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trinity: empirical evidence from  
1991-2009**

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**IS MALAYSIA EXEMPTED FROM THE IMPOSSIBLE TRINITY?  
AN EMPIRICAL ANALYSIS FROM 1991-2009**

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## **ABSTRACT**

### **IS MALAYSIA EXEMPTED FROM THE IMPOSSIBLE TRINITY? AN EMPIRICAL ANALYSIS FROM 1991-2009**

*This paper examines Bank Negara Malaysia's (BNM) monetary policy autonomy in 1991-2009, a period of volatile capital flows, during which BNM operated under several exchange regimes: managed floating; fixed exchange rates; and fixed exchange rates with selective capital controls. Using a modified version of the Brissimis, Gibson and Tsakalotos (2002) model, the paper's empirical estimates show that the same-period offset coefficients are significantly less than unity under all regimes, indicating that the Malaysian central bank possesses some short-run control over monetary policy (even under fixed exchange rates). Although the long-run offset coefficient continues to be less than unity under managed floating, it is not significantly less than unity under fixed exchange rates. These results show that Malaysia is not exempted from the impossible trinity except in the very short-run. Perhaps one of the reasons Malaysia abandoned its US dollar exchange rate peg on 20 July 2005 to move back to managed floating is to increase its monetary policy independence. One implication of the Malaysian monetary policy experience is that managed floating with active sterilization may be a viable strategy for emerging market economies to deal with volatile capital flows.*

**JEL CODES:** E52; F41

**KEYWORDS:** Offset Coefficient, Sterilization Coefficient, Monetary Autonomy, Impossible Trinity

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# 1. INTRODUCTION

The Impossible Trinity (or trilemma of international finance) postulates that a central bank cannot conduct an independent monetary policy while simultaneously maintaining a fixed exchange rate regime and an open capital account. At any one time, it can only choose two of these three policy objectives. In the mid 1980s, most developing countries adhered to the trinity's constraint by choosing stable exchange rates and discretionary monetary policy while keeping the capital account relatively closed. In the early 1990s, however, globalization prompted many developing countries (especially those from East Asia) to embrace financial liberalization and begin to open their capital accounts. However, they have tended to continue with stable exchange rates as well as pursuing their own discretionary monetary policy—in apparent violation of the trinity. The policy mix had uncertain success but during the Asian Currency Crisis (ACC), the crisis-hit countries had to abandon one of their targets—stable exchange rates—to move to free-floating exchange rates. Nevertheless following recovery from the ACC, some countries have again moved back towards stabilizing their exchange rates (Kim and Yang, 2009).

Malaysia's approach has been broadly similar. It had a managed float exchange regime<sup>1</sup> but moved to fixed exchange rates in September 1998 (in contrast to the others, it moved to fixed rates at the height of the ACC, not after). Under fixed exchange rates, Malaysia at first adhered to the trinity's constraint by combining fixed rates with selective controls on capital outflows.<sup>2</sup> After 2000, however, the selective capital controls were largely removed<sup>3</sup> (and significant freedom was again available for both capital inflows and outflows) but the country continued with fixed exchange rates through July 2005<sup>4</sup> while continuing to pursue discretionary policy; apparently in violation the trinity's constraint. According to the impossible trinity, the country could not have successfully conducted discretionary monetary policy in 2001-2005 since it would have lost all monetary autonomy. That view, however, is not shared by several observers. For instance, Latifah (2005)<sup>5</sup> argues that Malaysia did violate the impossible trinity successfully by maintaining an open capital account under fixed exchange rates and conducting successful

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1. The Malaysian ringgit has been pegged to a basket of currencies since 1983. The regime had lasted until July 1997, when Bank Negara Malaysia (BNM) gave up to sustain the exchange rate in the wake of the Asian Currency Crisis 1997-98. The Ringgit was allowed to float in the market until September 2, 1998 where it was pegged to the US dollar at RM3.80 per USD.
  2. The capital controls mainly covered some aspects of portfolio investment and restriction on capital outflows. Foreign direct investment, international trade, and repatriation of FDI-related capital and dividends by non-residents were not subjected to such controls.
  3. In September 1998, non-residents were required to hold their principal sum of portfolio investment for at least 12 months in Malaysia. On 15 February 1999, this requirement was then replaced by an exit levy on repatriation of portfolio funds, with a higher levy rate the shorter the duration of the capital. On 21 September 1999, this was amended with a single rate of 10 per cent imposed on profit repatriated by foreigners. On 1 May 2001, this 10 per cent exit levy was also abolished and no more levy was imposed on capital outflows.
  4. There has been a significant progress of liberalization in the financial and capital markets in Malaysia. This process was guided by the Financial Sector Masterplan and the Capital Market Masterplan, both launched in 2001.
  5. The author is an Assistant Governor of BNM from Oct 1996 to Nov 2004.

independent monetary policies that supported domestic growth and price stability. She attributes the success to several potential factors, in particular, that interest rates in Malaysia have not been the main push-pull factor behind financial flows—citing as evidence that inflows into Malaysia were not excessive in the 2000s compared to the 1990s, despite higher domestic interest rates relative to foreign rates. This is partly attributed to the fact that Malaysia's policies not to internationalize its Ringgit have helped to prevent destabilizing capital flows. As a result, the foreign exchange reserves accumulated by BNM have tended to reflect current account flows rather than financial flows.

Besides Latifah (2005), several other studies have also argued that East Asian countries have been successful in overcoming the trinity's constraints. For instance, Fry (1988) finds that the monetary authorities of a sample of Pacific Basin countries (including Malaysia) were able to pursue independent monetary policies despite pegged exchange rates. Gan and Kwek (1994) find that intensive sterilization enabled BNM to manage its monetary aggregates in the later half of the 1980s through 1993. Takagawa (2005) finds that free capital mobility, stable exchange rates and independent monetary policy were mutually feasible for seven East Asian countries (including Malaysia) in 1977Q1-1996Q4 (prior to the ACC). By examining the degree of monetary policy autonomy, capital mobility, and exchange rate variability in Malaysia,<sup>6</sup> Umezaki (2007) concludes that even with high international capital mobility, Malaysia was able to retain some degree of monetary autonomy and to successfully manage fluctuations in its exchange rate. Umezaki attributes the monetary autonomy to successful sterilizations, imperfect albeit high capital mobility, and the allowance of some fluctuation in the exchange rate.

The objective of this paper is to evaluate the independence of Malaysia's monetary policy under different exchange and capital account regimes. We choose the period 1991-2009 because Malaysia operated under several different regimes over the period: managed floating, open capital account in 1991-1997; fixed exchange rates with selected controls on capital outflows in 1998-2000;<sup>7</sup> fixed exchange rates and open capital account in 2001-July 2005;<sup>8</sup> and back to managed floating, open capital account again in Aug. 2005-present. While the studies by Latifah (2005), Takagawa(2005) and Umezaki (2007) conclude that Malaysia enjoyed some degree of monetary

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6. The study aims to examine the monetary policy, the exchange rate policy and the capital controls in Malaysia. First, the degree of autonomy in monetary policy was tested by a forward-looking policy reaction function proposed by Clarida et al (1997, 1998), and the model was estimated by Generalized Method of Moment (GMM) with a set of instrumental variables to assume consistency due to nonlinearity of the model. The sample covers observations between January 1988 and August 1998. Second, the study examines the degree of variability of the exchange rate by regressing the percentage change in the Ringgit exchange rate on four currencies (Japanese yen, Deutsche mark, Singapore dollar, and US dollar) for the period from September 1975 to June 1997 (including three sub-periods i.e. September 1975 – October 1978; November 1978 – July 1985; September 1985 – June 1997). Last, the degree of international capital mobility has been investigated by the statistics descriptively and graphically reported by the relevant reports. The study concluded that BNM was able to attain monetary autonomy and exchange rate stabilization due to imperfect capital mobility, imperfect stabilization of the exchange rate, and the sterilized intervention in the foreign exchange market.

7. There is no control related to trade or FDI, the controls were in the capital account, comprising a standstill on foreign portfolio capital and restrictions on capital outflows by residents.

8. After July 2005, RM moved to a managed float linked to an undisclosed basket of currencies, back to exchange rate regime the country has had before the 1997 Asian Currency Crisis.

independence, they did not distinguish among these different sub-periods. It will be particularly interesting to examine whether there was a loss of monetary autonomy during the fixed exchange rate and open capital account period, when the trinity constraints were violated.

The paper estimates a modified version of the Brissimis-Gibson-Tsakalotos (BGT) (2002) model that derives both the offset and sterilization coefficients jointly from the same theoretical framework. The degree of sterilization (i.e. how much domestic credit changes in response to a change in net foreign assets), as well as the degree of capital mobility as measured by offset coefficients (i.e. how much private capital flow offsets changes in net domestic assets) are simultaneously estimated. Our empirical results show that in Malaysia, there is room for independent monetary policy in the very short run under all regimes. Although shocks to net domestic assets are not fully offset in the long run under managed floating, they are fully offset under fixed exchange rates, open capital account. Thus, under conditions of the impossible trinity—fixed rates, open capital account—Malaysia enjoys a degree of monetary policy independence in the very short run, but not in the longer run. We conclude then that Malaysia is not exempted from the constraints of the impossible trinity.

This paper is organized as follows. Section 2 describes the main features of capital inflows/outflows in Malaysia and the central bank's responses in recent decades. Section 3 reviews the model used and existing literature. Section 4 discusses the data and the variables used in the empirical study. Section 5 reports and discusses the empirical results. The final section concludes with a brief discussion of the macroeconomic policy implications and tradeoffs facing Malaysia in the future.

## **2. CAPITAL FLOWS AND STERILIZATION IN MALAYSIA**

As suggested above, the last two decades were a very volatile and difficult period for BNM and monetary management. The first decade began with surges in capital inflows, followed by volatile outflows and speculative attacks on the Ringgit during ACC. After ACC, current account surpluses led again to heavy inflows of NFA, followed by another bout of volatile outflows during the U.S. financial crisis.

Capital inflows to Malaysia first surged in 1989 (Bond, 1998). While foreign direct investment (FDI) has been the mainstay of capital inflows, portfolio flows gained increasing significance in the early 1990s. In fact, 1993 became known as the “year of the super bull run” because the large surge of portfolio inflows caused the Bursa Malaysia (formally known as KLSE) stock composite index to grow at 100 per cent per annum (Gan & Kwek, 1994). To maintain a stable RM/US dollar exchange rate and forestall excessive growth in reserve money, BNM sterilized about RM16 billion and

RM33 billion in 1992 and 1993, respectively.<sup>9</sup> However, the substantial capital inflows still resulted in annual M3 growth of 19% in 1992 and 23% in 1993.

The surging gross capital inflows in the early 1990s reversed to become large gross outflows in 1997-1998 during ACC. BNM again responded by sterilizing about RM40 billion in 1998 and RM30 billion in 1999. Since 1998, BNM has continued to contract its net domestic assets (NDA) significantly in order to sterilise the inflows arising mainly from large trade surpluses and, to a lesser extent from gross portfolio inflows (Latifah, 2005).<sup>10</sup>

## 2.1. BNM'S BALANCE SHEET – OVERALL MONETARY POLICY STRATEGY

To get a firmer picture of BNM's overall monetary policy strategy, observe the cumulative changes in BNM's balance sheet for 1990-2009 and in two sub-periods: 1990-97; and 1998-2009 (Table 1). Taking first the whole period, note that the increase in demand for reserve money over 1990-09 was rather small (at RM 40 billion)--largely because BNM reduced bank reserve ratios significantly from 1998. Given the small increase in money demand, BNM's overall monetary policy strategy was to reduce its NDA significantly (by RM 247 billion) in the face of heavy net NFA inflows (by RM 287 billion). In essence, the numbers suggest that BNM was heavily sterilizing NFA inflows throughout the period in order to avoid excess creation of reserve money, which could have stoked inflation. As a result of that strategy, inflation only averaged 2.9 percent during the period, while real GDP growth averaged 5.9 percent.

**TABLE 1: DEVELOPMENTS IN BNM'S BALANCE SHEET, 1990-2009**  
(RM, MILLION)

	Change in NFA	Change in NDA	Change in RM	Cumulative Current Account surpluses	Net capital inflows
90-09	286,734	-246,701	40,033	709,871	-400,259
Sub-periods					
90-97	38,716	29,397	68,113	-92,015	129,478
98-09	248,018	-276,098	-28,080	801,886	-529,737

Source: International Financial Statistics, IMF

Further on BNM's sterilization operations, observe that the NFA inflows were significantly larger in the second sub-period, which suggests that although BNM actively sterilized throughout the two decades, the bulk of its sterilization operations occurred in the second sub-period (NDA contracted by RM 276 billion). As noted above, observe also that

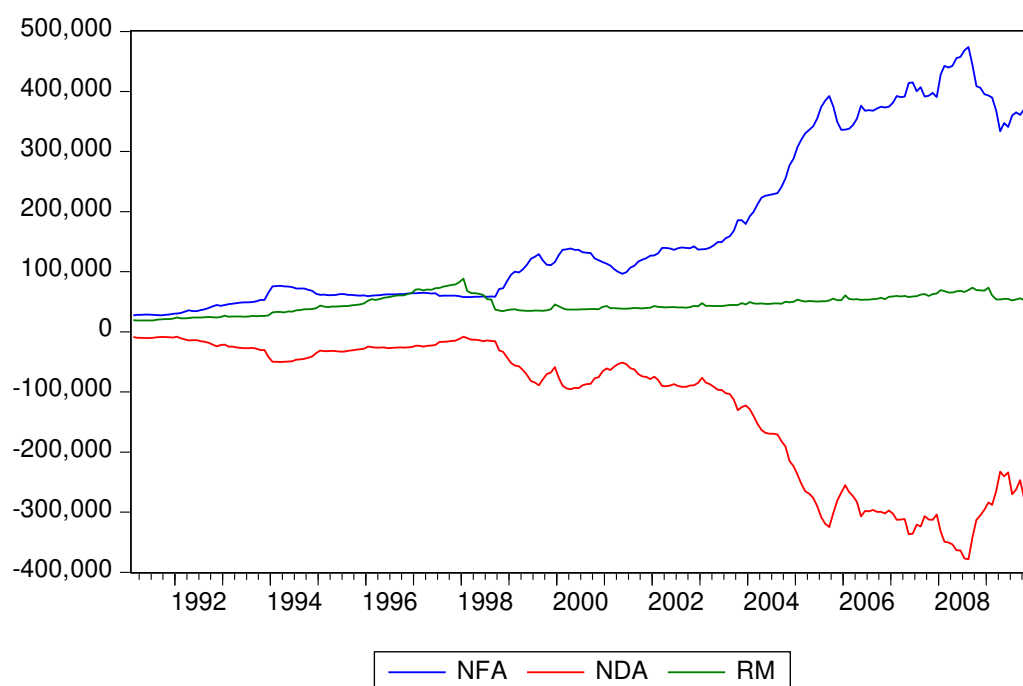
9. Like many countries, BNM does not make intervention and sterilization data public. However, occasionally the bank will report sterilization activity in the BNM annual report.

10. The year 1998 marked an important turning around of the trade account to large surpluses as export volume jumped and import volume remained stagnant, due to large depreciation of the Ringgit. In 1998, the current account turned around from Rm17bil deficit in 1997 to RM37bil surplus, and this offset the increased private short-term outflow of RM21bil. Reserves strengthened by RM40bil to RM90bil.

the NFA inflows reflected heavy net capital inflows in the first sub-period; but had surging current account surpluses in the second.

Figure 1 illustrates both these developments and the overall thrust of BNM's monetary policy in one picture. The open hands of the scissors-like graph from 1998 reflect BNM's attempts to offset rising NFA inflows (from surging current account surpluses) by steadily contracting its NDA while the demand for reserve money was flat.

**FIGURE 1: TIME SERIES PLOT OF NET FOREIGN ASSET (NFA) AND NET DOMESTIC CREDIT (NDC) IN MALAYSIA, 1991-2009 (IN RM BILLIONS)**



## 2.2. INSTRUMENTS OF BNM POLICY

The two major instruments of BNM policy are direct money market borrowing and the Wadiah Acceptance<sup>11</sup>. BNM used these two instruments to remove 62% of the excess liquidity drained in 2008 (BNM, 2008). The maturity structure for direct borrowing ranges between overnight to three months. In addition to these two instruments, BNM has also gradually shifted towards the use of repos and the Bank Negara Monetary Notes (BNMNs) (Ooi, 2008). The repo, which has a tenure from one month to three months, allows BNM to absorb surplus liquidity at a lower cost than direct borrowings. The BNMNs were introduced in December 2006 to replace the Bank Negara Bills and Bank Negara Negotiable Notes. They are used to absorb excess liquidity for longer term maturities,

11. Wadiah Acceptance is a transaction between BNM and the Islamic banking institutions, whereby the Islamic institutions placed their surplus fund with BNM based on the Islamic concept. BNM uses the Wadiah Acceptance to absorb liquidity in the market.



hence, reducing the need for larger turnover of short-term sterilization transactions on a daily basis (Ooi, 2008).

Malaysia has largely been able to avoid sterilization costs because its domestic interest rates have tended to be lower than foreign interest rates, minimizing the cost of servicing sterilization bonds (Ooi, 2008). In fact, as documented by Latifah (2004) and Ooi (2008), sterilized interventions have been effective and enabled BNM to manage its surplus liquidity while keeping interest rates in line with targets.

### 3. THE THEORETICAL FRAMEWORK

During the 1970s, a great deal of research was done on the theory and empirical analysis of sterilization and offsetting capital flows in order to assess whether monetary control is feasible under fixed exchange rates and high capital mobility (Kim, 1995). One strand of this research estimates the offset coefficient alone –the fraction of a given increase (decrease) in net domestic assets that is offset by capital outflow (capital inflow) during the same quarter (for example, Kouri & Porter (1974), Kouri (1975), Neumann (1978), Neumann (1984), Kamas (1986) and Pasula (1994)). This work used the Kouri-Porter (1974) framework<sup>12</sup>, which synthesized the portfolio balance approach and the monetary approach to the balance of payments by examining the relationship between net foreign assets and net domestic assets as follows:<sup>13</sup>

$$CF = -\beta_1 NDA - \beta_2 \Delta i^* - \beta_3 CU + \beta_4 \Delta Z + \varepsilon_t \quad (1)$$

where  $CF$  denotes capital flows,  $i^*$ , world interest rates,  $NDA$ , the net domestic assets of the central bank,  $CU$ , the current account balance, and  $Z$ , other relevant macroeconomic variables which can potentially influence capital flows.  $\beta_i$  is the offset coefficient, whose value is expected to range between zero to one.

Recall that  $\Delta NFA$  held by a central bank satisfies the following identity:

$$\Delta NFA = CF + CU \quad (2)$$

Rearranging Equation (1) into Equation (2) yields the following:

$$\Delta NFA = -\beta_1 NDA - \beta_2 \Delta i^* + (1 - \beta_3) CU + \beta_4 \Delta Z + \varepsilon_t \quad (3)$$

<sup>12</sup> The pioneers in this area of research.

<sup>13</sup> The offset coefficient can be empirically estimated by either the reduced form approach (Porter, 1972; Kouri and Porter, 1974; Gorton and Roper, 1977) or structural approach (Herring and Marston, 1977; Obstfeld, 1980). It is argued that both approaches should yield consistent conclusions, if the models are properly specified and estimation techniques are correctly used (Pasula, 1994). Existing literature documented that the reduced-form estimates tend to be biased toward -1 rather than the structural estimates (Kouri and Porter, 1974; Obstfeld, 1982).

The key coefficient is  $\beta_1$ , the offset coefficient which measures the independence of monetary policy. As shown by Kouri and Porter, if  $0 < \beta_1 < 1$ , the central bank will retain some monetary control.

The second research strand estimates the sterilization coefficient from the central bank reaction function (see Obstfeld, 1983; Kearney & MacDonald (1986), Hutchion (1988), Mastropasqua et al (1988) and Von (1989)). In the reaction function, NDA are typically related to NFA as well as a set of exogenous variables (such as the inflation rate, the gross domestic product). The sterilization coefficient is the coefficient on NFA—it shows the extent to which NDA is adjusted to offset changes in NFA. A simplified version of the reaction function is:

$$\Delta NDA = -\alpha_1 \Delta NFA + \gamma_1 X_p \quad (4)$$

where  $\Delta NDA$  is the change in NDA,  $\Delta NFA$  is the change in NFA,  $X$  is the vector of other relevant macroeconomic variables that may affect the behavior of net domestic assets. The parameter,  $\alpha_1$ , is the sterilization coefficient, whose value ranges from between zero and one. If estimated sterilization coefficient is one ( $\alpha_1 = 1$ ), sterilization is complete, which means that the central bank completely offsets the impact of any change in NFA on reserve money. If the estimated sterilization coefficient is zero, the central bank allows all changes in NFA to be fully reflected in changes in money.

The third research strand estimates the offset coefficient and sterilization coefficient from separate functions or equations (see Kim, 1995; Moreno & Spiegel, 1997; Savvides, 1998; Emir et al 2000; Waheed, 2007; Igor et al 2010). More formally, the offset coefficient is normally estimated from a capital flow equation, and the sterilization coefficient is estimated from a central bank reaction function as follows:-

$$\begin{aligned} \Delta NFA &= -\beta_1 \Delta NDA + \delta_j Z_j \\ \Delta NDA &= -\alpha_1 \Delta NFA + \gamma_1 X_p \end{aligned} \quad (5)$$

However, Argy and Kouri (1974), Herring and Marston (1977) and Obstfeld (1982) have suggested it is more appropriate to estimate Equation (5) simultaneously. This is because if capital inflow is systematically sterilized, the change in NDA will be correlated with the disturbance terms of the NFA equation, resulting in inconsistency of the OLS estimates.

In Equation (5), the choice of control variables (the variables in  $X$  and  $Z$ ) is also important. Most existing empirical studies choose a set of control variables based on informal theorizing (Ouyang et al, 2005, 2007 & 2010). Our literature survey indicates that only Brissimis et al (2002) (BGT) has developed a formal theoretical model that derives both the sterilization and the offset coefficients from the minimization of a loss function by the monetary authority. This loss function in turn is subject to a number of constraints that reflect the transmission mechanism of the economy. Ouyang et al modified the BGT's model in a number of ways and applied it to several Asian economies.

In this paper, we modify the BGT and Ouyang model by introducing the stock market as an influence on capital flows. In addition, we take into account that both changes in NDA and NFA can affect interest and exchange volatilities. This is discussed in greater detail below. The model we estimate is as follows:

Following the simplified loss function of Ouyang et al (2005) we have:

$$L_t = \beta(\Delta P_t)^2 + \gamma(Y_{c,t})^2 + \delta(\sigma_{r,t})^2 + \varepsilon(\sigma_{s,t})^2 \quad (6a)$$

The central bank's loss function (L) is determined by the extent of inflation (the change in the logarithm of the price level (i.e. the difference in  $P_t$  and  $P_{t-1}$ ); size of cyclical income ( $Y_{c,t}$ ); and the volatility of the interest rate ( $\sigma_{r,t}$ ) and the exchange rate ( $\sigma_{s,t}$ ). All the parameters are positive.

The central bank minimizes this loss function by choosing foreign exchange market intervention ( $\Delta NFA_t$ ) and domestic money market intervention ( $\Delta NDA_t$ ), given these constraints:

## I. THE INFLATION RATE

$$\Delta P_t = \pi_1(\Delta NFA_t + \Delta NDA_t) + \pi_2 \Delta P_{t-1} + \pi_3 \Delta s_t \quad \pi_1 > 0, 0 < \pi_2 < 1, \pi_3 > 0 \quad (6b)$$

The inflation rate depends on the change in the current monetary base (both  $\Delta NFA_t$  and  $\Delta NDA_t$ ), the past inflation rate and the current exchange rate.

## II. CYCLICAL INCOME

$$Y_{c,t} = \varphi_1(\Delta NFA_t + \Delta NDA_t) + \varphi_2 Y_{c,t-1} \quad ; \varphi_1 > 0, 0 < \varphi_2 < 1 \quad (6c)$$

Cyclical income is a function of the monetary base and the cyclical position of the economy in the previous period.

## III. BALANCE OF PAYMENT AND THE EXCHANGE RATE

$$\Delta NFA_t = CA_t + \Delta NK_t \quad (6d)$$

where  $CA_t$  is the current account balance, assumed to be exogenously determined, and  $\Delta NK_t$  is the net capital inflow in period  $t$ .

$$\Delta NK_t = (1/c)\Delta [s_t - Es_{t+1} + r_t - r_t^*] + m_1\Delta sp_t + m_2\Delta sp_{t-1} \quad (6e)$$

where  $s_t$  is the current exchange rate,  $Es_{t+1}$  is the current expectation of the exchange rate at time  $t+1$ ;  $r$  is the domestic interest rate,  $r_t^*$  is the foreign interest rate,  $sp_t$  and  $sp_{t-1}$  is the percentage change in stock index at time  $t$  and  $t-1$ .  $c$  represents the degree of risk aversion between domestic and foreign assets. If  $0 < c < \infty$ , assets are substitutes but not perfect substitutes. If  $c = 0$ , assets are perfect substitutes and Equation (6e) reduces to the interest parity condition.

It is expected that there is a negative relationship between domestic interest rate and the level of the monetary base, and hence:

$$\Delta r_t = -\psi[\Delta NDA_t + \Delta NFA_t] \quad \psi > 0 \quad (6f)$$

Substitute (6d) & (6f) into (6e) yields:

$$\begin{aligned} c\Delta(\Delta NFA_t - CA_t) &= \Delta s_t - \Delta[r_t^* + Es_{t+1}] - \phi[\Delta NDA_t + \Delta NFA_t] + cm_1\Delta sp_t + cm_2\Delta sp_{t-1} \\ \Delta s_t &= c\Delta NFA_t - cCA_t + \Delta[r_t^* + Es_{t+1}] + \phi[\Delta NDA_t + \Delta NFA_t] - cm_1\Delta sp_t - cm_2\Delta sp_{t-1} \\ &= (c + \phi)\Delta NFA_t + \phi\Delta NDA_t - cCA_t + \Delta[r_t^* + Es_{t+1}] - cm_1\Delta sp_t - cm_2\Delta sp_{t-1} \end{aligned} \quad (6g)$$

Equation (6g) says that an increase in net foreign assets (as a result of intervention to sell the domestic currency) causes  $s_t$  to increase (i.e. exchange rate depreciates); an increase in the current account surplus causes  $s_t$  to fall (appreciate); an increase in the monetary base causes  $s_t$  to increase (depreciate); an increase in either the expected depreciation or the foreign interest rate will increase  $s_t$  as capital flows out of domestic assets; and lastly, an increase in the past and current percentage changes in the stock indexes causes  $s_t$  to fall as capital flows into domestic stock markets. We have introduced the stock market variable to capture the effect of the Malaysian bourse on net capital flows as noted by several observers (e.g., Latifah (2005)).

Now, substitute (6g) into (6b), and the Equation (6h) is obtained:

$$\begin{aligned} \Delta P_t &= \pi_1(\Delta NFA_t + \Delta NDA_t) + \pi_2\Delta P_{t-1} + \pi_3\Delta s_t \\ &= \pi_1(\Delta NFA_t + \Delta NDA_t) + \pi_2\Delta P_{t-1} + \pi_3\left\{(c + \phi)\Delta NFA_t + \phi\Delta NDA_t - cCA_t + \Delta[r_t^* + Es_{t+1}] - \pi_3cm_1\Delta sp_t - cm_2\Delta sp_{t-1}\right\} \\ &= [\pi_1 + \pi_3(c + \phi)]\Delta NFA_t + [\pi_1 + \pi_3\phi]\Delta NDA_t + \pi_2\Delta P_{t-1} - \pi_3cCA_t \\ &\quad + \pi_3\Delta[r_t^* + Es_{t+1}] - \pi_3cm_1\Delta sp_t - \pi_3cm_2\Delta sp_{t-1} \end{aligned} \quad (6h)$$

#### IV. INTEREST RATE VOLATILITY

$$\sigma_{r,t} = \eta\sigma_{r,t-1} - \zeta(\Delta NDA_t - d_1\Delta NDA_t) - \zeta(\Delta NFA_t - d_1\Delta NFA_t) \quad \eta, \zeta > 0 \quad (6i)$$

The first two components of Equation (6i) on the RHS state that interest rate volatility is positively related to its previous period volatility, but negatively related to the absolute amount of intervention undertaken by the central bank in the domestic money market.  $D_1$  is a dummy which takes on a value of zero when the central bank intervenes by increasing its NDA, i.e., providing liquidity to the system; but takes on a value of 2 when the central bank intervenes by draining liquidity (NDA falls) from the system. The dummy variable allows us to represent central bank interventions in absolute terms; and shows that central bank intervention in the money market is always intended to reduce interest rate volatility, i.e. the coefficient,  $L$ , is always positive.

The BCG model includes only these two components in Equation (6i). However, central bank interventions in the money market in any period are likely to be associated with some changes in net foreign assets, which would also affect liquidity and interest volatility and potentially affect the size and impact of central bank's interventions in the money markets. To account for NFA's impact, we modify BCG's model by adding the third term on the RHS in Equation (6i); and for the same reasons, the corresponding NDA term in Equation (6j) below.

#### V. EXCHANGE RATE VOLATILITY

$$\sigma_{s,t} = \kappa\sigma_{s,t-1} - \zeta(\Delta NFA_t - d_2\Delta NFA_t) - \zeta(\Delta NDA_t - d_2\Delta NDA_t) \quad \kappa, \zeta > 0 \quad (6j)$$

Equation (6j) shows that exchange rate volatility is similarly affected by its previous period volatility; the absolute value of central bank interventions in the foreign exchange markets (with  $d_2=0$  when the central bank increases its NFA; and  $d_2=2$  when NFA is decreased; and the additional NDA term).

Assuming that the central bank minimizes Equation (6a) with respect to the policy instruments ( $\Delta NDA_t$  and  $\Delta NFA_t$ ) and subject to the constraints in Equations (6b), (6c), (6g), (6i) and (6j), the following equations are obtained:

$$\begin{aligned} \partial L_t / \partial \Delta NDA_t &= (\partial L_t / \partial \Delta P_t)(\partial \Delta P_t / \partial \Delta NDA_t) + (\partial L_t / \partial Y_{c,t})(\partial Y_{c,t} / \partial \Delta NDA_t) + (\partial L_t / \partial \sigma_{r,t})(\partial \sigma_{r,t} / \partial \Delta NDA_t) \\ &\quad + (\partial L_t / \partial \sigma_{s,t})(\partial \sigma_{s,t} / \partial \Delta NDA_t) \end{aligned} \quad (6k)$$

$$\begin{aligned} \partial L_t / \partial \Delta NFA_t &= 0 = (\partial L_t / \partial \Delta P_t)(\partial \Delta P_t / \partial \Delta NFA_t) + (\partial L_t / \partial Y_{c,t})(\partial Y_{c,t} / \partial \Delta NFA_t) + (\partial L_t / \partial \sigma_{r,t})(\partial \sigma_{r,t} / \partial \Delta NFA_t) \\ &\quad + (\partial L_t / \partial \sigma_{s,t})(\partial \sigma_{s,t} / \partial \Delta NFA_t) \end{aligned}$$

$$\partial L_t / \partial NDA_t = (\beta \Delta P_t)(\pi_1 + \pi_3 \phi) + (\gamma Y_{c,t})(\varphi_1) + (\delta \sigma_{r,t})[\zeta(d_1 - 1)] + (\varepsilon \sigma_{s,t})[\zeta(d_2 - 1)] = 0 \quad (6l)$$

(6m)

$$\partial L_t / \partial NFA_t = (\beta \Delta P_t)(\pi_1 + \pi_3)(c + \phi) + (\gamma Y_{c,t})(\varphi_1) + (\delta \sigma_{r,t})[\zeta(d_1 - 1)] + (\varepsilon \sigma_{s,t})[\zeta(d_2 - 1)] = 0$$

(6n)

Now, substituting Equations (6b), (6c), (6g), (6i) and (6j) and solving for semi-reduced-form equation for  $\Delta NDA_t$  and  $\Delta NFA_t$  we obtain:

$$\begin{aligned} \Delta NDA_t = & - \left[ \{ (\delta d_1 + \varepsilon d_2 - \delta - \varepsilon) \zeta^2 (d_2 - 1) + \beta (\pi_1 + \pi_3 \phi) [\pi_1 + \pi_3 (c + \phi)] + \gamma \varphi_1^2 \} / \theta_1 \right] \Delta NFA_t \\ & - \left[ \beta (\pi_1 + \pi_3 \phi) \pi_2 / \theta_1 \right] \Delta P_{t-1} + \left[ c \beta (\pi_1 + \pi_3 \phi) \pi_3 / \theta_1 \right] CA_t \\ & - \left[ \beta (\pi_1 + \pi_3 \phi) \pi_3 / \theta_1 \right] \Delta (r_t^* + Es_{t+1}) + \left[ \beta (\pi_1 + \pi_3 \phi) \pi_3 / \theta_1 \right] cm_1 sp_t \\ & + \left[ \beta (\pi_1 + \pi_3 \phi) \pi_3 / \theta_1 \right] cm_2 sp_{t-1} - \left[ \gamma \varphi_1 \varphi_2 / \theta_1 \right] Y_{c,t-1} - \left[ \eta \delta \zeta (d_1 - 1) / \theta_1 \right] \sigma_{r,t-1} - \left[ \varepsilon \zeta \kappa (d_2 - 1) / \theta_1 \right] \sigma_{s,t-1} \end{aligned} \quad (6o)$$

Where  $\theta_1 = (\delta d_1 + \varepsilon d_2 - \delta - \varepsilon) \zeta^2 (d_1 - 1)^2 + \beta (\pi_1 + \pi_3 \phi)^2 + \gamma \varphi_1^2$

$$\begin{aligned} \Delta NFA_t = & - \left[ \{ (\delta + \varepsilon) \zeta^2 (d_1 - 1) (-\delta - \varepsilon + \delta d_1 - \varepsilon d_2) + \beta (\pi_1 + \pi_3 \phi) [\pi_1 + \pi_3 (c + \phi)] + \gamma \varphi_1^2 \} / \theta_2 \right] \Delta NDA_t \\ & - \left[ \beta \pi_2 (\pi_1 + \pi_3 (c + \phi)) / \theta_2 \right] \Delta P_{t-1} + \left[ c \beta [\pi_1 + \pi_3 (c + \phi)] \pi_3 / \theta_2 \right] CA_t \\ & - \left[ \beta (\pi_1 + \pi_3 (c + \phi)) \pi_3 / \theta_2 \right] \Delta (r_t^* + Es_{t+1}) + \left[ \beta (\pi_1 + \pi_3 (c + \phi)) \pi_3 / \theta_2 \right] cm_1 dsp_t \\ & + \left[ \beta (\pi_1 + \pi_3 (c + \phi)) \pi_3 / \theta_2 \right] cm_2 dsp_{t-1} - \left[ \gamma \varphi_1 \varphi_2 / \theta_2 \right] Y_{c,t-1} - \left[ \delta \eta \zeta (d_1 - 1) / \theta_2 \right] \sigma_{r,t-1} - \left[ \kappa \varepsilon \zeta (d_2 - 1) / \theta_2 \right] \sigma_{s,t-1} \end{aligned} \quad (6p)$$

Where  $\theta_2 = (\delta d_1 + \varepsilon d_2 - \delta - \varepsilon) \zeta^2 (d_2 - 1)^2 + \beta [\pi_1 + \pi_3 (c + \phi)]^2 + \gamma \varphi_1^2$

## 4. DESCRIPTION OF THE DATA SET

The sterilization and offset coefficients are estimated using monthly data from January 1991 to December 2009. Monthly data was used because Equations (6o) and (6p) contain mostly monetary variables, which react quickly to changes in the monetary environment (Christensen, 2004); quarterly data would hide a lot of information in monthly movements. In addition, we have more degrees of freedom due to the greater frequency of monthly data. The data are obtained from the International Financial Statistics (IFS; International Monetary Fund). Appendix 1 summarizes the definitions and sources of the data. Because of the unavailability of monthly GDP and current account data, we use the industrial production index (IPI) and trade balance (TB) as proxies for those two variables.

*NFA* are the central bank's net foreign assets; *RM*, reserve money; and *NDA*, the central bank's net domestic assets, is obtained as the difference between *RM* and *NFA*. We adjust *NDA* and *NFA* data to take out revaluation changes that are not the result of central bank policy actions. These revaluation changes are subtracted from *NFA* and added back to *NDA* to preserve the identity of  $NFA + NDA = RM$  (Ouyang et al. 2007).

Revaluation changes in gold are obtained from IFS but data on exchange rate revaluations are not directly reported by BNM or in IFS. Many studies have thus had to rely on imperfect proxies (Edison, 1983).<sup>14</sup> However, our literature and data survey shows that BNM began to revalue its foreign currency assets and liabilities only from September 1998; and with effect from 1<sup>st</sup> January 1999, BNM has continued to revalue its foreign assets and liabilities on a quarterly basis (Monthly Statistics Bulletin, March, 1999). Although these revaluation data are publicly reported on an annual basis in the Balance of Payment Accounts (under the sub-section "Errors & Omissions")<sup>15</sup> monthly revaluation data are reported by BNM<sup>16</sup> only under 'other reserves,' mixed in with other categories like the investment fluctuations reserve, the insurance reserves and contingency reserves; with the exchange fluctuations reserve being the largest category (Glossary, Monthly Statistics Bulletin). Using the annual data as a guide, we were able to extract the monthly revaluation data from BNM's "other reserves."

A second major adjustment relates to the *NDA* variable. Theoretically, changes in this variable should reflect all changes in the central bank's monetary policy stance. While monetary policy initiatives using open market operations would be directly captured in changes in *NDA*, one important instrument of Malaysia's monetary policy (bank's statutory reserve requirement (SRR)) would not necessarily be reflected as such. To account for monetary policy changes from changes in SRR, which occurred

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<sup>14</sup> Ouyang et al (2005, 2007) for example, assumes that all the reserves are held in US dollars and adjusts the reserves for changes in the bilateral US dollar rates.

<sup>15</sup> See BNM Annual Report, various series after 1999

<sup>16</sup> Monthly balance sheet of BNM is available at Monthly Statistics Bulletin, BNM on line, <http://www.bnm.gov.my/index.php?ch=109&pg=294&ac=211&yr=2010&mth=7&eld=box1>

frequently in the earlier years through 1999,<sup>17</sup> the *NDA* data need to be adjusted accordingly. To do that, we follow the strategy of Cumby and Obstfeld (1981) which creates an adjusted *NDA* series that reflects how *NDA* would change, if the intended policy change were enacted through changing the *NDA* instead of changing the *SRR*. The Cumby & Obstfeld strategy is explained in greater detail in Appendix 2.

Finally, the variables  $\Delta NDA$  and  $\Delta NFA$  are scaled with lagged reserve money ( $RM_{t-1}$ )<sup>18</sup> to control for any increase in nominal variance over time; and two interaction dummies, *duec* and *dfixer* are created to take into account the periods when the exchange and capital regimes differ.

To take into account the period of capital controls, we let:

*duec* = 1 in 1998.9 till 2000.12  
= 0 for otherwise;

To take into account the fixed exchange period, we let:

*dfixer* = 1 in 1998.9 till 2005.7  
= 0 for otherwise.

So, altogether, we distinguish 3 periods: *duec*=0; *dfixer*=0 covers managed floating; *duec* = 1; *dfixer* =1 covers the period with capital controls and fixed exchange rates; *duec* = 0; *dfixer* =1 covers fixed exchange rates with no capital controls.

By including these two dummy variables, Equations (60) and (6p) become:

$$\begin{aligned} \Delta NFA_t = & \alpha_0 + \alpha_1 \Delta NDA_t + \alpha_2 \Delta NDA_{t-1} + \alpha_3 \Delta NFA_{t-1} + \alpha_4 \Delta P_{t-1} + \alpha_5 IPI_{t-1} + \alpha_6 \Delta TB_{t-1} + \alpha_7 \Delta (r_{t-1}^* + E_t S_{t+1}) \\ & + \alpha_8 (d_1 - 1) \sigma_{r,t-1} + \alpha_9 (d_2 - 1) \sigma_{s,t-1} + \alpha_{10} \Delta sp_t + \alpha_{11} \Delta sp_{t-1} + \alpha_{12} duec \Delta NDA_t \\ & + \alpha_{13} dfixer \Delta NDA_t + \varepsilon_t \end{aligned} \quad (8)$$

<sup>17</sup> During the period 1988-99, there were several revisions in *SRR*. Prior to 1998, *SRR* was gradually revised upwards from 3.5% to 13.5%, to curb inflationary pressures arising from a large excess liquidity in the market. However, in 1998, in order to stimulate economic activity in the aftermath of the Asian Currency Crisis, *SRR* was revised downwards four times from 13.5% to 4% on 16 September, 1998.

<sup>18</sup> Christensen (2004), Marstropasqua et al (1988), Cavoli and Rajan (2005) divided the *NDA* and *NFA* variables with lagged of reserve money. Quyang (2007) divided the *NDA* and *NFA* variables with lagged of GDP. Ouyang (2005) found there is no difference in the estimated values of the sterilization and offset coefficients using either lagged of reserve money or lagged of GDP.



$$\begin{aligned}
\Delta NDA_t = & \beta_0 + \beta_1 \Delta NFA_t + \beta_2 \Delta NFA_{t-1} + \beta_3 \Delta NDA_{t-1} + \beta_4 \Delta P_{t-1} + \beta_5 IPI_{t-1} + \beta_6 \Delta TB_{t-1} + \beta_7 \Delta(r_{t-1}^* + E_t S_{t+1}) \\
& + \beta_8 (d_1 - 1) \sigma_{r,t-1} + \beta_9 (d_2 - 1) \sigma_{s,t-1} + \beta_{10} \Delta sp_t + \beta_{11} \Delta sp_{t-1} + \beta_{12} ducec \Delta NFA_t \\
& + \beta_{13} dfixer \Delta NFA_t + v_t
\end{aligned}
\tag{9}$$

To account for simultaneity problems, Equations (8) and (9) are estimated using the Two Stage Least Square (2SLS) method. 2SLS requires the selection of instrumental variables but theory does not provide precise guidance as to which instruments are most appropriate in our context except that a good instrument must be highly correlated with the explanatory endogenous variable but uncorrelated with the residuals of the estimated model. Therefore, we have chosen the net contribution of Employees Provident Fund (EPF)<sup>19</sup> and the lagged change in the growth of real GDP (proxied by growth of the industrial production index) as the instruments for the change in NDA; and a dummy for the end-1993 spike in capital flows and lagged accelerations of the stock market index as instruments for the change in NFA.

The estimated equations were tested for the presence of heteroscedasticity and autocorrelation using the White test and the Lagrange Multiplier test (LM test), respectively. Autocorrelation and heteroskedasticity were corrected using the Newey-West method.

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<sup>19</sup> Government deposits and pension funds can form a sizeable part of money supply. In Malaysia, the authorities frequently shifted the EPF fund from the commercial banks to the central bank. For example, in 1992, more than US\$2.6 billion of the pension funds was centralized with Bank Negara Malaysia (Lim, 1998).

## 5. EMPIRICAL RESULTS

Table 2 reports the results of unit root tests for the variables used. Both the ADF and PP tests consistently suggest that the dependent variables of the equations,  $\Delta NFA$  and  $\Delta NDA$ , are stationary in levels or  $I(0)$  process. Other exogenous variables are also stationary or  $I(0)$ , except for the trade balance ( $TB$ ) variable which is non-stationary in levels,  $I(1)$ .

**TABLE 2: THE UNIT ROOT TEST RESULTS**

Series	Type of test	ADF		PP	
		In Levels	In first differences	In levels	In first differences
$\Delta NFA_t$	intercept	-10.50***		-10.48***	
$\Delta NDA_t$	intercept	-10.73***		-10.78***	
$\Delta P_t$	intercept	-3.96***		-3.21**	
$IPI_t$	intercept	-3.86***		-3.84***	
$(d_2-1)vex_{t-1}$	intercept	-3.52***		-14.78***	
$(d_1-1)vi_{t-1}$	intercept	-5.41***		-10.19***	
$TB$	Trend and Intercept	-2.88	-17.30***	-2.62	-34.56***
$\Delta(r_t + E_t S_{t+1})$	intercept	-12.04***		-12.55***	
$\Delta sp_t$	intercept	-8.70***		-13.35***	

Note: \* denotes significant at 10%, \*\* denotes significant at 5%, \*\*\* denotes significant at 1%.

The 2TLS estimates of the capital flows equation and the central bank reaction function (i.e. Equations (8) and (9) above) are reported in Tables 3 and 4 respectively. Taking first the capital flow equation, note that the estimated coefficient of  $\Delta NDA$ , which gives us the same-period (short-term) offset, is -0.56 and significant at the 1 percent level. The result indicates that under managed floating/no capital controls, capital flows offset 56% of any change in monetary stance during the same month.

### 5.1. SHORT-RUN OFFSET COEFFICIENTS UNDER DIFFERENT REGIMES

We can distinguish different short-run coefficients for different exchange and capital regimes using results provided by the interaction dummies. First, consider the case of fixed exchange rates/no capital controls. The interaction dummy for fixed exchange rates is -0.29 and significant at 5 percent, thus, the amount of short-term offset under fixed rates, no capital controls is -0.85 (i.e. the sum of -0.56 and -0.29) sizably larger than the offset under managed floating. However, this higher short-term offset is still significantly different from minus one, underscoring that BNM continued to have short-run monetary control even under fixed rates/no capital controls. Second, consider the interaction dummy for capital controls. Capital controls had an effectiveness of 0.20 (significant at 1 percent) meaning it reversed any offset by .20. That is, the short-run offset during the fixed rate/capital controls period (1998-2000) was (-0.56 –

0.29 + 0.20) or – 0.65. Considering the combined effect of managed floating and capital controls, the short-run offset is reduced to (-0.56 + 0.20) or -0.36, quite a bit lower. While effective, the Malaysian capital controls during ACC nevertheless did not completely choke off the capital account.

**TABLE 3: ESTIMATED CAPITAL FLOW FUNCTION**

Dependant variable: $\Delta NFA$		
Method: 2SLS		
Sample: March 1991 – October 2009		
No. of observation: 224		
Instrumental Variable : $\Delta NDA_{t-1}, \Delta NFA_{t-1}, IPI_{t-1}, \Delta P_{t-1}, \Delta TB_{t-1}, \Delta(r_t + E_t S_{t+1})_{t-1}, \Delta sp_t, \Delta sp_{t-1}, (d_1-1)vi_{t-1}, (d_2-1)vex_{t-1}, du_{ec} * \Delta NDA_{t-1}, dfixer * \Delta NDA_{t-1}, du93, epf\_rm, \Delta IPI_{t-1}$		
Variable	Coefficient	Standard error (t-stat)
constant	0.021677	0.002663 (8.1407)
$\Delta NDA_t$	-0.558327	0.136657 (-4.0856)***
$\Delta NDA_{t-1}$	-0.404753	0.063274 (-6.396805)***
$\Delta NFA_{t-1}$	-0.309284	0.075897 (-4.075021)***
$IPI_{t-1}$	0.000333	0.000295 (1.128034)
$\Delta P_{t-1}$	-0.004337	0.000964 (-4.500406)***
$\Delta TB_{t-1}$	0.139278	0.034685 (4.015462)***
$\Delta(r_t + E_t S_{t+1})$	-0.049853	0.010668 (-4.672990)***
$\Delta sp_t$	0.001066	0.000604 (1.764041)*
$\Delta sp_{t-1}$	0.001910	0.000794 (2.404700)**
$(d_1-1)vi_{t-1}$	-0.033582	0.008430 (-3.983845)***
$(d_2-1)vex_{t-1}$	-0.010357	0.002342 (-4.421556)***
$du_{ec} * \Delta NDA_{t-1}$	0.200044	0.014456 (13.83828)***
$dfixer * \Delta NDA_{t-1}$	-0.294944	0.128400 (-2.297069)**
$du93$	0.152962	0.048489 (3.154590)***
$R^2 = 0.8271$	Adjusted $R^2 = 0.8156$	
SE of regression	0.070770	

## 5.2. LONG-RUN OFFSET COEFFICIENTS UNDER DIFFERENT REGIMES

Table 3 shows that the lagged terms for the change in NDA and NFA are both significant at the 1 percent level; this allows the computation of the long-run offset coefficients. Considering first managed floating/no capital controls, the long-run offset coefficient is  $(-0.56 - .40)/(1.31)$  or - 0.73 (73 percent) higher than the short-run coefficient of 56 percent, but still significantly less than negative one. Thus, the offset to any monetary action by BNM increases but the offset is still not complete, meaning the central bank retains monetary control even in the long run under managed floating. Consider now the long-run offset under fixed rates/no capital controls. The coefficient is  $(-0.56 - 0.4 - 0.29)/(1.31)$  or – 0.95, not significantly different from minus 1, implying a full offset. Thus, under fixed exchange rates, BNM has more trouble maintaining monetary control in the longer run, as all attempts at independent monetary policy appear to wash out by the second month. This result suggests that Malaysia is not exempted from the Impossible Trinity in the longer run.

### 5.3. OTHER ESTIMATES

The estimates for the other independent variables are mostly in line with expectations and significant at 5 percent. First, an increase in the adjusted foreign interest rates [ $\Delta(r_{t-1}^* + E_t S_{t+1})$ ] reduces capital inflows; an increase in both the interest and exchange rate volatility variables decreases capital inflows; a higher positive trade balance ( $\Delta TB$ ) and an acceleration in last period stock prices ( $\Delta sp_{t-1}$ ) increase capital inflows (the current acceleration in stock prices,  $\Delta sp_t$ , is significant at ten percent). An increase in last period's inflation decreases capital inflows as expected although an increase in the proxy for real income growth is insignificant, with the wrong sign. The dummy variable introduced to capture the 1993 "super bull" surge in capital inflows is statistically significant, and positive.

### 5.4. SHORT-RUN STERILIZATION COEFFICIENTS

The short-run sterilization coefficient from the central bank reaction function (Table 4) is  $-0.78$  (relatively high but significantly different from minus one) under managed floating. Thus, BNM did not attempt to sterilize capital flows completely in the same period, but the relatively high coefficient suggests that BNM was sterilizing changes in NFA extensively throughout this period.

The interaction dummies show that the intensity of sterilization increased during the fixed exchange rate regime (1998-2005). Table 4 shows that the interaction dummy for the fixed rate/no capital controls period is  $-0.11$ , statistically significant at 1 percent, such that the sterilization coefficient under fixed exchange rates/no capital controls is  $(-0.78 - 0.11)$  or  $-0.89$ . The higher coefficient confirms that the intensity of sterilization activity increased during the fixed rate period as suggested by the scissors-shaped graph in Figure 1 above. This greater degree of sterilization mostly likely reflects more robust NFA flows during the fixed rate period.<sup>20</sup>

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<sup>20</sup> Somewhat surprisingly, the interaction dummy for capital controls is also negative at  $-0.07$ , and significant at 1 percent, implying that sterilization activity was most intense during the fixed rate/capital controls period (1998-2000); estimated at  $(-0.78 - 0.11 - 0.07)$  or  $-0.96$ , not significantly different from minus 1. It is possible that this period coincided with very volatile capital flows, that both heightened sterilization intensity and prompted BNM to impose the selective capital controls.

**TABLE 4: ESTIMATED MONETARY POLICY REACTION FUNCTION**

Dependant variable: $\Delta NDA$		
Method: 2SLS		
Sample: March 1991 – October 2009		
No. of observation: 224		
Instrumental Variable : $\Delta NDA_{t-1}, \Delta NFA_{t-1}, IPI_{t-1}, \Delta P_{t-1}, \Delta TB_{t-1}, \Delta(r_t + E_t S_{t+1})_{t-1}, \Delta sp_t, \Delta sp_{t-1}, (d_1-1)vi_{t-1}, (d_2-1)vex_{t-1}, duec * \Delta NDA_{t-1}, dfixer * \Delta NFA_{t-1}, du93, \Delta(\Delta sp_{t-1}), \Delta(\Delta sp_{t-2})$ ,		
Variable	Coefficient	Standard error (t-stat)
constant	-0.003939	0.005223 (-0.754068)
$\Delta NFA_t$	-0.779448	0.033436 (-23.31173)***
$\Delta NDA_{t-1}$	-0.125081	0.033228 (-3.764330)***
$\Delta NFA_{t-1}$	-0.269096	0.085251 (-3.156517)***
$IPI_{t-1}$	-0.000191	0.000328 (-0.580748)
$\Delta P_{t-1}$	0.004761	0.001960 (2.428411)**
$\Delta TB_{t-1}$	-0.007962	0.186371 (-0.042720)
$\Delta(r_t + E_t S_{t+1})_{t-1}$	0.015586	0.010915 (1.427870)
$\Delta sp_t$	-0.000304	0.000993 (-0.305876)
$\Delta sp_{t-1}$	0.000210	0.000140 (1.494512)
$(d_1-1)vi_{t-1}$	-0.081962	0.036609 (-2.238836)**
$(d_2-1)vex_{t-1}$	0.003862	0.002328 (1.659122)
$duec * \Delta NFA_{t-1}$	-0.068492	0.006387 (-10.72388)***
$dfixer * \Delta NFA_{t-1}$	-0.112360	0.041832 (-2.685996)***
$R^2 = 0.832610$	Adjusted $R^2 = 0.822247$	
SE of regression	0.072813	

## 5.5. LONG-RUN STERILIZATION COEFFICIENTS

Table 4 shows that the lagged terms for the change in NFA (- 0.27) and the change in NDA (- 0.13) are significant at 1 percent. The long-run sterilization coefficient under managed float thus increases to  $(- 0.78 - 0.27)/(1.13)$  or  $- 0.93$  (93 percent). Under fixed rates/no capital controls the long-run coefficient rises to  $(- 0.78 - 0.11 - 0.27)/(1.13)$  or minus 1, suggesting that BNM attempted to sterilize completely changes in NFA during this fixed rate period. This attempt of BNM is particularly noteworthy here because as noted above the long-run offset coefficient during this period is also not significantly different from minus one which implies that BNM had no long run control over monetary policy in 2000-2005.

Thus, it was unlikely that BNM succeeded in achieving its monetary targets via full sterilizations--in the sense of chasing after a constantly vanishing target--because its efforts would be completely offset through the capital account. However, the data do suggest that BNM was not deterred and intensified its efforts, which led to very substantial accumulations of NFA. Again, these long-run results are consistent with the scissors-shaped observations from Figure 1. While BNM did not offer this as the reason, these results also suggest plausibly that BNM switched out of fixed exchange rates back to managed floating in July 2005, perhaps, as part of a desire to regain a greater measure of monetary control and policy independence.

## 5.6. OTHER ESTIMATES

Table 4 shows that the only significant coefficient estimate (at 5 percent) is that for the interest volatility variable. An increase in previous period interest volatility leads to BNM intervention to reduce the volatility. This is in line with one of the policy objectives frequently indicated by BNM. Quite surprisingly, the coefficient for exchange volatility is insignificant at 5 percent and has the wrong sign. All the other independent variables in the reaction function were also not significant at 5 percent.

## 6. CONCLUSIONS AND POLICY IMPLICATIONS

The last two decades were a very volatile and difficult period for BNM, an emerging market central bank, and its monetary policy. Surges in volatile capital flows prompted BNM to impose different exchange/capital regimes and to sterilize heavily to maintain monetary control. This paper uses monthly data from this rich and diverse period to examine empirically whether BNM succeeded in maintaining monetary control through the myriad shocks and regime changes. In particular, it aims to assess whether BNM has been able to escape the constraints of the Impossible Trinity.

Using a modified theoretical model of BGT (2002), the paper's estimates of offset and sterilization coefficients indicate that BNM has short-run monetary control but loses monetary control in the long run under a regime of fixed exchange rates and open capital account. In particular, the short-run (same period) offset coefficient indicates that about 56 percent of changes in net domestic assets are offset under managed floating; and about 85 percent offset under fixed rates/open capital account. While these offsets are sizable, they are both significantly less than unity, suggesting that BNM has some measure of monetary control in the short-run, most likely reflecting imperfect capital mobility or less than instantaneous portfolio re-adjustments.

In the long run, however, the offset coefficient increases to 73 percent (still significantly less than 100 percent) under managed float; but 95 percent (*not* significantly different from 100 percent) under fixed rates/open capital account. BNM thus loses monetary control in the longer run under fixed rates/open capital because changes in BNM's NDA are fully offset in that regime over time. The paper thus concludes that Malaysia is not exempted from the Impossible Trinity.

The estimated short-run sterilization coefficients are also sizable--78 percent under managed floating; and 89 percent under fixed rates/open capital account, indicating that BNM engaged heavily in sterilizing capital flows throughout the period. In the long run, the coefficient rises to 93 percent under managed floating; but 100 percent under fixed rates. These long run results indicate persistence in BNM sterilizations, including an increase in intensity under fixed rates, when BNM strove to sterilize capital flows fully over time.

An interesting implication here is that BNM's attempts at full sterilizations were likely not successful in hitting its monetary targets---in the sense of chasing a constantly vanishing target--because the long-run offset coefficient under this regime, as noted, was also 100 percent; implying a loss of monetary control for BNM. These attempts, however, are consistent with our open-scissors graph in Figure 1, which shows tightening NDA and rising net NFA accumulations during the fixed rate period. Thus, even if BNM was unsuccessful in longer-term monetary control, it ended up accumulating huge amounts of foreign exchange reserves under fixed rates. Perhaps the inability to escape the Impossible Trinity in the longer run explains in part why Malaysia eventually abandoned its fixed rate regime and moved back to managed floating on 20 July 2005.

BNM's general success in monetary management during the turbulent period under study offers hope for other emerging markets faced with similar problems. Buffeted by the adverse effects of one regional, and then later, an international financial crisis, BNM guided Malaysia towards an average inflation rate of 2.9 percent annually in 1991-09, while real GDP growth averaged 5.9 percent. Although sterilization has often been dismissed or viewed skeptically as a long-term instrument, BNM's success in restraining excessive money creation and containing inflation via intensive sterilization over two decades suggests that sterilization may be a more effective policy instrument than commonly expected.

Although it is true that Malaysia could not escape the Trinity's constraints-- because sterilization's effectiveness was undercut by a full offset coefficient—a switch to managed floating could restore sterilization's effectiveness. Thus, a possible lesson from the Malaysian experience in 1991-09 is that a managed float (that offers an escape from the Trinity) combined with active sterilization could be a viable strategy for emerging economies faced with volatile capital flows. In addition, under very adverse situations, short-term selective capital controls could also be justified. The viability of managed floating and sterilization is also consistent with recent research by Aizerman et al (2008) that finds emerging markets trending towards intermediate regimes as opposed to the old polar regimes of either free float and fixed rates.

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### APPENDIX 1: DESCRIPTION OF VARIABLES USED IN THE EMPIRICAL STUDY

Variables	Definitions	Measured as	Source
$\Delta NFA_t$	The change in net foreign assets (NFA) scaled by reserve money (RM) from the previous period	$\Delta NFA_t / RM_{t-1}$	IFS
$\Delta NDA_t$	The change in net domestic assets (NDA) scaled by reserve money (RM) from the previous period	$\Delta NDA_t / RM_{t-1}$	IFS
$\Delta TB_t$	The change in trade balance scaled by reserve money (RM) from the previous period	$\Delta TB_t / RM_{t-1}$	IFS
$\Delta P_t$	Year-on-year change of the inflation rate	$\frac{CPI_t - CPI_{t-12}}{CPI_{t-12}} * 100$	IFS
$IPI_t$	Year-on-year change of the industrial production index	$\frac{IPI_t - IPI_{t-12}}{IPI_{t-12}} * 100$	IFS
$\Delta sp_t$	Percentage change in the stock index	$sp_t - sp_{t-1} / sp_{t-1} * 100$	IFS
$\Delta r_t^*$	The change in foreign interest rate	$r_t^* - r_{t-1}^*$	IFS
$\Delta E_t S_{t+1}$	The expected change in nominal exchange rate depreciation (RM/US)	$\frac{s_{t+1} - s_t}{s_t}$ if perfect foresight	IFS
$\sigma_{ex}$	Volatility of exchange rate	The standard deviation of the daily exchange rate, RM/\$	Datastream
$\sigma_r$	Volatility of domestic interest rate	The standard deviation of the daily overnight rate	Datastream
$d_1$	Dummy variable for $\Delta NDA_t < 0$	$d_1 = 2$ if $\Delta NDA_t < 0$ ; $= 0$ if $\Delta NDA_t > 0$	
$d_2$	Dummy variable for $\Delta NFA_t < 0$	$d_2 = 2$ if $\Delta NFA_t < 0$ ; $= 0$ if $\Delta NFA_t > 0$	

## APPENDIX 2: THE CUMBY & OBSTFELD METHOD ON THE ADJUSTED MONETARY BASE

The adjusted monetary base is defined as follows:

$$RMA_t/q_0 = RM_t/q_t$$

where  $RMA_t$  = adjusted monetary base;  $RM_t$  = unadjusted monetary base;  $q_0$  = base period reserve ratio; and  $q_t$  = current reserve ratio.

From the equation above, we see that  $RMA_t$  is the base that would support a level of money supply equal to  $RM_t/q_t$  if the reserve ratio remains at  $q_0$ , i.e., had not been changed. In other words, instead of changing the reserve ratio from  $q_0$  to  $q_t$ , the central bank could essentially have obtained the same monetary policy effect by changing the base to  $RMA_t$  and maintaining the reserve ratio at  $q_0$ . We can write the change in the adjusted base as in Equation (1a):

$$\begin{aligned} \Delta RMA_t &= \frac{q_0}{q_{t-1}} (\Delta NFA_t + \Delta NDA_t + \Delta RM_t^*) \\ &= \frac{q_0}{q_{t-1}} \Delta NFA_t + \frac{q_0}{q_{t-1}} \Delta NDA_t + \frac{q_0}{q_{t-1}} \Delta RM_t^* \end{aligned} \quad (1a)$$

and

$$\begin{aligned} \Delta RM_t^* &= \left[ \frac{(q_{t-1} - q_t)}{q_t} \right] RM_t \\ &= \left[ \frac{q_{t-1}}{q_t} - 1 \right] RM_t \end{aligned} \quad (2b)$$

where  $\Delta RM_t^*$  is the increase in the unadjusted base that would, at reserve ratio  $q_{t-1}$ , bring about the same increase in the money supply as would a reduction in the reserve ratio from  $q_{t-1}$  to  $q_t$  keeping the unadjusted base  $RM_t$  unchanged; where  $RMA_t$  is the adjusted base at time  $t$ ,  $q_0$  is the base -period reserve ratio,  $q_t$  is the current reserve ratio,  $RM_t$  is the unadjusted base,  $\Delta NFA_t$  is the change in net foreign asset at time  $t$  (adjusted for exchange rate revaluation),  $\Delta NDA_t$  is the change in net domestic assets at time  $t$  (adjusted for exchange rate revaluation).

Substitute (1b) into (1a) yields:

$$\begin{aligned}
 \Delta RMA_t &= \frac{q_0}{q_{t-1}} \Delta NFA_t + \frac{q_0}{q_{t-1}} \Delta NDA_t + \frac{q_0}{q_{t-1}} \Delta RM_t^* \\
 &= \frac{q_0}{q_{t-1}} \Delta NFA_t + \frac{q_0}{q_{t-1}} \Delta NDA_t + \frac{q_0}{q_{t-1}} \left[ \frac{q_{t-1}}{q_t} - 1 \right] RM_t \\
 &= \frac{q_0}{q_{t-1}} \Delta NFA_t + \frac{q_0}{q_{t-1}} \Delta NDA_t + \left[ \frac{q_0}{q_t} - \frac{q_0}{q_{t-1}} \right] RM_t
 \end{aligned} \tag{1c}$$

The last two terms on the RHS of Equation(1c) combine to give the change in NDA that has been adjusted to take into account reserve ratio changes; this fully adjusted change in NDA is the dependent variable of the central bank reaction function. Equation (1c) says that the change in the adjusted base is equal to the change in NFA [adjusted by  $q_0/q_{t-1}$ ] plus the change in the fully adjusted NDA.