On Some Subtle Implications of the Choice of Numeraire for Monetary Policy in Developing Countries[1]

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Abstract

Numeraire choice is often deemed a problem of purely analytical convenience. In this paper I show that there is more to numeraire selection than meets the eye for the formulation of monetary policy in countries with weak fiscal institutions. I show how (a) improper numeraire choice can dramatically overstate or understate Central Bank profits and (b) how this can threaten the ability of a Central Bank to keep inflation under control. I show point (a) in the context of Monte Carlo experiments calibrated for the Venezuelan economy and point (b) in an infinitely lived representative agent model that illustrates the problem of joint determination of the ideal level of foreign currency reserves and of the desired level of transfers of Central Bank profits to the Treasury when the objective is to eliminate the possibility of a hyperinflation.

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1. Introduction

In this paper I study two important but often overlooked themes in the formulation of monetary policy in many developing countries: (1) whether and how Central Banks profits (positive changes in net worth of the Central Bank) should be transferred to the Treasury and (2) how much foreign currency reserves should the Central Bank hold. While the natural temptation for a Central Banker is to indefinitely accumulate net worth and foreign currency reserves to aid it its mission of controlling inflation, such accumulation has naturally an opportunity cost as society may find many alternative uses to those resources. Hence, the need to come up with sensible principles that would help the Central Bank in a developing country determine the adequate level of net worth transfer to the Treasury and the ideal level of foreign currency reserves to hold to prevent a hyperinflationary crisis.

The purpose of this paper is to study how these two questions are related and to provide a framework which enables us to provide answers to those questions that are consistent with the Central Bank's ability to keep inflation under control. Interestingly, a seemingly irrelevant issue for analytical purposes, that of numeraire choice, becomes crucial for a proper understanding of the mistakes a Central Bank can make in the design of profit transfer rules, and how a Central Bank must compensate for this mistake under the form of higher foreign currency reserves, if it wishes to avoid a hyperinflation. To illustrate some of the points I make I use the Venezuelan economy as an example but it is clear that the issues raised here are relevant for many other developing countries as well.

1.1 Preview of the results

Two sets of results are presented in this article. The first group of results relate to issues of proper computation of central bank profits. The second group of results relates to issues related to the uses that ought to be given to those profits and how they relate to ideal foreign reserve levels.

The main issue studied in this paper is that many central banks in developing countries sell hard currency at a price that is usually higher than the price they paid for it and hence derive a profit given by the difference between the selling and the buying price. Because

the worth of a unit of hard currency is, in its own terms, always equal to one, many central bankers assert that the bulk of those profits are purely accounting profits, therefore not real, and therefore should not be transferred to the Treasury. In this paper I hold those assertions to be only partially true.

I also argue that numeraire selection turns to be critical for proper computation of Central Bank profits. Big positive profits under a certain numeraire may be zero or negative according to a different numeraire.

Once the proper numeraire has been chosen one is left with yet another problem: that of appropriate inventory valuation method among, for example, the well-known methods such as *first in first out* (FIFO), *last in first out* (LIFO), weighed average and so on. In a separate paper (Zambrano, 2005) I argue that weighted average is the most appropriate method to use in this context as it treats the units that remain in inventory and the units sold in a symmetrical manner.

To see the importance that numeraire selection and inventory valuation method may have in practice I use Monte Carlo Experiments calibrated to fit the Venezuelan economy to highlight the dramatic differences that using different methods produced on the computation of Central Bank profits.

The second group of results relate to issues regarding the uses that ought to be given to those profits and how they relate to ideal foreign reserve levels. In many developing countries, Venezuela included, those issues are dealt with separately. To study this further I use an infinitely lived representative agent model that was developed by Sims (2005) to study the connections between the balance sheet of the Central Bank and of the Treasury.

An important lesson that I draw from my analysis is that how much of the Central Bank profits to transfer and how much foreign reserves to have should be determined jointly. In particular, the study of the net worth of the Central Bank allows me to determine a "critical" level of foreign currency reserves that eliminates the technical feasibility of a hyperinflationary crisis. When foreign currency sales drive reserves below such critical

level Central Bank profits should not be transferred because they are necessary to replace the desired level of reserves without eroding the level of net worth of the Central Bank. On the other hand, when foreign currency sales situate reserves above such critical level, Central Bank profits can safely be transferred to the Treasury without this undermining the Central Bank's ability to keep inflation under control.

The structure of the rest of this article is as follows. In Section 2 I discuss conceptually and through examples the issue regarding numeraire choice and how it determines the existence or non-existence of Central Bank profits. In Section 3 I discuss issues regarding proper computation of such profits and present Monte Carlo experiments done for the Venezuelan economy that illustrate the cost of employing improper methods of computation of Central Bank profits. In Section 4 I use a model by Sims (2005) to study the connections between price stability, transfer of profits to the Treasury and the desired level foreign currency reserves. I present some conclusions in Section 5.

2. Are Central Bank profits real?

Our analysis must begin with the question of the very existence of Central Bank profits. A Central Bank typically keeps a stock of foreign currency and other liquid foreign assets. Those assets could be the source of profits in several ways: when the assets are sold, when the assets appreciate in value, and when the assets have an intrinsic real return (such as interest paid by bonds and the like). Profits due to sales are those that arise when the Central Bank sells the asset at a price higher than the one it takes to replace it (the opportunity cost). Profits due to asset appreciation arise when the price at which one may replace the asset exceeds the price one paid for the asset. Finally, the profits due to the intrinsic return of the asset are self-explanatory.

In the Venezuelan case profits due to sales are minimal as there is a set price markup of about 0.4% between the price at which the Central Bank sells currency and the price at which it buys. Profits due to the intrinsic return of the asset are low, stable, and do not generate much debate as to their proper use. Profits due to asset appreciation, however, can be quite sizable, as the Central Bank tends to hold foreign assets in its inventory for quite

some time before they decide to sell them. It turns out that the size of those profits can vary dramatically depending on the specifics of how they are computed.

There is an ample debate among Central Bank economists in developing countries about these matters. A prominent view among Central Bankers is that, because the worth of a unit of hard currency is, in its own terms, always equal to one, profits from asset appreciation are viewed as purely accounting profits, therefore not real, and therefore should not be transferred to the treasury. From my standpoint, however, whether they are right or not about this simply depends on numeraire choice, as the simple example below shows:

Example 1. *An investor buys 12,100 shares of a company in the stock market at a price of 100 bills (the domestic currency) per share. Those shares go up in price to 121 bills per share; hence the investor is wealthier by an amount equal to 254,100 bills. The argument given by the Central Bankers above applied to this case would suggest that, since the number of shares held by the investor hasn't changed, distributing the profits back to the investor would require selling 2,100 shares, leaving him with a final capital of only 10.000 shares.*

The problem with this argument, of course, is that an investor is not really interested in the final number of *shares* (or *bills*) in his portfolio but instead on the purchasing power of those shares and bills. A proper computation of profits then entails computing the change in net worth by estimating price changes of the assets in the portfolio in terms of the units of the goods that the investor typically consumes.

Example 1. *(cont.) Assume the typical basket of goods the investor normally buys initially costs 100 bills and then it increases to 110 bills. This means that the value of the initial wealth in terms of consumption baskets is 12,100 baskets. After all prices change in the*

economy the final value of wealth is now 13,310 baskets, which means price changes leave the investor with a profit equal to 1,210 baskets, that is 133,100 bills.

This leaves us with three estimates of the size of profits: our initial estimate of 254,100 *bills* (the one that would be preferred by the Treasury), the subsequent estimate of zero *bills* (the one preferred by the Central Bankers), and our intermediate estimate of 133,100 *bills*. It is immediate that each estimate is correct relative to a particular choice of numeraire: the first estimate arises out of the choice of *bills* as numeraire, the second estimate arises out of the choice of *shares* as numeraire, and the third estimate arises out of the choice of *baskets* as numeraire.

The example, simple as it is, reveals two basic yet somewhat subtle principles of modern microeconomic theory:

(α) The sign and magnitude of certain comparative static exercises may critically depend on numeraire choice[3].

(β) Proper numeraire choice ought to depend on the preferences of the underlying decision makers of the economic problem under study.[4]

Hence, the themes of existence and magnitude of Central Bank profits are intimately linked. They are linked through the subtle issue of numeraire choice.

3. The computation of Central Bank profits

So, how to determine which is the proper numeraire to use? Fortunately, principle (β) above provides an answer to this question: even when profits are a residual of Central Bank operations, what a society wishes to know when measuring the balance sheet of the Central Bank is how much in the way of real resources it costs to society to keep the Central Bank in operation, so that they can compare those costs to the benefits (measured also as real

[3] See, e.g,., Mas Colell (1991), Zambrano and Vogelsang (2000) and Nachbar (2002).

resources ultimately deemed for consumption) of having a modern Central Bank. It seems, then, that the proper numeraire is the so-called basket of goods that the typical member of society consumes.

Once the proper numeraire has been chosen then the issue becomes one of appropriate valuation of the inventory of foreign currency.[5] In a separate paper (Zambrano, 2005) I argue that "weighted average[6]" is the most appropriate method to use in this context as it treats the units that remain in inventory and the units sold in a symmetrical manner.

In short, in this article I argue that the proper numeraire is the typical consumption basket of the representative agent and that the proper inventory valuation method is the so-called "weighted average" method. In the next sub-section I show the discrepancies that may ensue from using other numeraires or inventory valuation methods.

3.1 The cost of improper computation of Central Bank profits

To illustrate the differences that exist between the different methods I performed Monte Carlo experiments on the size of the profits due to asset appreciation that would accrue over one semester in Venezuela. The parameters of the random variables used in the experiments were estimated from data from the Venezuelan economy for the period 1990-2003. The details are in Appendix 1. I present summary statistics of the simulations in Table 1.

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[4] See Grodal and Dierker (1999)

[5] This becomes an issue since the Central Bank typically sells at any given moment a fraction of the reserves it holds, reserves it typically bought at different moments in time, at different prices. Hence, the need to decide, for the purpose of computation of profits, "which of the units were the ones sold" and which of the units remain in the inventory.

[6] A method by which the cost of each unit sold at a moment in time is simply the average cost of all the units in stock at the moment the sale takes place.

Table 1

Simulated semester-long Central Bank Profits for two numeraires and three inventory valuation methods for the Venezuelan economy

Summary Statistics

(Billions of Bolívares)

	Numeraire: Bolívar (domestic currency)			Numeraire: Domestic CPI consumption baskets		
	FIFO	LIFO	Weighted Avg.	FIFO	LIFO	Weighted Avg.
Mean	3.5	0.3	1.9	-0.9	-0.1	-0.5
Stdev	4.4	0.8	2.5	3.1	0.5	1.7
t	1.261	2.963	1.352	-3.328	-4.321	-3.056
Prob. (U<=0)	17%	61%	18%	55%	81%	56%
Percentil 5% (1)	-3.3	-0.2	-2.1	-7.1	-1.1	-4.0
Percentil 95% (2)	11.5	1.7	6.3	2.8	0.3	1.5
(2)-(1)	14.8	1.9	8.5	10.0	1.3	5.6

Below I summarize the lessons derived from the analysis of the simulations.

1. When the numeraire is the dollar profits are identically zero, regardless of inventory valuation method.

2. When the numeraire is the domestic currency (the *Bolivar* in the case of Venezuela) the inventory valuation method is of great importance. The estimated expected value of Central Bank profits is *thirteen times higher* when using FIFO as inventory valuation method relative to the case when LIFO is used. The dispersion of profits is also higher under FIFO relative to LIFO. The results regarding the weighted average method are somewhere in between, as expected.

3. When the numeraire is the basket of goods represented in the Venezuelan CPI in the majority of the simulations we observe Central Bank losses rather than profits.[7] Inventory valuation methods do not affect the sign of the profits but they affect their magnitude. The estimated expected losses are *eight times highe*r under FIFO than under LIFO.

4. A fourth related lesson has to do with the following: Central Bankers routinely measure the changes in net worth of their Central Banks in terms of domestic currency and employ the FIFO inventory valuation method to minimize their size. What the simulations reveal is that such combination is far from being a good substitute for the prescription of using the domestic consumption baskets as numeraire: while it is true that LIFO understates profits relative to FIFO when the domestic currency is numeraire, FIFO also underestimates losses relative to any other inventory valuation method when the domestic consumption basket acts as numeraire. Hence, FIFO does not really do the job of protecting the net worth of the Central Bank in an environment of real exchange rate appreciation.

The discussion above and all the other statistics presented in Table 1 reveal that different methods for estimating Central Bank profits have substantial consequences on their sign and magnitude. In Section 4 below I examine the macroeconomic implications of using an improper method of computation of Central Bank profits.

4. Macroeconomic implications: desired foreign reserve levels, Central Bank profit transfer rules, and price stability

To better understand the problems that could arise from improper profit transfer from the Central Bank to the Treasury I use a model by Sims (2005), where the balance sheet of the Treasury and of the Central Bank are not consolidated. The contribution of this Section is that I use this model to study the effect of varying the profit transfer rules on several macroeconomic variables. The model allows us to understand when it is desirable and when

[7] This is of course related with the real exchange rate appreciation that took place in Venezuela during the period out of which the data employed to compute the parameters of the simulations was extracted.

it is undesirable to transfer Central Bank profits to the Treasury in a country with weak fiscal institutions.

4.1 The model

The economy is composed of infinitely lived agents who face the problem:

$$\underset{C_t}{Max} \int_0^{\infty} e^{-\beta t} \log C_t dt \qquad (1)$$

By choice of C, F_p, B and M subject to:

$$C\left(1+\psi(v)\right)+\dot{F}_p+\frac{\dot{M}+\dot{B}}{P}=Y+\rho F_p+\frac{rB}{P}+\tau \qquad (2)$$

The interpretation is as follows: at every instant the representative agent must choose how much to consume (C), how much to save in nominal government bonds (B), how much to save in real assets (F_p), and how much wealth to keep under the form of money (M).

At every instant the sources of funds are equal to the sum of the agents' real income (Y), the return on the agent's real investments (ρF_p, where ρ is the real interest rate), the return on government bond holdings (rB/P, where r is the nominal interest rate and P is the price level) and the government transfers (τ).

Each agent uses his real resources in accumulating real assets ($\dot{F}_p$), government bonds $\left(\dot{B}/P\right)$, real money balances $\left(\dot{M}/P\right)$, in consuming, and in "facilitating consumption." The meaning of "facilitating consumption" is as follows: if the agent wishes to consume an amount C of goods, it must purchase an amount equal to $C\left(1+\psi(v)\right)$ of goods. The expression $\psi(v)$ captures the cost of making transactions in the economy and it is an increasing function of the velocity of money (v), defined here as v=PC/M. Hence, the higher the agent's money holdings, the lower the transaction costs incurred for by the agent given a certain level of desired consumption.

The solution to this problem can be summarized in the following expressions:

$$r = \rho + \frac{\dot{P}}{P} \tag{3}$$

$$r = \psi' v^2 \tag{4}$$

$$\rho - \beta = \frac{\dot{C}}{C} + \frac{(2\psi' + \psi'' v)\dot{v}}{1 + \psi + \psi' v} \tag{5}$$

In this economy the Central Bank uses an interest rate rule given by

$$\dot{r} = \theta_0 + \theta_1 \frac{\dot{P}}{P} - \theta_2 r \tag{6}$$

Assume for simplicity that the real assets of the government are being held by the Central Bank and that the Bank does not hold any government bonds. Then the Central Bank's budget constraint is given by:

$$\dot{F}_G = \rho F_G + \frac{\dot{M}}{P} - \tau_B \tag{7}$$

The interpretation is as follows: The central bank obtains real resources through base money issuance, $\frac{\dot{M}}{P}$, and through the real return obtained from its holdings of real assets (ρF_G). Those resources are used to accumulate more real assets ($\dot{F}_G$), and to transfer profits to the Treasury, (τ_B). Think of F_G as the hard currency reserves held by the Central Bank. For more details on the setup of the model see Sims (2005).

The contribution of this section is that I use this model to explore the macroeconomic implications of three profit transfer rules: A "zero transfer" rule, a rule by which only the real return of the reserves, ρF_G is transferred to the Treasury, and a rule in which, in addition to ρF_G, the Central Bank transfers the amount $\left(\dot{P}/P\right)F_G$, that is, the amount of goods corresponding to the nominal appreciation of F_G, that is, the size of Central Bank

profits under the "domestic currency" numeraire. This is the case of "improper" transfer that I study in this Section. As in Sims (2005), I assume that the transfer becomes zero when seignorage revenue becomes negative.

4.2 Analysis

This economy has two equilibria (c.f. Sims, 2005): one with stable inflation and one with an explosive inflation (given by an arbitrarily high velocity of money and real money balances equal to zero). This has the following interpretation: even in an environment of price stability there are shocks to the economy that could trigger the economy to move from the stable equilibrium into the unstable equilibrium. The crux of Sims' analysis is that this could not occur if there was a way to make it impossible for the explosive inflation situation to be an equilibrium.

Sims (2005) suggests that such can be the case if the Central Bank is prepared to redeem the entire stock of money at a given upper bound P* for the price level. Such promise is credible only if the Central Bank has enough reserves F_G such that $M/P^* < F_G$, which would prevent the agents to have incentives to contribute to the demonetization of the economy, which in turn would produce the hyperinflation. Notice that the $M/P^* < F_G$ if and only if $P^* F_G - M > 0$, that is, if the Central Bank has positive net worth at the critical price level.

This means that price stability indeed requires a minimal reserve level, which can be computed in such a way to ensure a positive net worth at the critical price level. Below I show a parametrization of the model that clearly illustrates this.

Following Sims (2005), consider the case where transaction costs are given by $\psi(v) = \gamma v/(1+\phi v)$ and the economy is initially at a steady state with zero inflation and real interest rates equal to 2%. I use this scenario to study the effect of varying the profit transfer rules on the minimal reserve level that is required to eliminate the explosive inflation equilibrium.

The policy rule for this experiment is defined by θ_0=0.02, θ_1=1.2 y θ_2=1. The transactions technology is defined by γ=0.02 y ϕ=0.3. Consider an unexpected drop in the real interest rate to 1.8%. The new stable equilibrium would require a drop in the nominal interest rates to a new level equal to 0.8%. Imagine, however, that following the drop in the real interest rates the nominal interest rate adjustment is incomplete as it falls only to 1%. In this case the resulting price level is above the price level that is consistent with the stable equilibrium. This leads to policy actions that steadily drive the interest rates upwards. Figure 1 shows the evolution of interest rates, velocity of money, the log of money holdings and inflation in this economy.

Whether the Central bank can avoid this explosive price path to materialize depends on its initial net worth and its profit transfer rules. Figure 2 shows the ratio of reserves to real money balances for the case where the Central Bank transfers zero profits to the treasury for different initial levels of F_G (This ratio is above one for a positive net worth for the Central Bank).

Figure 1

Implications of an insufficient response of r to a drop in ρ

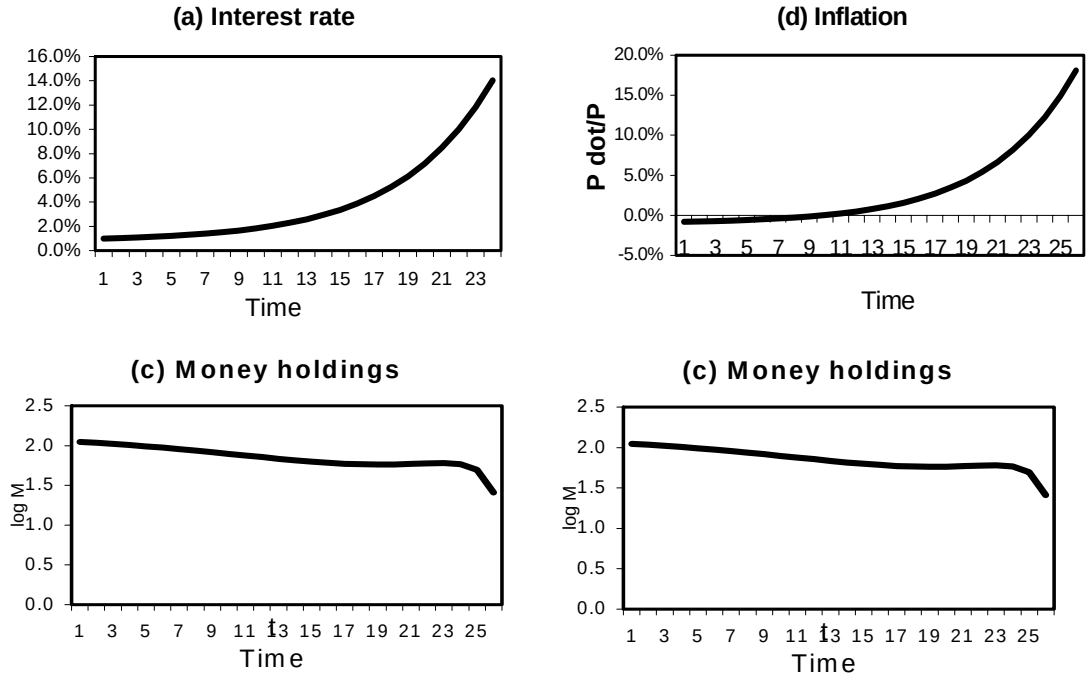
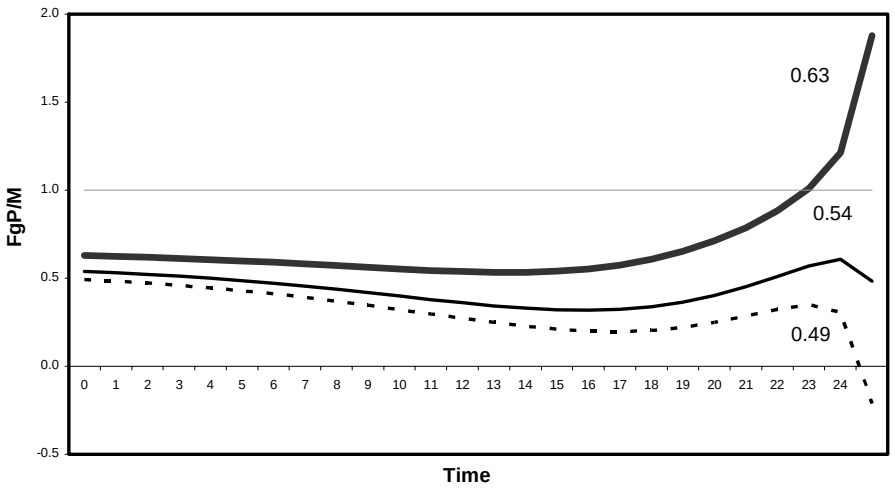


Figure 2 shows that there is an initial level of $F_G P/M$ such that, even if the Central Bank initially has negative net worth, it is only a matter of time before the accumulation of profits drives net worth to the point where the Central Bank can cut inflation by announcing that it can redeem the entire stock of money at the current price level. When the reserves to real money balances ratio is not high enough positive net worth can never be achieved, which would make it a matter of time before the Central Bank runs out of reserves. This, in turn, would make it impossible for the Bank to perform open market operations. In this example, the initial reserve level cannot be below 63% of real money balances to guarantee price stability.

Figure 2

Ratio of reserves to real money holdings

(Case 1: zero profit transfer rule)

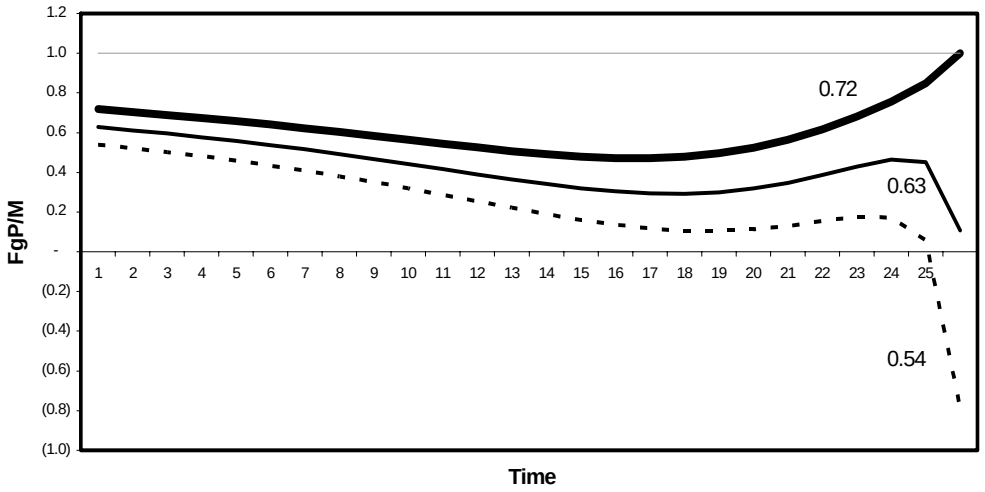


When the profit transfer rule is that of giving the government the real returns yielded by the reserves, the initial reserve level necessary to avoid the explosive inflation equilibrium increases. Figure 3 shows that an initial reserve to real money holdings ratio of 63% is no longer sufficient to avoid the explosive inflation equilibrium. In this example the initial reserve level cannot be below 72% of real money holdings if the explosive equilibrium is to be avoided.

Figure 3

Ratio of reserves to real money holdings

(Case 2: transfer of real returns of reserves to the Treasury)

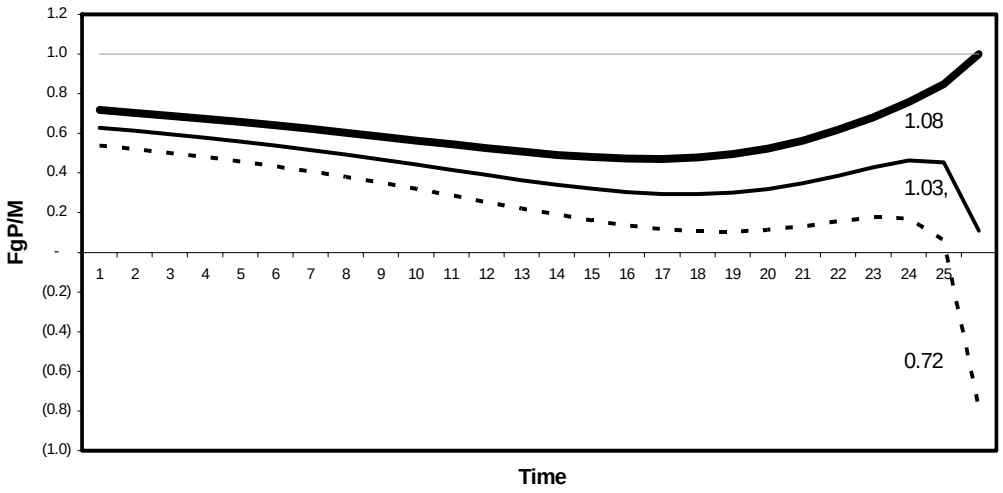


Consider now the case in which the Central Bank also transfers the nominal appreciation of the stock of reserves (our case of improper transfer). This case is interesting because reaching a ratio of reserves to real money holdings equal to 1 is no longer sufficient to avoid the explosive inflation equilibrium. In this case it is necessary for this ratio to be at least equal to 108% (leading to an seemingly excessive Central Bank capitalization) for the Central Bank to avoid the explosive inflation equilibrium, as Figure 4 shows.

Figure 4

Ratio of reserves to real money holdings

(Case 3: transfer of real returns of reserves plus their domestic appreciation to the Treasury)



Let me summarize the lessons that can be extracted from the example above:

First, to be sure, reserves are not really necessary in the stable equilibrium. Second, to avoid the explosive inflation equilibrium it is, however, necessary that the Central Bank hold a minimal reserve level consistent with an eventual positive net worth for the Central Bank. So the reserves are, in the end, a form of contingent backing of the stock of money in circulation in a country with weak fiscal institutions. Third, routine transfer of Central Bank profits increases the minimum level of reserves required to avoid the explosive inflation equilibrium. Fourth, excessive Central Bank profit transfers (such as the ones implied by an improper choice of numeraire) require that the Central Bank have both a very high net worth and hence a fairly high level of reserves to avoid the explosive inflation. In short: there exists a direct relationship between the critical reserve level and the profit transfer rule. The more aggressive the profit transfer rule is, the more reserves it is necessary to hold in the Central Bank to avoid the explosive inflation.

Finally, the analysis allows us to derive a clear rationale for when it is desirable and when it is not desirable to transfer Central Bank profits to the Treasury: Given a target level of foreign reserves, reserves sales should trigger a transfer of profits to the treasury only when reserves, net of sales, are above the target level. When reserves, net of sales, are below the target reserve level, Central Bank profits should not be transferred, as those profits are necessary to replace the target level of reserves without adversely affecting the Central Bank's net worth. The level and sign of these transfers would be irrelevant if the Treasury was committed to helping the Central Bank, through additional taxation, avoid a balance sheet crisis, shall one become imminent, but the reality of the fiscal institutions in most developing countries does not lend credibility to this possibility.

5. Conclusions

In this article I show the importance of numeraire choice for the proper computation and distribution of Central Bank profits in a country with weak fiscal institutions. I also use a model initially developed by Sims (2005) to study the relation between the desired level of profit transfers to the Treasury and the desired level of foreign currency reserves.

I show that an improper numeraire choice can dramatically alter the sign and magnitude of Central Bank profits. I also show that there is a tradeoff between profit transfer and reserve levels if the Central Bank wishes to avoid a hyperinflation. Because reserve levels can serve as "contingent backing" for the stock of money in circulation, an improper choice of numeraire can lead to excessive profit transfers, and those in turn can lead to low Central Bank capitalization levels which can themselves become a serious threat to the prospect of price stability if the Treasury is not committed to helping the Central Bank avoid this problem. Such are the subtle implications of numeraire choice for monetary policy in developing countries.

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Appendix: Monte Carlo experments on the size of Central Bank profits for the Venezuelan economy

The simulation was prepared as follows. I took as starting point an age distribution of the stock of foreign reserves over a four-semester horizon. For the subsequent semester I simulated the following variables:

- Purchases of foreign reserves
- Sales of foreign reserves
- Exchange rate depreciation of the Bolivar against the dollar for the current semester and the four previous semesters
- Inflation for the current semester and the four previous semesters

I modeled these variables as a vector of normally distributed random variables with means, standard deviations and correlation matrix estimated using data for the period 1990-2003. I simulated these variables 1000 times and computed the exchange rates at which the current stock of reserves were purchased, together with the value of the CPI for those semesters.

Out of that information I compute the Central Bank profits for each realization of the random variables according to three numeraires: the Dollar, the Bolívar and the CPI basket, and according to three well-known methods of inventory valuation: FIFO, LIFO and weighted average. The summary statistics of the simulations can be seen in Table 1 in the paper.