ($\theta \leq \theta^*$) The investment of the productive agent is given by the equation (23). As we discussed, a very low θ means that only a small proportion of the goods can be lent to productive agents, so unproductive agents will remain with goods at their hands and they decide to invest. This critical level of θ is found as

$$\theta < (1 - s_t)\frac{\gamma}{\alpha} = \theta^* \tag{25}$$

as can be seen in Figure 5. The higher the productivity level of the productive agent, the lower the critical level θ^*. Again, a lower α, a higher γ and a s_t level means a lower θ^*. Interest rate will fall to the level of the productivity of unproductive agents.

[15] Note that, r_t should always be greater than or equal to γ, otherwise both productive and unproductive agents would prefer to borrow but there is no one to invest. Therefore, in a competitive credit market interest rate rises.

$$r_t = \gamma \tag{26}$$

The flow of funds constraint turns into:

$$y_{t+1} - (b_{t+1}^{hl} - b_{t+1}^{lh}) = \alpha^+ (y_t - \left(b_t^{hl} - b_t^{lh}\right) - c_t) \tag{27}$$

where:

$$\alpha^+ = \frac{(1-\theta)\alpha}{1 - \frac{\theta\alpha}{\gamma}} > \alpha \tag{28}$$

is the rate of return on saving for productive agents, which is greater than α as a result of lower interest rate compared to the unconstrained equilibrium.

The growth rate of the constrained economy can be written as a function of the share of the net worth of productive agents in total net worth (s_t).

$$G_t^c = \frac{W_{t+1}}{W_t} = \beta \left[\gamma + (\alpha - \gamma) \left(\frac{1}{1 - \frac{\theta\alpha}{\gamma}} \right) s_t \right] \tag{29}$$

Note that growth rate of the constrained economy (29) is smaller than the growth rate of the economy without borrowing constraints in (18).

The evolution of the net worth of productive agents is described by:

$$s_{t+1} = \frac{(1-\delta)\alpha^+ s_t + n\delta\gamma(1-s_t)}{\alpha^+ s_t + \gamma(1-s_t)} \equiv f(s_t) \tag{30}$$

Figure 6 illustrates the evolution of the share of the net worth of productive agents. The black line ($M = 1$) is the evolution of the share of the net worth of productive agents as given in equation (30). It converges to a unique steady state s^*[16] . Net worth increases at a decreasing rate as s grows which implies concavity in Figure 6.

Plugging the steady state value into equation (25) the critical value is obtained as:

$$\theta^* = \frac{\delta\gamma}{(\alpha - \gamma) + \delta\gamma\,(1+n)} \tag{31}$$

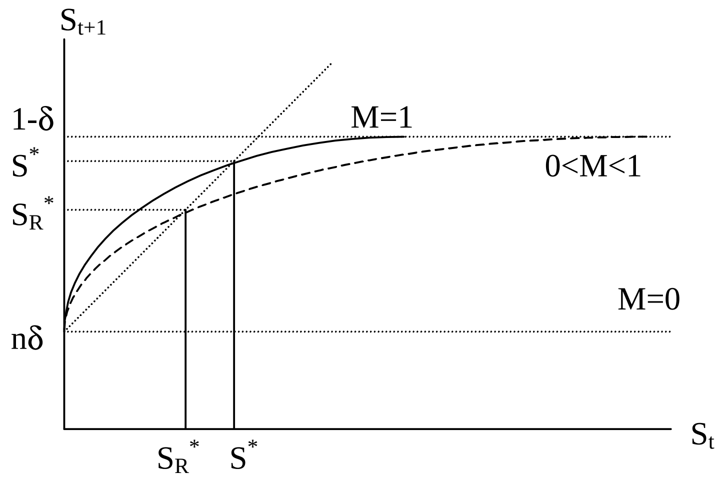
Equation (30) implies another important point. When the share of the productive agent in whole economy (s_t) is big enough, the critical level θ^* (25) may go down below θ, therefore the agent may leave the credit constrained region. We will also show in Case 3 that that holding reserves both lowers the increasing pace of s_t and increases the critical level θ^* at every point.

Case 2b-ii: The constraint is binding, but still only productive ones invest ($\theta^* < \theta < \theta^{**}$) This is the middle region in Figure 5 where $\theta^* < \theta < \theta^{**}$. In this region, the constraint is still binding but unproductive agents do not invest in equilibrium[17]. However, they also cannot lend all their resources to unproductive agents from α, because of lack of full commitment. Therefore, to make sure that the productive agent pays back, they lower the interest rate. But, again this will be a higher interest rate than γ in order to ensure that unproductive agents prefer lending over

[16] This curve is similar to Figure 1 in Kiyotaki (1999). We will compare it with the reserve holding case (where $0 \leq M < 1$) in Case 3.

[17] In fact, for analysing the reserve holding case, we will mainly focus on the previous case where unproductive ones also invest (where $\theta < \theta^*$), however, we should discuss about this middle region case for the sake of completeness.

Figure 6: Evolution of the Net Worth Share of the Productive Agents



investing. Therefore, we will have $\gamma < r_t < \alpha$. The interest rate level in the middle region, where borrowing constraint binds but still only productive agents invest, is:

$$r_t = \frac{\alpha\theta}{1 - s_t} \tag{32}$$

The share of the net worth is a constant in this region

$$s_{t+1} = s_t = s^* = (1 - \delta)(1 - \theta) - n\delta\theta$$

Therefore the interest rate will be:

$$r_t = \frac{\alpha\theta}{\delta - \theta(1 - \delta - n\delta)}$$

The interest rate is between, γ and α. Note that, interest rate is a function of θ in this region. We have $\frac{d}{d\theta} r_t > 0$ which implies that higher the θ, higher the interest rate.

2.3 Case 3: Borrowing constraint and an ad-hoc reserve policy

After presenting the effect of borrowing constraints on the output, we incorporate the ad-hoc reserve policy as given in (10). We assume that after the borrowing takes place, the agent holds $(1 - M)$ fraction of the amount he can spend on investment as reserves every period, therefore $\Omega = (1 - M)\beta$. Moreover, the unproductive country is not allowed to lend these resources back to the productive country in the same period, so has to invest itself.

This saving policy is somewhat representative of benchmark rules of most central banks nowadays, as explained in the second section. It captures the behavior of the central banks which are trying to keep *i)* reserves to GDP ratio, *ii)* reserves to imports ratio or *iii)* reserves to debt ratio (Greenspan-Guidotti rule), constant. For the second one of these rules, imports can be thought at a constant share of consumption or net worth. The last one could be motivated via the borrowing process in our model that takes place against collateral which is a constant fraction θ of net worth.

Incorporating this reserve policy into the model, (23) turns into:

$$K_t = \frac{\beta M A_t}{1 - \frac{\theta\alpha}{\gamma}} \tag{33}$$

The critical level becomes:

$$\theta < (1 - M s_t)\frac{\gamma}{\alpha} = \theta^* \tag{34}$$

Comparing (34) with (25) we see that the higher the reserve holdings the higher the critical level of θ. This is intuitive because higher reserve holding means lower net worth for the productive agent, which means that he can provide less of a collateral. Therefore, a higher θ level is required for the economy to be in the unconstrained region again.

The growth rate of the whole economy under reserve holding is:

$$G_t^R = \frac{W_{t+1}}{W_t} = \beta\left[\gamma + (\alpha - \gamma)\left(\frac{1}{1 - \frac{\theta\alpha}{\gamma}}\right) M s_t\right] \tag{35}$$

The evolution of net worth of productive agents is characterized as:

$$s_{t+1} = \frac{(1-\delta)\alpha^+ M s_t + n\delta\gamma(1 - M s_t)}{\alpha^+ M s_t + \gamma(1 - M s_t)} \equiv f^R(s_t) \tag{36}$$

The critical value using steady state level of s is:

$$\theta_R^* = \frac{\gamma\,(1 - M + M\delta)}{(\alpha - M\gamma) + \delta\gamma M\,(n+1)} \tag{37}$$

We summarize characteristics of the constrained economy with the ad-hoc reserve holding policy in the following proposition:

Proposition 1 *If the productive agent holds reserves in the credit constrained region where $\theta < \theta^*$:*
i) Steady state level is smaller compared to no reserve holding case.
ii) Growth rate of the economy is slower compared to no reserve holding case.
iii) Critical value of the θ^* level is higher compared to no reserve holding case.

Proof. See Appendix. ■

We picture the evolution of share of the net worth in the graph for both cases in Figure 6. The black curve is for no reserve holding case and the dashed curve is for positive reserve case where $0 < M < 1$. Note that the dashed curve with positive reserve level is lower than the black curve with no reserves at every point[18].

[18] Log-linearizing equation (36):

$$\widetilde{s}_{t+1} = \widetilde{s}_t \frac{M\left\{\left[(1-\delta)\alpha^+ - n\delta\gamma\right] - s(\alpha^+ - \gamma)\right\}}{\left[sM(\alpha^+ - \gamma) + \gamma\right]}$$

We check two extreme situations for M. If $M = 1$ where no reserves are hold we have

$$\left.\frac{\partial\widetilde{s}_{t+1}}{\partial\widetilde{s}_t}\right|_{M=1} = \frac{(1-\delta-s)\alpha^+ + \gamma(s - n\delta)}{[s(\alpha^+ - \gamma) + \gamma]}$$

We know that $1 - \delta < s < n\delta$. Therefore, as s goes up, the numerator goes down and the denominator goes up, therefore growth rate will decrease. This can be seen by the concavity of the black line in Figure 6.

If $M = 0$ where productive agents make no investment and hold everything in terms of reserves then the growth rate is zero. The share of the productive agent remains the same at the lowest level $n\delta$, which is depicted by the horizontal line.

Proposition 1 explains the impact of reserve holding in a credit constrained economy where the degree of constraints is determined endogenously. There are three effects which reinforce each other, as a result of leverage effect of the debt. First, as a result of transfer of funds from productive to unproductive agents, the steady state level of the share of productive ones net worth in the economy is smaller and its growth rate is lower compared to no reserves case. Second, as a result of lower leverage, productive agents can provide less collateral and therefore the critical level of θ, where they are not credit constrained anymore, goes up. This is important because in an economy where there are productive agents and unproductive agents, we expect resources to go to productive ones, so the share of productive ones grow and at some point in future, the share of productive ones are high enough that they are not credit constrained anymore. However, a positive reserve policy delays this process. Third, the growth rate of the whole economy is lower.

In the next section we see dynamics of the system more clearly.

3 Dynamics

To analyze aggregate dynamics, we calibrate the dynamic system consisting of aggregated choice variables $\{C_t,\ K_t,\ C_t',\ K_t'\}$and state variables $\left\{K_{t-1},\ K_{t-1}'\right\}$ where[19]:

$$\widetilde{C}_t = \kappa_{ck}\widetilde{K}_{t-1} + \kappa_{ck'}\widetilde{K}_{t-1t}' \tag{38}$$

$$\widetilde{C}_t' = \kappa_{c'k}\widetilde{K}_{t-1} + \kappa_{c'k'}\widetilde{K}_{t-1t}' \tag{39}$$

$$\widetilde{K}_t = \kappa_{kk}\widetilde{K}_{t-1} + \kappa_{kk'}\widetilde{K}_{t-1t}' \tag{40}$$

$$\widetilde{K}_t' = \kappa_{k'k}\widetilde{K}_{t-1} + \kappa_{k'k'}\widetilde{K}_{t-1}' \tag{41}$$

The parameters we use in calibration is given in Table 1 and selected as follows: The productivity rate of the productive agents, α, is taken as 1.06 which equals one plus the average GDP growth rate for 2007 for five selected developing countries: Argentina, Chile, Brazil, Korea and Turkey (see Table 2). The productivity rate of the unproductive agents, γ, is taken as 1.03, which equals one plus the GDP growth of high income countries defined under World Bank classification. The discount rate, β, is 0.97 which equals $1/\gamma$. The δ parameter for Markov-switching assumption and the initial ratio of the population of the productive to unproductive agents, n, are 0.45 and 0.35, respectively. These two numbers are chosen such that $\delta + n\delta = 0.61 < 1$, so the first assumption holds[20]. Accordingly, to ensure a steady state we chose $\theta = 0.74$. Then, $\theta^* = 0.75$ by (25) so $\theta < \theta^*$ and we are in the region where both productive and unproductive agents invests. This makes $\theta\alpha = 0.78 < \gamma$, so the second assumption also holds.

Table 1: Parameter Values

$\alpha = 1.06$	$\gamma = 1.03$
$\beta = 1/\gamma = 0.97$	$\delta = 0.45$
$n = 0.35$	$\theta = 0.74$

We compare impulse responses to a positive productivity shock on the aggregate levels of consumption, capital and wealth for three different reserve holding ratios. As a benchmark, we assume

[19] We have used Harald Uhlig's toolkit and the companion paper Uhlig (1999) both of which can be obtained from his website at http://www2.wiwi.hu-berlin.de/institute/wpol/html/toolkit.htm.

[20] Remember that we need this assumption to guarantee a steady state where the capital flow from the unproductive agents to the productive ones are sustained in steady state. However, results of the impulse response analysis are very sensitive to the selection of these two parameters.

that ten percent of the net worth is held as reserves, $M = 0.9$ (or $R = 1 - M = 0.1$ in the notation of the Figure 6). We chose this level because as shown in Figure 2, around ten percent of the world GDP is held as reserves. Then, we reduce the reserve ratio to 9 and 8.5 percent of the net worth level and compare the effect of the shock on these alternative reserve policy specifications[21].

Table 2: Average GDP growth rates for 2007 (percent)	
Chile	5
Argentina	9
Brazil	5
Turkey	4
Korea	5
(Average)	6
High Income Countries (Average)	3

Source: World Bank, World Economic Indicators

Figure 7 illustrates impulse responses to a positive shock to productivity in C, C', K, K' and W. The y-axis gives the percentage deviation from the steady state due to a one standard deviation shock to α. The x-axis gives the periods after the shock. As a result of the Markov-switching assumption, impulse responses are very sensitive to the selection of parameters. The straight line shows the case for reserve ratio of ten percent for all graphs. When we reduce the reserve ratio to nine percent, which is depicted by the line with squares, the effect of a shock decreases on aggregate level of consumption for the productive agent, increases on the consumption level of the unproductive agent, yet positive for both reserve ratios. However, a further half point reduction in reserve ratio to 8.5 percent changes the sign of the effect on aggregate consumption levels for both agents, as depicted by the dashed line. A similar sign change also happens for the aggregate wealth of the economy, w shown in the fifth graph.

Impulse responses are more consistent for aggregate capital levels. The impulse response to a one standard deviation technology shock is positive on the capital level of productive agents, K, and negative on the capital level of unproductive agents, K'. Moreover, the lower is the reserve ratio, the lower is the effect of the shock on capital level for both type of agents. However, as discussed above, in general responses are very sensitive to a small change in the chosen parameters δ and n[22].

4 Conclusions

In this study, we discuss the role of foreign exchange reserves under imperfectly functioning capital markets on account of the presence of borrowing constraints. Reserves act as an implicit collateral against borrowing for financially constrained developing economies in international lending markets. We develop a model where holding foreign exchange reserves indicate a transfer of

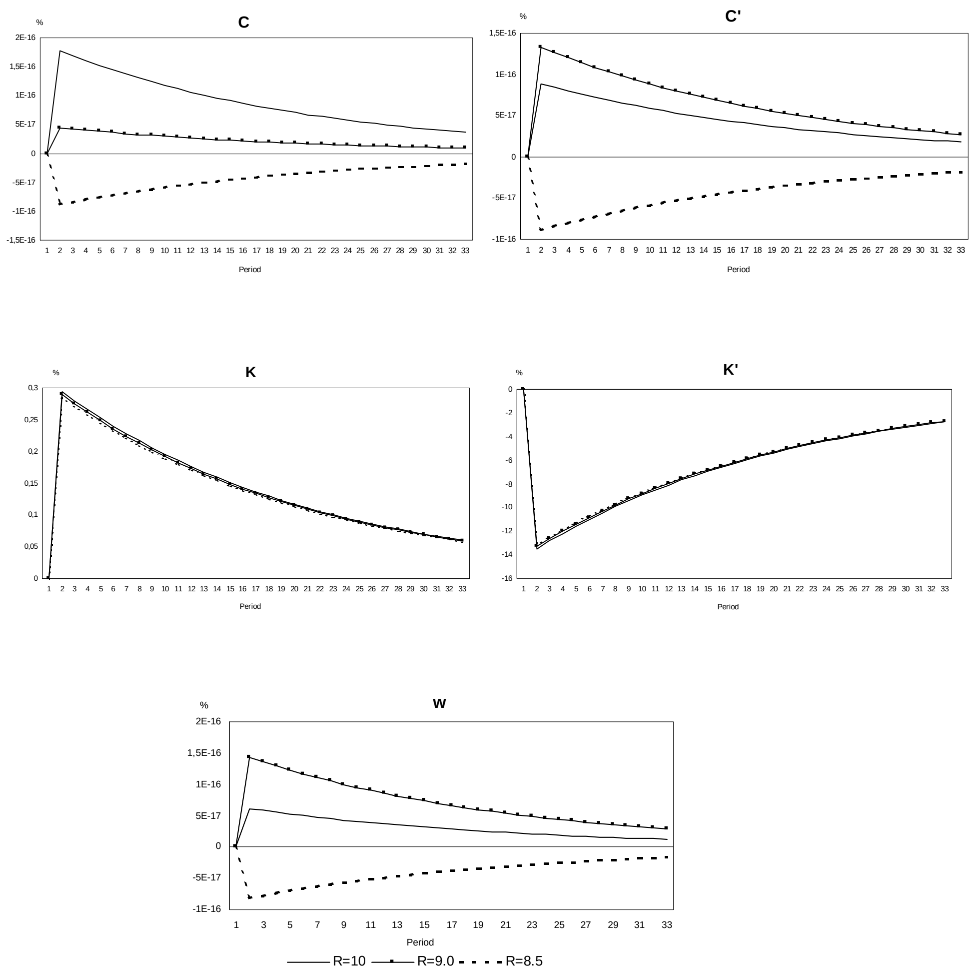
[21] The coefficients κ_{ck}, $\kappa_{c'k'}$, κ_{kk}, are positive. Moreover, the Markov switching assumption (A1) ensures that , $\kappa_{c'k}$, $\kappa_{c'k}$, $\kappa_{kk'}$, $\kappa_{k'k}$ are also positive. The sign of $\kappa_{k'k'}$ term depends on the initial ratio of the population of the productive to unproductive agents, n, as well as other parameters.

[22] For example, if the reserve level satisfies

$$R \geq 1 - \frac{(\gamma - \theta\alpha) - \sqrt{\alpha\theta(\gamma - \theta\alpha)}}{\gamma((1-\delta)(1-\theta) + n\delta\theta)}$$

then a positive shock on α will still have positive effect on the aggregate level of capital of the unproductive agents, K', but the effect will be decreasing in reserve level.

Figure 7: Impulse Responses of Aggregate Variables to a Shock in Productivity Level under Alternative Reserve Policies



Note: Y-axis gives the percentage deviation from steady state. X-axis gives the period after the shock.

resources from productive to unproductive areas, which confirms the Lucas paradox. We assume a reserve accumulation policy and examined effects of this policy on aggregate macroeconomic variables in the world economy.

We first show that reserve holding lowers the growth rate in global terms, since reserves are transferred resources from productive areas to unproductive ones. Second, we show that the reserve holding policy have different impacts in a borrowing constrained economy than an unconstrained one. In our economy the level of capital market imperfection (degree of credit constraints) is determined endogenously by two factors: the level of the productive country's share in the world and the difference in productivity level of countries. We compare the evolution of the share of productive agents under credit constraints, with and without the reserve policy. As a result of leverage, reserve holding both lowers the pace of increase in share of productive agents in the economy and increases the critical level of θ. This is important because in an economy where there are productive agents and unproductive agents, we expect resources to go to productive ones, so the share of productive ones grow and at some point in future, the share of productive ones are high enough that they are not credit constrained anymore. However, a positive reserve policy delays this process.

Our results contribute to an existing literature that describes the suboptimality of reserve accumulation process in developing countries. Caballero and Panageas (2008) agree that reserve accumulation is costly for developing countries that are already constrained financially. They recommend use of contingent hedging instruments that would insulate the developing countries from sharp capital reversals. Mendoza et al. (2007) and Durdu et.al (2008) argues that financial globalization is the main determinant of the surge in reserve holdings rather than a motivation to smooth consumption against cyclical volatility since the latter is not supported by empirics.

We exempted from exchange rate uncertainty in our framework, which could be of interest for further studies. Exchange rate level affects the value of reserves and is taken into account under a portfolio management framework. Moreover, while a significant number of developing countries chose more flexibility in exchange rate officially, many of them engage in managed floating to avoid volatility in exchange rates. Central banks require reserves for announced or unannounced interventions for this purpose as well. These could be taken as a separate determinant of foreign exchange reserve demand of the developing countries from precautionary savings against sudden capital reversals.

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5 Appendix

Proof of Proposition 1

i) It is enough to show that the identity in equation (36) is smaller than the one in (21). Simplifying we get:

$$s_t \gamma \alpha^+ (1 - M)(\delta + n\delta - 1) < 0$$

This always holds since by Assumption 1 we have $\delta + n\delta < 1$ and $0 < M < 1$.

ii) Since $0 < M < 1$ we have $G_t^R > G_t^c$ by comparing (35) and (29)

iii)We want to show that the level of θ_R^* in equation (37) is greater than θ^* level in equation(31). Simplifying we get:

$$\gamma (1 - M)[(\alpha - \gamma)(1 - \delta) + \delta n \gamma] > 0$$

This is always true since $0 < M < 1$ and $\alpha > \gamma$.