Exchange Rate Regimes and Optimal Reserve Holdings in a World of Capital Account Crises

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Introduction

In the traditional literature on optimal reserves, fluctuations in the balance of payments were usually taken as being independent of the level of reserves. The development of second generation crisis models and a number of empirical studies of recent currency crisis suggest that for countries in the vulnerable zone between strong and poor fundamentals, reserve levels can have an important influence on the probability of crisis. We develop a formal optimizing model in which we can evaluate the effects of alternative exchange rate regimes on optimal international reserve holdings for emerging-market countries, based on estimates from the recent empirical literature on the effects of alternative exchange rate regimes, prior capital inflows, and reserve levels on the probabilities of currency and financial crises (see Angkinand, Chiu, and Willett (2007) and Angkinand and Willett (2007)).

In our model reserves play two primary roles. We evaluate the benefits of international reserves in terms of their role of reducing the probability of crises, but we also consider the traditional cushioning role of reserves. Thus we model the output cost of a crisis as a function of the size of capital outflows during the crisis minus the portion of these outflows whose effects are cushioned by financing through reductions in reserves rather than currency depreciations and domestic adjustments.[1]

This type of formulation is relevant primarily for emerging market economies. In industrial countries currency depreciation is frequently expansionary in the short run. But for developing and emerging market economies with large unhedged foreign currency

[1] Perhaps surprisingly, recent research has shown that the correlation between conventional measures of currency crises and sudden stops or capital flow reversals is well below one. Our analysis is relevant for those cases where the two go together. Examination of the types of cases where the two do not go together is an important topic for research.

denominated liabilities, depreciation can initially be strongly contractionary. While the formulation of our model is thus relevant for only a limited set of countries, it is this set that have been in the forefront of the major currency crises and/or huge reserve accumulation since the mid 1990s.[2]

For analytic convenience we do not model the role of exchange rate regimes directly but rather introduce their effects through changes in the probability of crises, i.e., a country on an adjustable peg regime will have a higher probability of crisis than one with a managed float. The structure of our model allows us to take a broad range of factors into account through their influence on parameters in the model. For example, a surge of inflows of financial capital will increase optimal reserve holdings both through increasing the probability of crisis and by increasing the size of the expected capital outflow if a crisis does occur.

Because of the pressing time deadline we apply the model only to Thailand based on ballpark estimates of the key parameters drawn from the recent empirical literature. For the final version of the paper we plan to include several more countries, explore more carefully the reasonable upper and lower bounds for the key parameters, and provide more sensitivity analysis of the effects of variations in the parameters on calculations of optimal levels of reserves.

Exchange Rate Regimes, Capital Flows and the Demand for Reserves

In traditional models of the demand for international reserves a substantial increase in exchange rate flexibility was expected to sharply reduce the demand for

[2] An exception is the oil exporting Gulf states who have been amasing large increase in reserves but have had limited private capital inflows.

international reserves. This gave rise to fears that the breakdown of the Bretton Woods regime of pegged exchange rates in the early 1970s would generate a huge dollar overhang and that a massive sell off of dollar reserves would threaten international monetary stability.

This sell-off didn't occur. Willett (1980) posited a likely reason: contrary to the assumption of standard optimizing models of reserve holdings, once reserves reach an adequate level, their weight in the government's utility function may change. Selling off excess reserves can require actions that conflict with other economic objectives, for example by requiring inflation or appreciation.[3] Willett presented a public choice-oriented interpretation of Mrs. Machlup's Wardrobe theory of international reserves that suggested that countries would be willing to hold much higher levels of reserves than they considered optimal. More recently, Bar-Ilan, Marion and Perry (2004) have also shown that a country might wish to accumulate reserves over a long period of time if the cost of adjusting reserve levels downward is high in relation to the cost of holding additional reserves. These may well explain why empirical studies have generally failed to find evidence of strong negative effects of exchange rate flexibility on the demand for international reserves.

Recent analyses of crisis suggest additional reasons why the link between exchange rate regimes and international reserve holdings may be weak. In the traditional literature the function of reserves was to avoid the costs of balance of payments adjustment and balance of payments developments were assumed to be independent of

[3] In some cases, reducing reserves will not be costly, however. An example is where the government has repayment of foreign debt coming due. By not renewing such borrowing reserve levels can be reduced. Chile followed this route when it decided to reduce its reserve levels based on an analysis by the Bank of Chile. See Jadresic (2007).

the level of reserves (e.g., Heller 1960, Kenen and Yudin 1965, Kelly 1970, Frenkel and Jovanovic 1981). Such a view was quite relevant for the era of current account crises in which it developed, but not for today's world of capital account crises. International reserves are now also important for the oversight of internationalized domestic financial systems, and in second-generation crisis models reserve adequacy can influence the probabilities of crisis when countries have fundamentals in the vulnerable zone (Obstfeld 1994). Thus, international reserve adequacy is now understood to have an important role to play in helping to prevent both currency and financial crises, as well as reducing their costs if they do arise (Kaminsky and Reinhart, 1999). Such considerations help to explain why there has been a substantial increase in post-crisis reserve holdings in Asia despite the also substantial increase in exchange rate flexibility for many countries in the region.[4]

Such lack of gross correlation shouldn't be taken to show that there is no relation between exchange rate regimes and optimal levels of international reserve holdings, however. Sula (2008) shows that countries which fall into the mid-range of reserve holdings do take exchange rate variability into account in their reserve level decisions. On the other hand, the same study finds that larger reserve holders give less weight to the exchange rate regime in their demand for reserves. These results suggest that the traditional approach of estimating the demand for international reserve functions based only on calculations of optimal reserve holdings are likely not to offer a sufficient guide to actual reserve holdings and likewise that studies based on actual holdings may not give

[4] It is true of course that the country with the largest increase in reserve, China, had little exchange rate flexibility until recently. The increase in China's exchange rate flexibility since 2005 has been associated with continuing large increases in reserve levels. This we interpret as being largely motivated by desires to avoid short run adjustment costs, rather than optimal reserve or traditional mercantilist considerations. See Li, Sula, and Willett (forthcoming).

a good indication of optimal reserve holdings. Thus above average reserve holdings for a country would not necessarily imply that it was pursuing mercantilist policies.

Another problem is that in a world of sudden stops the recent variability of payments positions may not give a good indication of the prospects for future shocks. Past use of export variability as a guide clearly needs to be with consideration of capital account variability. The biggest concern, however, is not variability per se but large capital flow reversals such as sudden stops. Sula and Willett (2007) have shown that standard measures of capital flow variability during inflow periods have little predictive value for the size of capital flow reversals. Thus, drawing on the approach suggested in Kim et al (2004), we use analysis of past episodes of capital account reversals to develop estimates of likely capital outflows during crises. We combine this with recent research by Sula (2007) on the relationships between large financial capital inflows and the probability of subsequent crises. This will help us to investigate how optimal reserve levels should increase as a function of inflows of financial capital.

The model

In this section, we present a simple model that enables us to describe the marginal benefits and costs of international reserves. Assume that the central bank chooses the amount of reserves to hold in order to minimize the following loss function:

$$\Lambda = P\Delta Y + RC_R \qquad (1)$$

where P is the probability of a crisis, ΔY is the fall in output due to crisis, R is the level of reserves and C_R is the unit cost of reserves.

The first term in the loss function represents the expected cost of a crisis. While crises come in many varieties and in some cases can have positive effects on the economy, (for example, the Italian and UK crises in the early 1990s), we focus on a typical type of crisis for emerging market countries where the currency crisis is associated with a significant reversal in financial capital flows. In these types of crises leakages from the foreign currency denominated debt also cause depreciation to have substantial negative output effects on the economy.

Our model is similar to Garcia and Soto (2006) and Li and Rajan (2006) where the central bank accumulates reserves mainly for precautionary reasons. Our contribution is the inclusion of the cushioning effect of reserves against capital reversals. As noted, the major benefits from holding reserves are twofold. One, a stockpile of reserves may reduce the probability of a crisis occurring in the first instance, i.e. crisis prevention role. Two, reserves can help reduce the adjustment costs if a crisis does occur by financing a portion of the capital outflows and thus reducing the amount of accompanying depreciation and/or increase in domestic interest rates. This cushioning effect highlights the crisis management role of reserves. Therefore, both P and ΔY are functions of reserve holdings.

The second term in the loss function is the opportunity cost of reserves. The cost of holding reserves is the forgone investment opportunities, since the returns on reserve holdings are generally lower. We assume the unit cost of reserves to be constant.[5]

[5] An alternative assumption is the endogeneity of the interest rate spread, and therefore the unit cost to the size of reserves. Thus up to some point increasing reserves will reduce the risk premia in a countries interest rate thus reducing the cost of holding reserve (as well as providing the other benefits of a lower risk premia). This issue has recently been addressed by Levi-Yeyati (2007), Jadresic (2007) and McCauley (2007)

Following the theoretical and empirical literature, we define the probability of crisis as a function of reserves relative to a scale variable, *S*, the type of the exchange rate regime, *XR*, the total accumulated financial capital inflows, *K*, as well as a vector of fundamentals, *Z*. For concreteness, we assume the following logistic functional form:

$$P = P(R/S; XR; K; Z)$$

$$P = \frac{e^{\beta_0 - \beta_1 R/S + \beta_2 XR + \beta_3 K + \beta_4 Z}}{1 + e^{\beta_0 - \beta_1 R/S + \beta_2 XR + \beta_3 K + \beta_4 Z}} \qquad (2)$$

The ratio of reserves over the scale variable enters the equation with a negative coefficient as it has been shown that lower values for this ratio is a good indicator of vulnerability to currency crisis (e.g., see Radelet and Sachs 1998, Busiere and Mulder 1999). Short-term debt, domestic money supply and GDP are among some of the choices for *S* in empirical studies. The effect of the degree of flexibility of the exchange rate regime is not linear. On a spectrum of exchange rate regimes from hard fixes to freely floating, we expect the middle, the adjustable peg regime, to be the most prone to crisis. We also expect the capital inflows to increase the probability of a crisis if they are above a threshold that would be considered excessive. Vector Z consists of various other factors that increase the probability of a crisis. Large current account deficits, fast expansion of domestic credit, and real exchange rate appreciation are among the most widely used variables in the empirical sudden stop and currency crisis studies.

The crisis prevention role of reserves can be summarized as follows:

$$\frac{\partial P}{\partial R} = -(\beta_1 / S)P(1-P) \qquad (3)$$

As (3) illustrates, the marginal effect of reserves on the probability of crisis is not linear and depends on the probability of crisis which is determined by a combination of all the other factors (*XR*, *K*, *Z* and *R/S*).

The cost of a crisis is captured by ΔY .

$$\Delta Y = \theta(\alpha K - \gamma R) \qquad (4)$$

$$\theta > 0,\ 0 \le \alpha \le 1, 0 \le \gamma \le 1$$

where θ measures the sensitivity of output loss to capital outflows that are not cushioned by the sale of reserves, *K* is total accumulated financial capital inflows, α is the share of these inflows that are reversed in a crisis, and γ represents the proportion of reserves that the government is willing to sell during a crisis. We assume that $\alpha K > \gamma R$, i,e. that crises are costly.

The intuition for this formulation is that the cost of a crisis will be a positive function of the size of the crisis as proxied by net private capital outflows not by running down reserves. These net private capital outflows are assumed to be a function of previous net capital inflows times α, their propensity for reversal.[6] Thus, for example, the higher was the ratio of long term to short term bank loans in the capital inflows, the lower would be α. The amount of reserves used to cushion the effects of these outflows will be

[6] Of course some domestic funds will also flee. Analysis of recent crises suggests, however, that these combined outflows are typically only a fraction of previous capital inflows. See Kim et al (2004).

a function of the level of reserves and the government willingness to use them, γ. It is worth emphasizing here that using a simple ratio oversimplifies the governments behavior during crisis. Governments will be concerned with minimum absolute levels of reserves as well. The ability to obtain official loans will also be relevant.

The outflows not financed by reserves will require adjustments in interest rates and exchange rates that are likely to have short run, recessing effects in emerging market economies. The more fragile is the domestic financial system the greater are these costs likely to be. Depreciation can cause insolvency for firms with large unhedged net foreign currency liabilities while higher interest rates and drying up of credit can generate domestic distress. In the extreme these can accumulate into a domestic financial crisis greatly increasing the size of the accompanying recession.[7] In our model such factors influence the value of θ.[8] So far, there has been relatively little empirical work attempting to estimate the values of θ and their determinants. This is an important area for further research.

The crisis management role of reserves can be summarized as follows:

$$\frac{\partial C_c}{\partial R} = -\theta\gamma \qquad (5)$$

Since θ and γ are positive, an increase in reserves, lowers the costs of a crisis.

[7] While there is some debate about whether the costs of such twin crises are greater than the sum of having these crises individually, they are unquestionably far larger than having only one crisis.
[8] Another important factor may be the ratio of traded to non traded goods. See, for example, Tornell and Westerman (2005).

The optimal level of reserves is based on minimizing the loss function (1). The first order condition of this minimization problem is:

$$\frac{\partial P}{\partial R} C_C + \frac{\partial C_C}{\partial R} P = -C_R \qquad (6)$$

Plugging in (3), (4) and (5) into (6), we have:

$$(\beta_1 / S) P(1-P)\theta(\alpha K - \gamma R) + \theta\gamma P = C_R \qquad (7)$$

The left hand side of equation (7) can be interpreted as the marginal benefit of holding reserves, while the right hand side is the marginal cost of reserves. In other words, an optimizing central bank should continue to build up reserves as long as the marginal benefits of doing exceed the marginal costs (opportunity costs). While this result is intuitive, the contribution of the simple model is to flesh out the factors that impact the marginal benefits which in turn allow us to analyze the nexus between capital flows, exchange rate regimes and reserve holdings.

Optimal Reserves

In this section, we perform numerical exercises that evaluate the adequacy of actual reserve holdings for several nations for the period between 1982 and 2002. In this first draft of the paper we present our results only for Thailand.

First, for a given probability of crisis and fixed values for θ, γ and β_1, we determine the optimal level of reserves. Next, we examine the optimal reserve response

to changes in the probability of crisis. This will also aid us in understanding the role of large capital inflows and exchange rate regimes on the adequacy of reserves. Finally, we investigate the sensitivity of the model to the choice of the parameter values.

We use the marginal cost-benefit equation (7) to compute the optimal level of reserves. We take the initial probability of crisis as exogenous, and then find the level of reserves that makes the marginal benefit equal to marginal cost. If we had accurate numbers for all of the parameter values we could calculate the crisis probabilities from our model. However, given uncertainties about some of them due in part to the potential importance of non linearity, at this stage we decided to impose crisis probabilities directly. We initially assume P=0.10 which is an approximation of the unconditional probability of currency and sudden stop crises in emerging markets based on several recent studies (i.e. Hutchison and Noy, 2006, Glick, Guo and Hutchison, 2006)[9].

While we take the initial probability of crisis given, we still want to show that reserves have a crisis prevention role. Therefore we need an estimate for β_1 in (2). Garcia and Soto (2006) carry out a similar exercise to ours where they estimate the effect of the ratio of reserves to short-term debt on the probability of crisis to obtain estimates for β_1.[10] We take their benchmark estimate β_1=0.25 and set S equal to short-term external debt from the Global Development Finance (GDF) database of the World Bank.

The data for R, αK and C_R comes from the International Financial Statistics (IFS) database of the IMF. As our initial proxy for reversible capital flows, αK, we take

[9] Estimates of unconditional probability vary between 5 to 15% depending on the sample and the definition of the crisis indicator.
[10] They use annual observations for 31 emerging markets for the period 1977-2003.

the sum of accumulated other private flows and portfolio flows[11]. As proxy for opportunity cost, we take the difference between the domestic lending rate and US money market rate. We use reserve data excluding gold. Finally, we assume that $\gamma = 0.8$ and $\theta = 1$.

Figure 1 plots the optimal and the actual reserve holdings for Thailand. The solid line represents the actual reserve holdings. The optimal level of reserves is shown as the dashed line. We see that Thailand's actual reserves are below the optimal levels for most of the sample period. The size of the gap between optimal and actual reserves is especially large in the years immediately preceding the 1997 Asian Crisis.[12] This is consistent with the view that Thailand's inadequate levels of reserve holdings were one of the major causes of both the onset and the cost of the crisis. Figure 1, also shows us that the gap between actual and optimal reserves had closed by 2002.

Next, we present the optimal reserve levels for a range of crisis probabilities. We choose 1996, the year preceding the Asian financial crisis and 2002, the most recent data point we have in our current set (this will be updated). The sizes of Thailand's reserve holdings were also very close in these two years, around 38 billion dollars. Figure 2 plots the optimal and actual level of reserves.

Figure 2 has several implications. First, both in 1996 and 2002 the optimal levels converge to a specific value as the probability increases. A higher probability of a crisis increases the optimal level of reserves, but once reserves are large enough so

[11] In other words, we take the accumulated values from financial account of the balance of payments excluding FDI and official flows.

[12] Note that the numbers on Thailand's actual reserve levels are based on official statistics and are misleading for the crisis period. While the chart shows reserves of over $30 billion prior to the crisis forward sales by the Bank of Thailand resulted in net usable reserves that had fallen to a level of only a few billion dollars. From the rather modest declines in reserves after the baht was floated it appears that loans from the IMF were used to pay off a considerable portion of the maturing forward contracts.

that $\alpha K < \gamma R^*$, a higher probability of crisis no longer increases optimal reserve levels. For Thailand, we see that this effect comes in at fairly lower levels of probabilities; nine per cent in 1996 and six per cent in 2002.

Second, given the size of the interest rate differential and the size of the accumulated capital inflows in 1996, the optimal reserves for Thailand are around 132 billion dollars whether the crisis probability is 20 per cent or 90 per cent. Thailand's actual reserves however, are 38 billion dollars, clearly inadequate based on our model. On the other hand, in 2002, Thailand had almost the same level of reserves, and the optimal levels are very close (30 billion dollars) once the crisis probability is above six per cent.

Third, Figure 2 shows that the size of optimal reserves are very sensitive to the probability of crisis when $\alpha K > \gamma R^*$. Even a difference of one percent in the probability can cause a significant increase in optimal levels. Considering that the unconditional probability of crisis for emerging markets is somewhere between five to fifteen percent, this finding may explain the variation in the size of reserve holdings across emerging markets.

Figure 2 can also be utilized to understand the effects of exchange rate regimes on optimal reserve holdings. Angkinand et al. (2007) show that the probability of a currency crisis is significantly higher under an adjustable peg system. Using several different measures of exchange rate regimes, these authors find that the probability of crisis under

an adjustable peg is at least 10 per cent greater than the probability under a hard peg or a managed float.[13]

Our analysis shows that the effect of the exchange rate regime on the optimal reserves is very strong if the initial probability of crisis is low or the amount of reserve holdings are less than the potential capital flow reversals. However, once the optimal reserves exceed a certain threshold, the choice of the exchange rate regime no longer affects the optimal level of reserves.

The model suggests that the size of capital inflows is also an important determinant of optimal reserves. The following simple exercise illustrates how Figures 1 and 2 can be utilized to explore the effects of capital inflows on optimal level of reserves. In our model large amounts of financial capital inflows will increase the potential size of reversals and therefore positively affect the optimal level of reserves. Referring back to Figure 1, the sharp increase in optimal reserves is mainly due to the speedy accumulation of financial capital in Thailand before 1997. From 1989 to 1996, accumulated private financial flows in Thailand increased from 19 to 105 billion dollars. As a result, optimal reserves reflect this change by rising from 25 billion in 1989 to 132 billion. Furthermore, Sula (2007) finds that a surge in capital inflows defined as an increase in capital inflows greater than four per cent of GDP significantly increases the probability of a sudden stop crisis. Especially, if associated with a current account deficit and real exchange rate appreciation, this increase in the probability of a sudden stop can increase by as much as 30 per cent. Based on Thailand's conditions in 1996, it can be safely assumed that the probability of crisis was above the 9 per cent threshold that we see in Figure 2.

[13] A tightly managed float is an exception. The study finds that the probability of crisis is also very high under this type of exchange rate regime.

The optimal reserve predictions that we generated above are by no means definitive. There is a range of uncertainty about the true values of all of our parameters. Furthermore, both the size and the direction of the effects of the parameter values on the optimal level of reserves depend on the assumptions about the other parameters. The final draft of this paper will include the formal characterization of the optimal reserve responses to changes in assumptions. In this draft, we present a brief discussion of the sensitivity of Thailand's optimal reserves to our assumptions about parameter values. Specifically, we examine Thailand's optimal level of reserves for a range of possible values of the parameters of interest while holding the other parameters of the model fixed at their benchmark values.

First, we look at Thailand's optimal reserves for a range of values for θ from 0.5 to 1.5. Figure 3 plots the optimal and actual levels in 1996 and 2002. We see a pattern similar to the one in Figure 2; an increase in θ increases the optimal level of reserves, but once the reserves levels are high enough to cushion any possible capital flow reversals the θ parameter is no longer binding.

Figure 4 repeats the same exercise for γ. The size of optimal reserves goes down as gamma increases. If the government is willing to sell more of its reserves, holding everything else constant, optimal amount of reserves to accumulate would be relatively lower.

Finally, to assess the sensitivity of the optimal reserves to β_1, we calculated the optimal reserves for a range of β_1 values from 0 to 1. We find that optimal levels of reserves for Thailand are not sensitive to the changes in the value of this parameter.

Concluding Remarks

While we certainly do not believe that our calculation of optimal reserve levels for Thailand are definitive, we do think that our model presents a useful way to think about a number of the key issue relevant for determining optimal or at least safe or reasonable reserve levels. For example, we show that Thailand's reserve holdings were well below the optimal levels in the year preceding the financial crisis. Our model also shows that if reserves are large enough to cover potential capital reversals, the type of exchange rate regime will not have any affect on the optimal level of reserves. On the other hand at lower reserve levels the effect can be quite substantial. Furthermore based on the initial probability of a crisis, a small change in the probability may have no effect or a very impact on the optimal level of reserves.

Of course parameter values are crucial in determining optimal levels for individual countries. For a number of parameters we have substantial bodies of empirical literature on which to draw. For several others, however, estimates are non-existent or rare. Thus we believe that one contribution of our analysis is to highlight several areas where further empirical research would be quite valuable. Examples include both the actual and desirable amounts of reserve use during crises and the factors that relate to the relationships between the sizes of crises and their output costs. There are other areas in which we have some estimates but could use further research before we have great confidence in our estimators. Examples include the effects of alternative exchange rate regimes on currency crisis and the likely degrees of reversibility of different types of capital flows.

Another point emphasized by our model is the non linear nature of many of the important relationships. The limited number of relevant historical episodes suggests that it will prove to be quite difficult to get very precise estimates of some of the important parameters, we can at least make use of plausible upper and lower bounds to inform policy officials.

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Figure 1: Optimal and Actual Reserves – Thailand 1982-2002

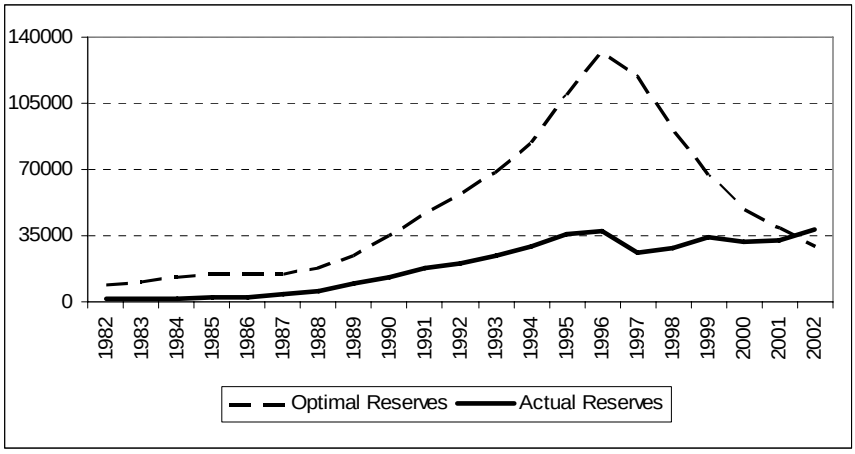

Figure 2: Probability of Crisis and Optimal Reserves – Thailand 1996 and 2002

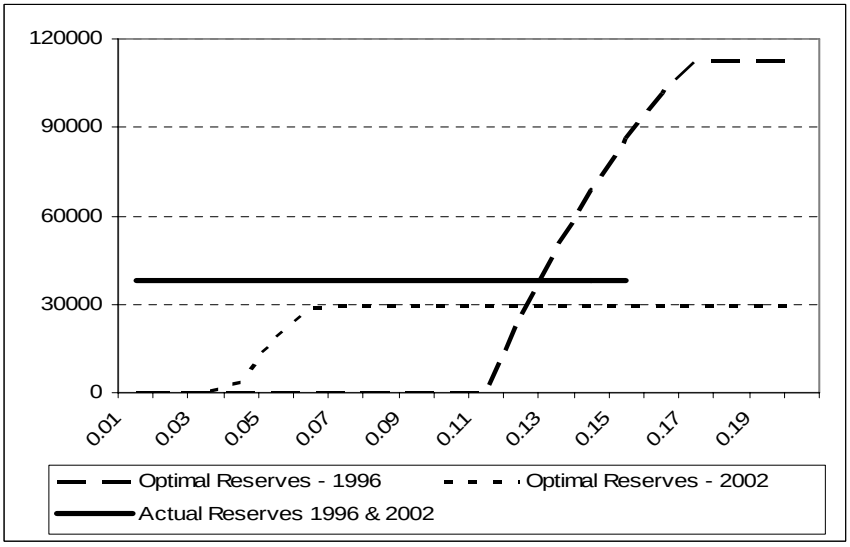

Figure 3: θ and Optimal Reserves – Thailand 1996 and 2002

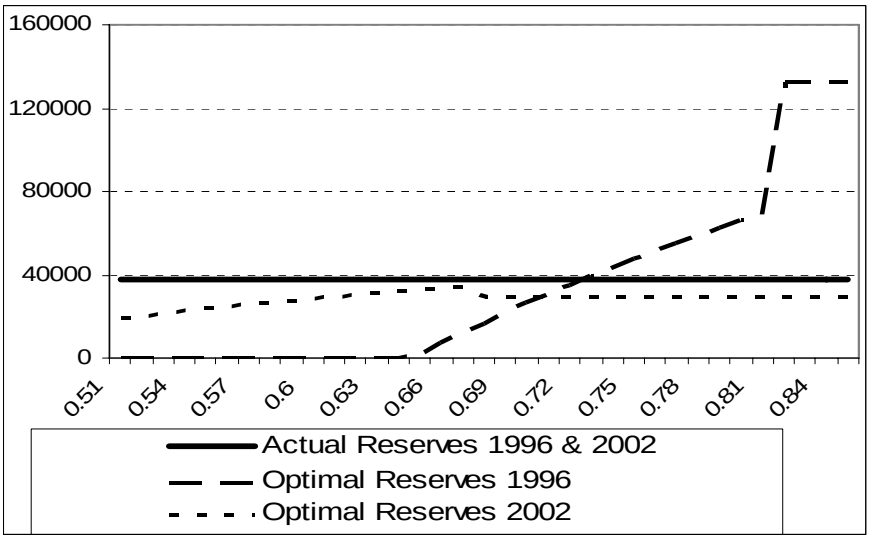

Figure 4: γ and Optimal Reserves – Thailand 1982-2002