International Reserves and Central Bank Independence: The Role of Limits on Central Bank Lending*

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Abstract

This paper studies how central bank independence affects the accumulation of international reserves in emerging economies. I provide a sovereign default model that captures two measures of independence: (i) how isolated is the CEO of the central bank from political pressures, and (ii) how stringent are the limits on central bank lending to public sector. I show that limits on central bank lending to public sector can explain the reserves-to-debt ratios observed in emerging economies. In a quantitative exercise, model simulations rationalize a positive correlation between independence and reserves-to-debt ratios across countries. Finally, I quantify the welfare effects of a central bank independence reform. I find that prohibit central bank lending to public sector increases the level of reserves, decreases the net debt position of the economy, and improve social welfare by 1.8%.

Keywords: Central Bank Independence, International Reserves, Sovereign Default

JEL Codes: E58, F32, F34, F41

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1 Introduction

Emerging market economies (EMEs) hold large amounts of international reserves and public debt. This is puzzling because economies facing default risk pay high interest rates on their debt and receive low returns on their assets.[1] Why do EMEs prefer to hold international reserves instead of paying back public debt? What drives the choice of reserves in emerging economies? Moreover, what is the adequate level of reserves for economies facing default risk? Many important papers such as Hur and Kondo (2016), and Bianchi, Hatchondo, and Martinez (2018) suggest that central banks in emerging economies accumulate reserves to build a buffer for liquidity needs and to prevent rollover risk. While these motives can certainly explain some of the variation we see in the data, all previous studies ignore the interaction between fiscal and monetary authorities by assuming a consolidated government who chooses reserves and debt.

In practice, reserves are often held by the monetary authority and debt is issued by the fiscal authority. Therefore, the assumption of a consolidated government could be inaccurate to study the accumulation of reserves because government entities may not have the same objective function. Moreover, evidence suggests that central bank independence (CBI) affects the reserves accumulation policy in emerging economies. Dincer and Eichengreen (2014) build a CBI index for the period 1998-2010 and show that there has been steady movement in the direction of greater independence over time. Figure 1 illustrates a positive correlation between CBI and reserves-to-debt ratios across countries.[2] Figure 2 decomposes the CBI index and shows that the reserves-to-debt ratios are mainly correlated with the stringency of limits on central bank lending to public sector. Panel a shows that there is no correlation between independence of the CEO and reserves-to-debt ratios, while Panel b shows that countries with strict limits on central bank lending accumulate higher levels of reserves as percentage of debt. This evidence suggests that a priority for theoretical work on the adequate level of reserves is to understand how CBI affects the accumulation of international reserves in emerging economies.

[1] Rodrik (2006) estimated that emerging economies incur anually in an average GDP loss of 1% for maintaning high levels of debt and reserves.

[2] I build my own index considering only two of the four criterias used by Dincer and Eichengreen (2014). Those criterias are independence of the CEO and stringency of limits on central bank lending to public sector.

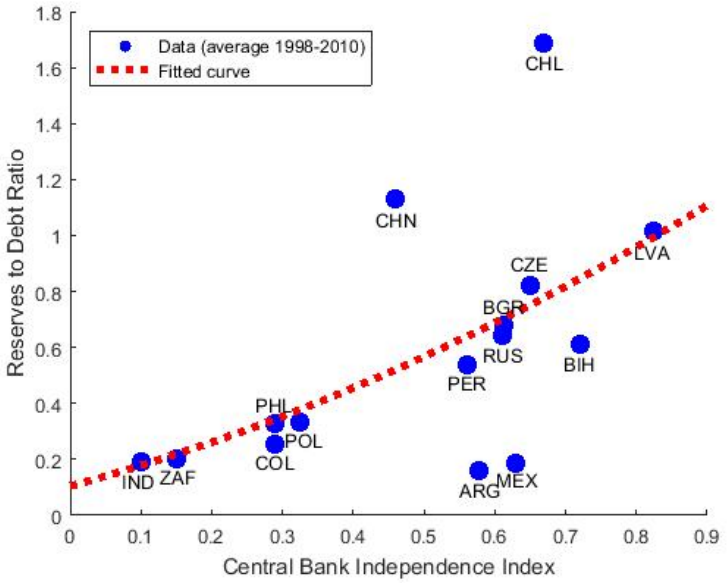
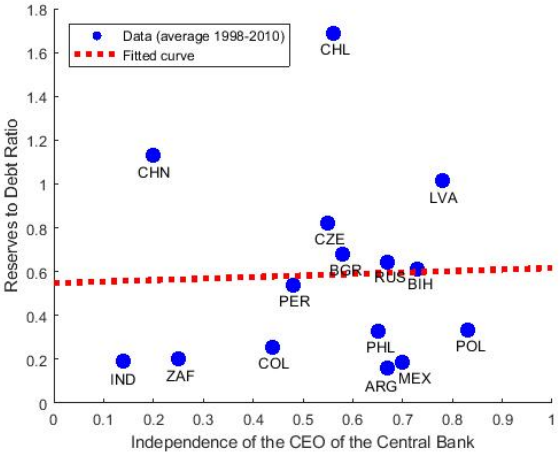
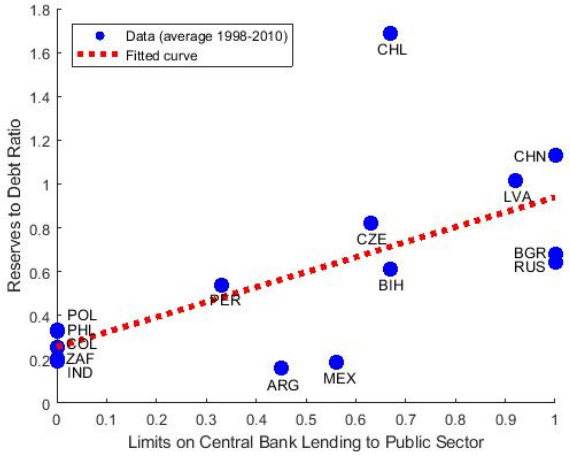


Figure 1: International Reserves and Central Bank Independence, 1998-2010



Panel a. Independence of the CEO



Panel b. Limits on Central Bank Lending

Figure 2: Components of Central Bank Independence Index, 1998-2010

In this paper, I study the accumulation of international reserves in a sovereign default model (Eaton and Gersovitz, 1981; Aguiar and Gopinath, 2006; Arellano, 2008) that captures two measures of CBI: (i) independence of the CEO, and (ii) stringency of limits on central bank lending to public sector. To introduce the independence of the CEO into the model, I assume two government entities where the monetary authority is more patient than the fiscal authority. This assumption is meant to capture the idea that fiscal authority is constrained by short-term political pressures[3]. To introduce limits on central bank lending to public sector into the model, I assume a constraint on the amount transfered from the monetary authority to the fiscal authority. This assumption departs from the related literature which implicitly assume no constraints on tranfers among government entities by assuming a consolidated government budget constraint. I find that an independent CEO is not enough to rationalize high levels of reserves in the long run. However, the stringency of limits on central bank lending to public sector can explain the reserves-to-debt ratios observed in emerging economies. These findings are consistent with the facts presented in Figure 2.

I measure independence of the CEO as a function of the relative distance between government entities discount factors. This implies that an independent central banker is more aligned with households than with the fiscal authority. I follow Alfaro and Kanczuk (2009) by choosing a low discount factor for the fiscal authority, and use data from Dincer and Eichengreen (2014) to set the value of the monetary authority's discount factor. I use the same dataset to calibrate the parameter that measures the stringency of limits on lending from the monetary authority to the fiscal authority. For the rest of the parameters, I use standard values from the related literature. The model rationalizes high levels of debt and reserves in a sovereign default model with one-period bonds.[4] Model simulations generate anually levels of reserves and debt of 14% and 37% of GDP, respectively, which are consistent with the observed average levels on my sample. In a quantitative exercise, I show that my two-government-entites approach accounts for the positive correlation between independence and reserves-to-debt ratios documented in Figure 1.

[3] On these two arguments see Walsh (2003) and Grilli, Masciandaro, and Tabellini (1991).

[4] In an important early work, Alfaro and Kanczuk (2009) studied the optimal reserves accumulation policy in a sovereign default model with one-period debt. They found that in this environment is not possible to match simultaneously high levels of debt and reserves.

I use the model to quantify the welfare effects of a central bank independence reform. I show that, departing from an economy without legal limits on central bank lending to public sector, a reform that prohibits central bank lending to the government increases the level of reserves, reduces the net debt position of the economy, and improve social welfare by 1.8%.[5] The main assumption behind this result is that the fiscal authority is non-benevolent. Therefore, in an environment where fiscal authority issues more debt than what is socially optimal, the benefit of accumulating reserves is to reduce the net debt position of the economy and reallocate the intertemporal consumption choices. The main lesson of this paper is that impose limits on central bank lending to public sector is both a good candidate to explain the observed levels of reserves and a effective way to mantain low net debt levels. Even though the reserves accumulation motive in this paper is quite mechanic, it shed light on the importance of CBI to understand the accumulation of reserves in an environment where fiscal authority is constrained by short-term political pressures.

Related Literature. I build on the quantitative sovereign default literature that follows Aguiar and Gopinath (2006) and Arellano (2008). They provide a framework that generates consistent predictions of sovereign default episodes and other features of emerging economies, including countercyclical spreads and procyclical borrowing. I present a model with two government entities with different objective functions, where the fiscal authority issues debt and monetary authority buys reserves. I show that my model is still consistent with key features of emerging markets. Moreover, my model is able to account for high levels of both reserves and debt observed in indebted economies.

Alfaro and Kanczuk (2009) study the joint accumulation of reserves and debt in a sovereign default model with one-period bonds. They show that a sovereign default model with a consolidated government, who issues one-period debt and buys reserves, cannot rationalize observed levels of debt and reserves. This result holds because holding reserves is costly, and a consolidated government can get the same net debt position by reducing debt instead of accumulating

[5]According to Dincer and Eichengreen (2014), Colombia, India, Poland, Phillippines, and South Africa are examples of countries without legal limits on central bank lending to public sector. On the other hand, Bulgaria, China, and Russia are examples of economies where central bank lending is prohibited.

reserves. Even though debt and assets are not perfect substitutes, they show that the reserves accumulation does not play a quantitatively important role in the model. In contrast, I show that my two-government-entities approach is consistent with the reserves-to-debt ratios observed in the data. I find that if I only consider independence of the CEO then the results are quite similar to Alfaro and Kanczuk. However, by introducing limits on central bank lending to public sector it is possible to rationalize high levels of reserves even with one-period bonds.

Bianchi, Hatchondo, and Martinez (2018) is one of the most succesfull attempts to account for levels of reserves and debt observed in the data. They show that by introducing long-term debt to a sovereign default model it is possible to rationalize positive levels of reserves and debt. In their model, reserves provides a hedge against rollover risk. This means that, by accumulating assets and long-term debt, the government transfers resources from states with low borrowing costs to states with high borrowing costs. Even though I recognize that this hedging motive against rollover risk can certainly explain some of the upward trend in reserves observed in emerging economies, I do not consider long-term debt because the focus of this paper is to study how CBI affects the reserves accumulation policy in debt constrained economies. In the future, I would like to extend my two-government-entities approach to a model with long-term debt.

Finally, Dincer and Eichengreen (2014) reports a measure of independence for more than 100 central banks. The index shows that there has been steady movement in the direction of greater independence over time. This measure reflects aspects such that the independence of the CEO of the central bank, its independence regarding policy formulation, objective or mandate, and the stringency of limits on its lending to public sector. I introduce the first two criterias into a structural model and use their dataset to calibrate the model. The rest of the paper is organized as follows: Section 2 presents the theoretical model. Sectio 3 presents the deterministic version of the model. Section 4 presents the quantitative analysis. Section 5 concludes.

2 The Model

Consider a small open economy that receives a stochastic endowment. The main assumption of this paper is that the government does not behave as a benevolent social planner. Instead, I assume two government entities with different objective function. In particular, I assume that the fiscal authority is more impatient than the monetary authority. The fiscal authority trades bonds with risk neutral competitive foreign lenders. Debt contracts are not enforceable and the fiscal authority can choose to default on its debt at any time. The monetary authority cannot borrow but it can buy a foreign reserve asset that pays a risk-free interest rate. I assume that government entities move simultaneously.

2.1 Environment

Endowments. Time is discrete and indexed by $t \in \{0, 1, ...\}$. The economy's endowment of the single tradable good is denoted by $y \in \mathbb{R}_{++}$. The endowment follows a Markov process given by

$$\log(y_t) = (1-\rho)\mu + \rho \log(y_{t-1}) + \varepsilon_t,$$

where $\mid \rho \mid < 1$ and $\varepsilon_t \sim N(0, \sigma_\varepsilon^2)$.

Domestic Households. The economy is populated by a risk averse representative agent with preferences given by

$$E_0 \sum_{t=0}^{\infty} \beta^t u(c_t)$$

where $0 < \beta < 1$ is the discount factor, c is consumption, and $u(.)$ is increasing and strictly concave. I assume that households discount future at the risk-free interest rate, this is $\beta \equiv \frac{1}{1+r^*}$. Households receive a stochastic stream of a tradable good y, lump sum transfers from the fiscal authority $T \in \mathbb{R}$, and pay an inflation tax to the monetary authority $\tau \in \mathbb{R}$. Therefore, the household's budget constraint at period t is given by

$$c = (1-\tau)y + T$$

Monetary authority. The monetary authority has a discount factor given by β^M, where $0 < \beta^M \leq \beta$, and its objective function is given by

$$E_0 \sum_{t=0}^{\infty} \left(\beta^M\right)^t u(c_t)$$

The central bank can make transfers to the fiscal authority $\Omega \in \mathbb{R}$, and buy foreign assets A' financed by segniorage and previous savings. I aslo assume that the monetary authority cannot borrow. Therefore, the associated budget constraint is

$$\Omega = \tau y + (1 + r^*)A - A'$$

To introduce into the model limits on central bank lending to public sector, I impose a constraint on the transfers among government entities. Let define $y^M \equiv \tau y + (1 + r^*)A$ as the central bank profits at period t. Then, I assume that the monetary authority is able to tranfer to the fiscal authority up to $(1 - \lambda)$ times of their profits y^M. This is,

$$\Omega \leq (1 - \lambda)\, y^M$$

where $\lambda \epsilon \left[0, \frac{1}{1+r^*}\right]$ represents the stringency of limits on central bank lending. Notice that by substituting the central bank budget constraint, $\Omega = \tau y + (1 + r^*)A - A'$, we can rewrite the lending constraint as a constraint on the new level of reserves given by

$$A' \geq \lambda \left[\tau y + (1 + r^*)A\right]$$

Fiscal authority. I consider a non-benevolent fiscal authority that is constrained by short-term political pressures. In particular, I assume that the fiscal authority's discount factor is given by β^F, where $0 < \beta^F < \beta^M \leq \beta$. Therefore, the fiscal authority's objective function is

given by

$$E_0 \sum_{t=0}^{\infty} \left(\beta^F\right)^t u(c_t)$$

The fiscal authority receives tranfers from the central bank and trades bonds with risk neutral competitive foreign lenders. When the fiscal authority pays back previous liabilities, it faces the following budget constraint:

$$T = \Omega + qD' - D$$

Otherwise,

$$T = \Omega$$

Notice that in the default period, the fiscal authority is excluded from financial markets and does not make any choice. During default, the monetary authority uses the reserves to smooth consumption. Therefore, the fiscal authority receives transfers from the monetary authority and inmediatly transfers them to the households.

Resource constraint. We can obtain the resource constraint by consolidating the household, the monetary authority, and the fiscal authority budget constraints. By sustituting Ω in the fiscal authority's budget constraint and plugging in T into the household's budget constraint, we obtain:

$$c + A' + D = y + (1 + r^*)A + qD'$$

Default. When the fiscal authority defaults, it will be temporary excluded from financial markets. As in most previous studies, I also assume that the recovery rate for debt in default (i.e., the fraction of the loan that lenders recover after a default) is zero. I follow Arellano (2008) by assuming that after default the economy's endowment is given by y^{def}, which considers an exogenous default cost. Therefore, the costs from default consist of two components: exclusion from international financial markets and direct output costs. Specifically, if the government defaults, I assume that current debts are erased from the government's budget constraint and

borrowing is not allowed. The fiscal authorithy will remain excluded from financial markets for a stochastic number of periods and will reenter to financial markets with an exogenous probability θ. Notice that when the fiscal authority is excluded from financial markets, the monetary authority still has access to asset markets. Therefore, if the fiscal authority chooses to default the resource constraint is given by:

$$c + A' = y^{def} + (1 + r^*)A$$

International Lenders. There is a continuum of identical risk neutral lenders with measure one. They have perfect information regarding the economy's endowment process and can observe the level of income every period. They have access to international credit markets in which they can borrow or lend as much as needed at the risk-free interest rate r^*. As in Arellano (2008), the equilibrium price of domestic bonds accounts for the risk of default that creditors face such that the price of bonds q must be equal to the risk-adjusted opportunity cost. This is,

$$q = \frac{(1 - \delta)}{1 + r^*}$$

The probability of default δ is endogenous and depends on the fiscal authority's incentives to repay debt. Since $0 \leq \delta \leq 1$, the zero profit requirement implies that equilibrium bond prices q lie in the interval $[0, (1 + r^*)^{-1}]$. However, the probability of default will depend not only on the new level of debt but also on the new level of reserves.

Timing. The timing of actions within each period is as follows:

1. The endowment shock y is realized, and the aggregate state of the economy is given by (y, D, A).

2. The fiscal authority chooses whether or not to default.

   (a) If default occurs, the fiscal authority is excluded from international financial markets, and the monetary authority chooses the new level of reserves A'.

(b) Otherwise, the fiscal authority, taking as given the price schedule $q(.)$, issues new debt D', and the monetary authority chooses the new level of reserves A'.

3. Households consume c.

2.2 Recursive Equilibrium

To define a recursive equilibrium, we work backward given the timing of actions described above. Households simply consume their endowment after taxes. International lenders are risk neutral and lend the amount of debt demanded by the fiscal authority as long as the expected return on the bonds equals $(1+r^*)$. Therefore, there are only two strategic agents in the model, monetary and fiscal authorities. In a simultaneous game, the state of an individual agent is the same as the aggregate state (y, D, A) for each player. In equilibrium, agents solve their problem by correctly predicting what the policy function, or best response, of other agents will be. I focus on Markov perfect equilibria. That is, I assume that in each period, the agents's strategies depend only on payoff-relevant state variables.

Fiscal Authority's Value Function. Let $V^F(y, D, A)$ be the the value function of the fiscal authority that has the option to default and that faces the state (y, D, A). Given the option to default, $V^F(y, D, A)$ satisfies

$$V^F(y, D, A) = \max_{\{r,d\}} \left\{ V_r^F(y, D, A), V_d^F(y, A) \right\}$$

where $d(y, D, A)$ denotes the policy function for the default choice given by

$$d(y, D, A) = \begin{cases} 0 & \text{if } V_r^F(y, D, A) \geq V_d^F(y, A) \\ 1 & \text{if } V_r^F(y, D, A) < V_d^F(y, A) \end{cases}$$

On one hand, the value of defaulting is given by

$$V_d^F(y, A) = u(c) + \beta^F \left\{ \theta E \left[V^F(y', 0, A') \mid y \right] + (1-\theta) E \left[V_d^F(y', A') \mid y \right] \right\}$$

s.t.

$$c = y^{def} - A' + (1 + r^*)A$$

$$A' = A_d(y, A)$$

where $A_d(.)$ denotes the policy function for reserves during default and it is choosen by the monetary authority.

On the other hand, the value of repayment is defined by

$$V_r^F(y, D, A) = \max_{\{D'\}} \left\{ u\left(c\right) + \beta^F E\left[V^F(y', D', A') \mid y \right] \right\}$$

s.t.

$$c = y - A' + (1 + r^*)A + q(y, D', A')D' - D$$

$$A' = A_r(y, D, A)$$

where $A_r(.)$ denotes the policy function for reserves in repayment states.

The solution to the fiscal authority's problem yields policy functions for default $d(y, D, A, A')$ and debt $D'(y, D, A, A')$. As in Arellano (2008), let define the repayment zone as follow:

$$R(D, A) = \left\{ y \in Y \mid V_r^F(y, D, A) \geq V_d^F(y, A) \right\}$$

and let $R^c(D, A)$ be the default zone defined by

$$R^c(D, A) = \left\{ y \in Y \mid V_r^F(y, D, A) < V_d^F(y, A) \right\}$$

Therefore, the probability of default is defined by

$$\delta(y, D', A') = \int_{R^c(D', A')} f(y', y) dy'$$

Monetary Authority's Value Function. When entering the period without access to

international debt markets, the monetary authority's value function is given by

$$V_d^M(y,A) = \max_{\{A'\}} \left\{ u\left(c\right) + \beta^M \left(\theta E\left[V_r^M(y',0,A') \mid y \right] + (1-\theta) E\left[V_d^M(y',A') \mid y \right] \right) \right\}$$

s.t.

$$c = y^{def} + (1+r^*)A - A'$$

$$A' \geq \lambda \left[\tau y^{def} + (1+r^*)A \right]$$

Denote that the solution to this problem by $A' = A_d(y,A)$. When entering the period with access to international debt markets, the monetary authority's value function is given by

$$V_r^M(y,D,A) = \max_{\{A'\}} \left\{ u\left(c\right) + \beta^M E\left[(1-d') V_r^M(y',D',A') + d' V_d^M(y',A') \mid y \right] \right\}$$

s.t.

$$c = y + (1+r^*)A - A' + q(y,D',A')D' - D$$

$$A' \geq \lambda \left[\tau y + (1+r^*)A \right]$$

$$D' = D'(y,D,A)$$

$$d' = d(y',D',A')$$

where $D'(y,D,A)$, and $d' = d(y',D',A')$ denotes the fiscal authority´s best response functions. Note that the solution to this problem is given by $A' = A_r(y,D,A)$.

Definition. The **recursive equilibrium** for this economy is a list of value functions $V_d^M(y,A)$, $V_r^M(y,D,A)$, $V^F(y,D,A)$; policy functions for (i) foreign assets $A_d(y,A)$ and $A_r(y,D,A)$, (ii) foreign debt $D'(y,D,A)$, (iii) default decision $d(y,D,A)$ (iv) repayment sets $R(D,A)$ and default sets $R^c(D,A)$, and (v) consumption $c(y,D,A)$, and a price function for bonds $q(y,D',A')$ such that:

1. $A_d(y,A)$ solve $V_d^M(y,A)$

2. $A_r(y, D, A)$ solve $V_r^M(y, D, A)$

3. $\{D'(y, D, A), \quad d(y, D, A)\}$ solve $V^F(y, D, A)$

4. Given the government policy, $c(y, D, A)$ satisfies the resource constraint

5. $q(y, D', A')$ satifies $q = \frac{1-\delta(y,D',A')}{1+r^*}$, where $\delta(y, D', A') = \int_{R^c(D',A')} f(y', y)dy'$

3 Deterministic Economy

In order to explain in the most transparent way how the accumulation of reserves reduces the net debt position of the economy in equilibrium, I begin by considering a deterministic version of the model where the only measure of CBI is the indnependence of the CEO, all endowments are known at period 0, and the fiscal authority is constrained by an endogenous borrowing limit.

Let denote by $r \equiv \frac{1}{q}$ the interest rate on domestic bonds, and assume that $y_t = y$ for all t. The endowment after default is given by $y^{def} = (1-\lambda)y$, where λ represents an exogenous default cost. In this environment, there is no default. Instead, there is an endogenous borrowing limit which respresents the maximum level of debt such that the fiscal authority is willing to repay. Lenders know that for any level of debt above the borrowing limit, the fiscal authority's optimal choice is to default on its liabilities. Therefore, they will not lend more than this amount. The following proposition characterize the borrowing limit for this specific case.

Proposition 1 (Characterization of the borrowing limit). If $\beta^M = \frac{1}{1+r^*}$ then $\bar{D} = \frac{\lambda y}{r}$.

Proposition 1 tell us that the borrowing limit does not depend on the asset holdings of the economy. This result follows from assuming that monetary authority discounts future at the same rate as the rest of the world. This assumption let me illustrate in a simple way the main mechanism of the model. Once I introduce endowment shocks, the economy will be debt constrained by the bond prices which depend on debt and reserves. The following proposition characterizes the equilibria for two different economies with a consolidated government. First,

I characterize the equilibria for an economy with a benevolent government (Social Planner). Second, I characterize the equilibria for an economy with an impatient government (Alfaro and Kanczuk).

Proposition 2 (Consolidated Government Equilibria). For given initial values of debt and reserves, D_0 and A_0, the following statements hold:

1. If $\beta^F = \beta^M = \frac{1}{1+r^*}$ then $D_t^{sp} = D_0$ and $A_t^{sp} = A_0$ for all t.

2. If $\beta^F = \beta^M < \frac{1}{1+r^*}$ then $\exists\ \bar{t}$ such that:

   (a) For all $t < \bar{t}$, $D_t^{alf} \epsilon \left[D_0, \bar{D}\right)$ and $A_t^{alf} \epsilon\, (0, A_0]$.

   (b) For all $t \geq \bar{t}$, $D_t^{alf} = \bar{D}$ and $A_t^{alf} = 0$.

Proposition 2 tell us that a consolidated government does not accumulate reserves. Let $N^{sp} \equiv D^{sp} - A^{sp}$ be the net debt position for an economy with a benevolent government. Figure 3 illustrates that the optimal choice is to rollover the net debt position of the economy. In the case of an impatient government, let $N^{alf} \equiv D^{alf} - A^{alf}$ be the net debt position for such economy. Figure 4 shows that the optimal choice is to reduce assets and increase debt up to the borrowing limit. These results hold because debt and reserves are sustitutes, so a consolidated government can get the same net debt position by choosing either debt or assets. Next proposition shows that by introducing the two government entities approach, is possible to rationalize positive levels of reserves.

Proposition 3 (Two Government Entities Equilibria). Let D_0 and A_0 be the initial values for debt and reserves. If $\beta^F < \beta^M = \frac{1}{1+r^*}$ then the following statements hold:

1. $\exists\ \bar{t}$ and $\bar{A} > A_0$ such that:

   (a) For all $t < \bar{t}$, $D_t \epsilon \left[D_0, \bar{D}\right)$ and $A_t\ \epsilon\ \left[A_0, \bar{A}\right)$.

   (b) For all $t \geq \bar{t}$, $D_t = \bar{D}$ and $A_t = \bar{A}$.

2. Let $N_t \equiv D_t - A_t$ be the net debt position at period t. Then $N_t = N_t^{sp} > N_t^{alf}$ for all t.

Proposition 3 tell us that in an environment where an impatient fiscal authority issues more debt than what is socially optimal, an independent central bank will accumulate reserves to reduce the net debt position of the economy. Figure 5 illustrates that the monetary authority's best response is to accumulate reserves as long as the fiscal authority increases debt. Moreover, Figure 6 shows that a benevolent central bank can implement the optimal net debt position of the economy by accumulating reserves. This result holds in the deterministic version of the model because holding reserves is costlesss. Once I introduce endowment shocks, accumulating reserves is costly due to the spreads on interest rates that reflect the sovereign default risk. In the next section, I show that when accumulating reserves is costly the independence of the CEO is not enough to rationalize high levels of reserves. Therefore, I need to assume limits on central bank lending to explain the accumulation of reserves in emerging economies.

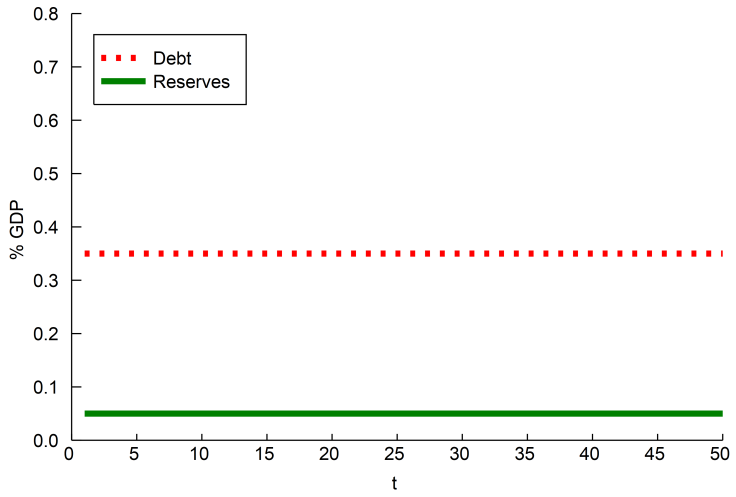


Figure 3: Social Planner Economy

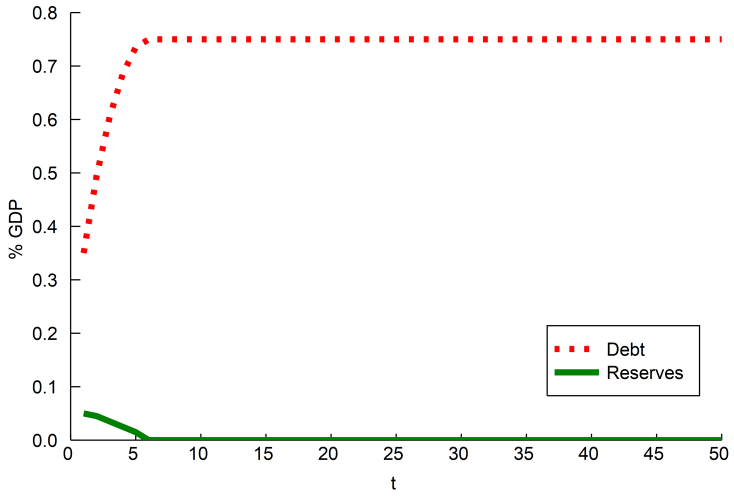


Figure 4: Alfaro and Kanczuk Economy

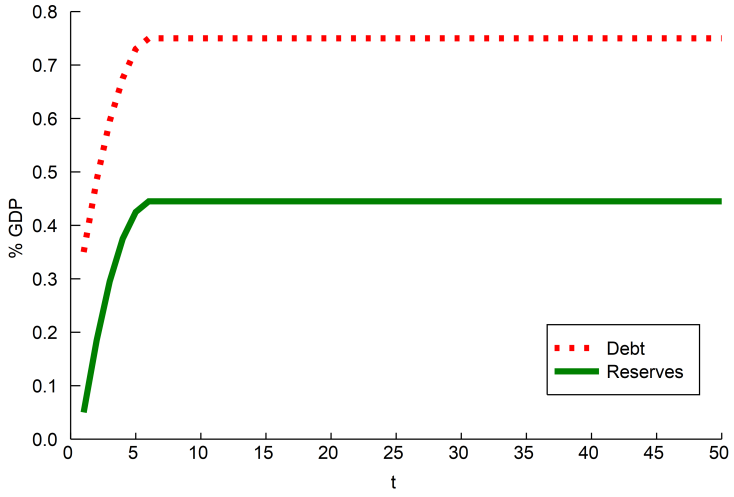


Figure 5: Independent Central Bank

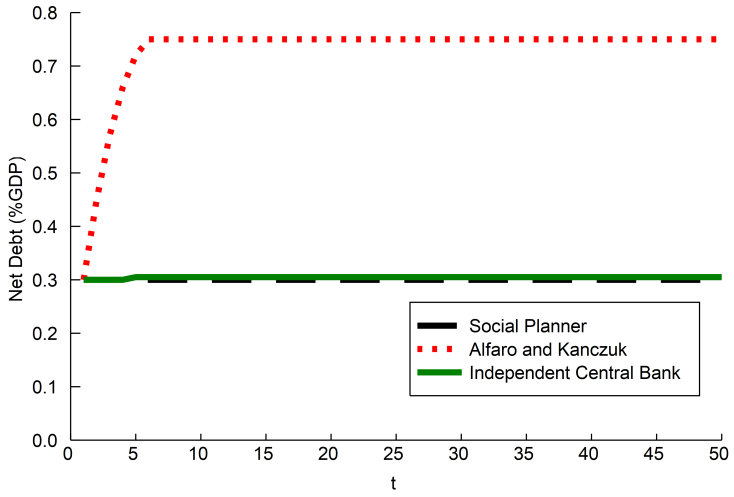


Figure 6: Net Debt Position

4 Quantitative Analysis

In this section, I present the quantitative analysis of the model. Section 4.1 describes the data for CBI. Section 4.2 describes the calibration and functional forms used in the simulations. Section 4.3 describes the computational algorithm. Finally, Section 4.4 presents the main results.

4.1 Data

Dincer and Eichengreen (2014) builds an index of central bank independence from 1998 to 2010. Their measure reflects aspects such as the independence of the CEO of the central bank, the stringency of limits on its lending to public sector, its independence regarding policy formulation, and the existence of an specific objective or mandate for central banks. Figure 7 illustrates that there has been steady movement in the direction of greater independence over time.[6] By comparing the CBI index in 1998 and 2010, they document an upward trend in CBI. In this paper, I explore the hypothesis that the large accumulation of reserves observed in emerging economies is explained by this upward trend in central bank independence. Since there is no money in the model, I do not consider the two criterias of independence related with monetary

[6]Figure 4 in Dincer and Eichengreen (2014).

policy. Therefore, I build an index using ther data but considering only two components: (i) independence of the CEO, and (ii) stringecy of limits on central bank lending to public sector. The CBI index is reported for both advanced and developing economies, I use a sample of 15 emerging economies that is consistent with Bianchi et. al (2018). Table 1 reports selected indicators for these 15 economies during the period 1998-2010.

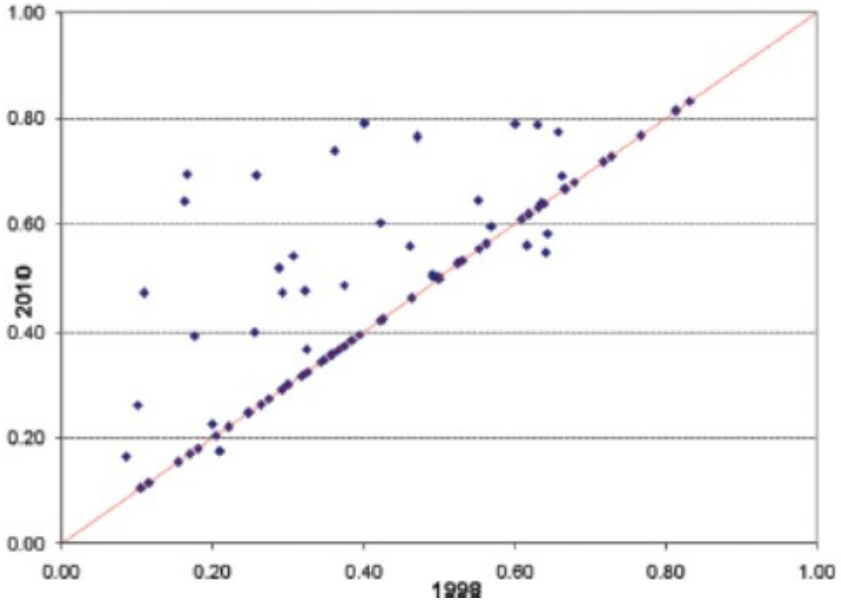


Figure 7: Comparison of CBI Index in 1998 and 2010

	Reserves (% GDP)	Debt (% GDP)	Reserves to Debt ratio	CBI Index
Argentina	10.8	67.8	0.16	0.58
Bosnia and Herzegovina	20.6	33.8	0.61	0.72
Bulgaria	28.5	42.1	0.68	0.61
Chile	16.4	9.7	1.69	0.67
China	29.8	26.4	1.13	0.46
Colombia	9.8	38.5	0.25	0.29
Czeck Republic	21.3	25.9	0.82	0.65
India	14.5	76.0	0.19	0.10
Latvia	15.9	15.7	1.01	0.82
Mexico	7.9	42.0	0.19	0.63
Peru	20.3	37.9	0.54	0.56
Philippines	17.8	54.4	0.33	0.29
Poland	14.8	44.1	0.34	0.32
Russia	18.2	28.3	0.64	0.61
South Africa	6.9	33.9	0.20	0.15
Average	16.9	38.4	0.59	0.50

Table 1: Selected Indicators (1998-2010)

4.2 Calibration

The model is solved numerically to evaluate its quantitative predictions regarding levels of debt and reserves observed across emerging economies.

Independence of the CEO. I measure CBI_1 as a function of the relative distance between discount factors,

$$CBI_1 = \frac{\beta^M - \beta^F}{\beta - \beta^F}$$

where β^F is fixed across countries. I follow Alfaro and Kanczuk (2009) by choosing a low discount factor for the fiscal authority. Therefore, I use data from Dincer and Eichengreen (2014) to set the value of the monetary authority's discount factor. I set $\beta^M = 0.78$ to match the average level of CEO independence observed in my sample, which is $CBI_1 = 0.60$.[7]

Stringency of Limits on Central Bank Lending. I measure CBI_2 as a linear function of λ in the interval given by $\left[\underline{\lambda}, \overline{\lambda}\right]$,

$$CBI_2 = \frac{\lambda - \underline{\lambda}}{\overline{\lambda} - \underline{\lambda}}$$

[7] Alternatively, it is possible to calibrate β^F to match the debt level in each country and use the function described above to get the country-specific β^M. For simplicity, I fix the fiscal authority's discount factor and calibrate the monetary authority's discount factor to an average level acroos countries.

where $\underline{\lambda}$ and $\overline{\lambda}$ are calibrated to match the minimum and maximum reserves-to-debt ratios observed in the fitted curve on Figure 1. This is, I set $\underline{\lambda} = 0.20$ to match the average reserves-to-debt ratio of the economies without lending limits[8], and I set $\overline{\lambda} = 0.60$ to match the average reserves-to-debt ratio of the economies with strict limits on central bank lending to public sector.[9]Finally, using data from Dincer and Eichengreen (2014) I choose $\lambda = 0.39$ to match the average level of CBI_2 which is 0.48.

Other parameter values. The next step of this project is to precisely calibrate the parameter values to match specific moments in the data. For now, I follow the literature for most of the parameters. For the output default cost, I follow Alfaro and Kanczuk (2009) by assuming a linear function given by

$$y^{def} = (1 - \gamma)y$$

I also assume that the functional form of the utility is given by

$$u(c) = \frac{c^{1-\sigma}}{1-\sigma}$$

Table 2 summarizes the parameter values.

[8]Colombia, India, Philippines, Poland, and South Africa.
[9]Bulgaria, China and Russia.

Parameter	Description	Value	Source/Target
r	Risk-free interest rate	0.04	
σ	Risk aversion	2	
θ	Reentry probability	0.50	
γ	Default cost	0.10	Alfaro and Kanczuk (2009)
ρ	Autocorrelation of y	0.85	
η	Variance of y	0.044	
β^F	Fiscal authority discount factor	0.50	
β^M	Monetary authority discount factor	0.78	Avg.$CBI_1 = 0.60$
λ	Stringency of CB lending limits	0.39	Avg.$CBI_2 = 0.48$
τ	Inflation tax	0.20	Avg. $A/D = 0.44$

Table 2: Parameters

4.3 Computation

The following algorithm is used to solve the model:

1. Start with a guess for the bond price schedule such that $q = \frac{1}{1+r^*}$ for all the states of the economy.

   (a) Start with a guess for the reserves policy function in repayment such that $A_r(y, D, A) = A$ for all states.

   (b) Solve the recursive problem of the monetary authority in default using value function iteration.

   (c) Solve the recursive problem of the fiscal authority using value function iteration.

   (d) Solve the recursive problem of the monetary authority in repayment states using value function iteration.

   (e) Repeat until the guess converges to the reserves policy function.

2. Calculate the bond price schedule using the probability of default as in Arellano (2008).

3. Repeat until the guess converges to the price schedule.

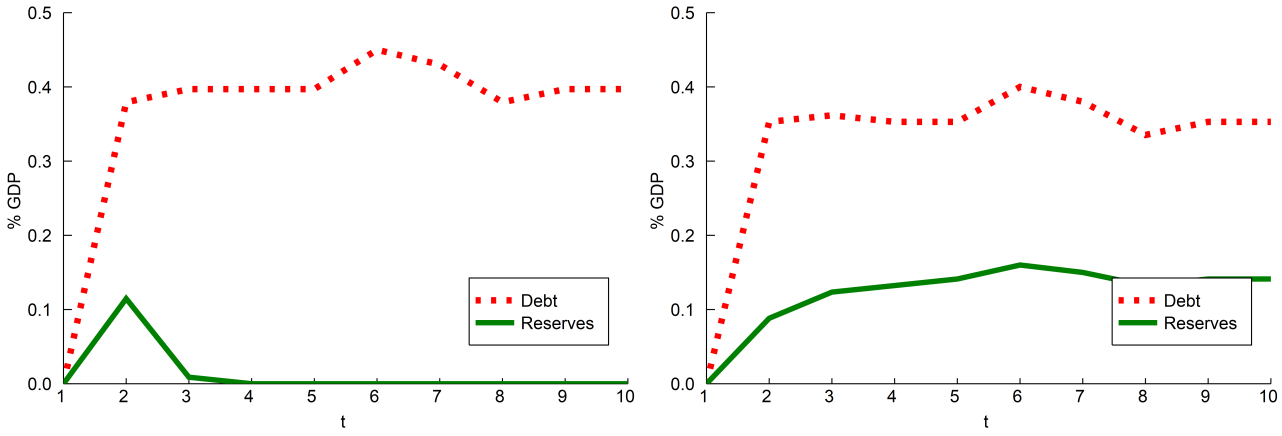
4. Generarate 1000 simulations for T periods and B different discount factors for the monetary authority.

4.4 Main Results (work in progress)

Alfaro and Kanczuk (2009) shows that a sovereign default model with a consolidated government, who issues one-period debt and buys reserves, cannot rationalize observed levels of debt and reserves. This result holds because holding reserves is costly, and a consolidated government can get the same net debt position by reducing debt instead of accumulating reserves. In this paper, I introduce a two government entities approach where fiscal authority is constrained by short-term political pressures while an independent central bank is not. These pressures are reflected in a relative impatience of the fiscal authority that leads to a disagreement about the net debt position of the economy. This disagreement is crucial for understanding why accumulating reserves can be welfare improving.

Figure 8a illustrates that the independence of the CEO is not enough to rationalize high levels of debt and reserves in the long run. For low levels of initial debt, the fiscal authority issues an oustanding amount of debt. Therefore, the monetary authority will accumulate reserves to reduce the net debt position of the economy. However, when the fiscal authority is debt constrained then is not optimal for the monetary authority to keep high levels of reserves. Instead, the central bank will deaccumulate reserves for consumption smoothing. By introducing limits on central bank lending it is possible to prevent the time inconsistency problem for the monetary authority, and mantain high levels of reserves in the long run. This result is quite mechanic because I introduce these limits into the model in a way that can be rewriten as a lower bound on the level of reserves. However, this mechanism is consistent with the data and let us rationalize high levels of reserves in a tractable model. Figure 8b, presents time series for debt and reserves in the case of a central bank that faces lending limits.

Figure 9 presents the reserves policy function for these two economies. In both cases the reserves accumulation policy is increasing in the initial level of reserves. However, for the case without lending limits the equilibrium is not to accumulate reserves as in Alfaro et.al. In contrast, my two-government-entities approach that considers a central bank with limits on central bank lending rationalizes a positive levels of reserves in equilibrium. Figure 10a shows that without lending limits, the fiscal authority issues higher level of debt in equilibrium. Figure 10b, shows that when the monetary authority faces lending limits the price of bonds reflects a higher probability of default. These results holds because accumulating reserves increase the default value and increase the incentives to default. Finally, Figure 11 shows that model simulations generate a positive correlation between independence and reserves to debt ratio which is consistent with the data.



Panel a. Independence of the CEO

Panel b. Limits on Central Bank Lending

Figure 8: Time Series for Debt and Reserves

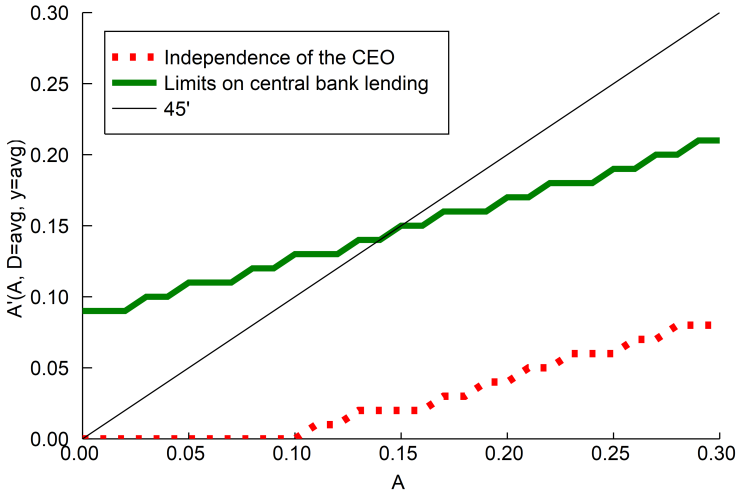
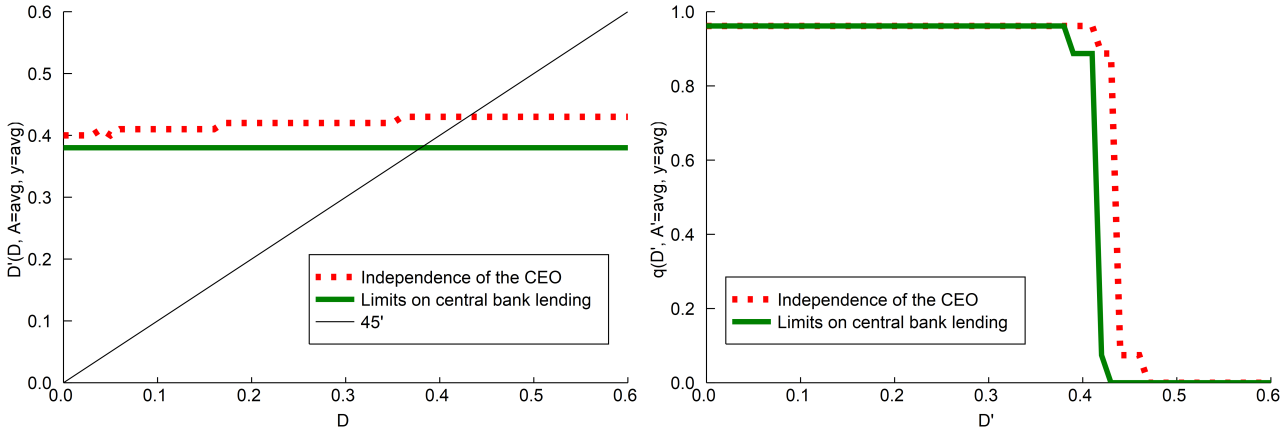


Figure 9: Reserves Policy Function



Panel a. Debt Policy Function Panel b. Bonds Prices

Figure 10: Debt Policy Function and Bonds Prices

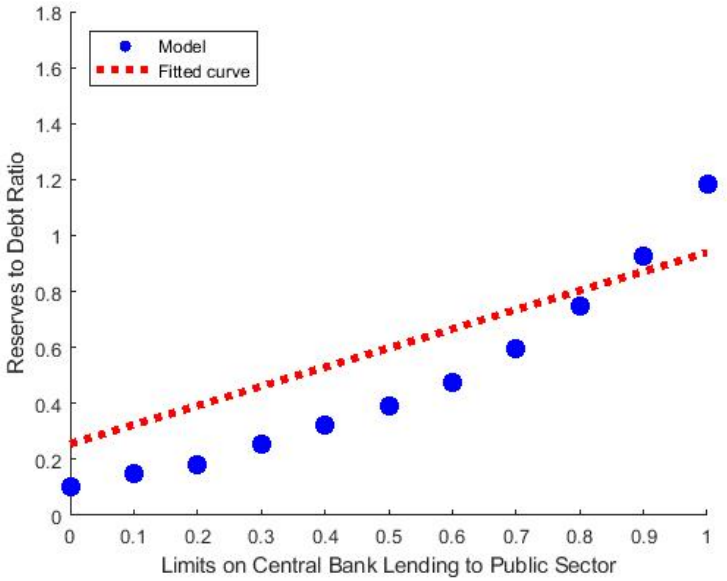


Figure 11: International Reserves and Central Bank Independence

5 Conclusions

This paper studies the accumulation of international reserves in a sovereign default model with an independent central bank. The model features two government entities: an impatient fiscal authority who issues one-period debt, and a patient monetary authority who buys reserves. In this setup there is a disagreement about the net debt position of the economy, which is key to understand the benefit of reserves accumulation. This benefit comes from the ability of an independent central bank to affect the equilibrium allocation. I show that in an environment where fiscal authority issues more debt than what is socially optimal, an independent central bank will accumulate reserves to reduce the net debt position of the economy. It is crucial for my result that the central bank faces lending limits. Otherwise, the monetary authority will not hold high levels of reserves due to a time inconsistency problem.

I measure independence of the CEO as a function of the relative distance between discount factors and introduce limits on central bank lending to the public sector as a lending constraint for the central bank. I use a CBI index to set both measures of CBI in the model. For the rest of

the parameters, I use standard values from the related literature. Model simulations accounts for a positive correlation between independence and reserves to debt ratio observed across countries. In a quantitative exercise, I show that a central bank independence reform that prohibit central bank lending to public sector increases the level of reserves, decreases the net debt position of the economy, and improve social welfare by 1.8%. Even though a precise calibration of the model seems crucial to quantify the impact of CBI in the accumulation of international reserves among emerging economies, these results shed light on the importance of an independent central bank in an environment where fiscal authority overborrows due to short-term political pressures.

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Appendix

A Omitted proofs

Proof of Proposition 1

Proof. We know that if the borrowing constraint is binding and the endowment is constant over time, the fiscal authority's best response is to rollover the debt and only pay the debt service. This is, $D'(y, A, A', \bar{D}) = \bar{D}$ for all (A, A'). Given the fiscal authority's best response, a benevolent monetary authority also chooses to rollover the asset position whenever the economy is in a stationary state. This is, $A_d(y, A) = A$ and $A_r(y, \bar{D}, A) = A$ for all A. The rest of the proof follows from the definitition of borrowing limit, $V_r^F(y, \bar{D}, A, A') = V_r^F(y, A, A')$. In equilibrium this is

$$V_r^F(y, \bar{D}, A, A_r(y, \bar{D}, A)) = V_r^F(y, A, A_d(y, A))$$

$\Leftrightarrow$

$$V_r^F(y, \bar{D}, A, A) = V_r^F(y, A, A)$$

$\Leftrightarrow$

$$\frac{u(y - r\bar{D} + r^*A)}{1 - \beta^F} = \frac{u((1 - \lambda)y + r^*A)}{1 - \beta^F}$$

$\Leftrightarrow$(by strictly concavity of u)

$$y - r\bar{D} + r^*A = (1 - \lambda)y + r^*A$$

$\Rightarrow$

$$\bar{D} = \frac{\lambda y}{r} \quad \bowtie$$