THE DETERMINANTS OF FOREIGN RESERVES IN NIGERIA
DETERMINANTS OF FOREIGN RESERVES IN NIGERIA

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This research work is dedicated to God Almighty.
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I will not stop thanking God Almighty for his grace and mercies.

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Abstract

Foreign exchange reserves’ adequacy is a key component of good macroeconomic management. Foreign reserves can be used to smoothen exchange rate volatility in illiquid foreign exchange markets. This study adopts a modified version of buffer stock model to analyze the determinants of Nigeria’s foreign reserves. Using annual time series data from 1970 to 2009, the study regresses international reserve variable on macroeconomic variables: real income, interest rate differential (a measure of opportunity cost), exchange rate volatility, financial openness, openness to trade (a measure of current account vulnerability), benchmark stock of reserves, and the demand for foreign exchange. In order to avoid any spurious regression results, the time series data was subjected to stationarity tests. The ADF - cointegration procedure was used to examine if there exists any potential long run relationships. The result indicates that the variables are cointegrated together. Hence, the short run dynamics was examined by means of an error correction model. The empirical evidence shows that growth in Nigeria’s foreign reserves is not influenced in the long run by trade openness (Top), the opportunity cost of holding reserves (DID) and the benchmark stock of reserves but by other determinants such as the real Gross Domestic Products (Y), exchange rate volatility (Ev), financial openness (Fop), and the demand for foreign exchange (DFex). Further, in the short run, growth in Nigeria’s foreign reserves is only not influenced by trade openness (Top), but by other determinants such as real Gross Domestic Products (Y), exchange rate volatility (Ev), financial openness (Fop), the demand for foreign exchange (DFex), the opportunity cost of holding reserves (DID), the benchmark stock of reserves (DFr*), and the error correction mechanism (ECM (-1)). It is also found that both in the long run and short run, the opportunity cost of holding reserves is about 2.5%, and about 6.0%. However, since the risk in reserve holding both in the long and short run is very low, management strategies that will aid in more reserve accumulation should be reconsidered by Nigerian government. More so, since in the long run the benchmark stock of reserves does not affect Nigeria’s foreign reserves (but does affect it in the short run), Nigerian government should make sure that adequate amount of reserves must be kept at all times (not only in the short run but also, in the long run) to help smooth the volatility in exchange rate. Finally, the study also found that there exists a disparity between foreign reserves (Fr) and the benchmark stock of reserves (Fr*) hence, Nigerian government should adopt management strategies that will equilibrate the two of them at least, in the short run.

Keywords: Foreign, Exchange, Reserves, Volatility, Determinants, Buffer, Stock, Variable, Macroeconomic, Benchmark, Spurious, regression, Stationarity, Cointegration, Long-run, Short-run, Error Correction.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title page</td>
<td>i</td>
</tr>
<tr>
<td>Approval page</td>
<td>ii</td>
</tr>
<tr>
<td>Dedication</td>
<td>iii</td>
</tr>
<tr>
<td>Acknowledgement</td>
<td>iv</td>
</tr>
<tr>
<td>Abstract</td>
<td>v</td>
</tr>
<tr>
<td>Table of contents</td>
<td>vi</td>
</tr>
<tr>
<td>CHAPTER ONE: INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>1.1 Background of the Study</td>
<td>1</td>
</tr>
<tr>
<td>1.2 Statement of the Problem</td>
<td>7</td>
</tr>
<tr>
<td>1.3 Objective of the Study</td>
<td>8</td>
</tr>
<tr>
<td>1.4 Statement of the Hypothesis</td>
<td>9</td>
</tr>
<tr>
<td>1.5 Justification of the Study</td>
<td>9</td>
</tr>
<tr>
<td>1.6 Policy relevance</td>
<td>9</td>
</tr>
<tr>
<td>1.7 Scope of the Study</td>
<td>10</td>
</tr>
<tr>
<td>CHAPTER TWO: LITERATURE REVIEW</td>
<td>11</td>
</tr>
<tr>
<td>2.1 Theoretical literature</td>
<td>11</td>
</tr>
<tr>
<td>2.1.1 Revived Bretton Woods System and Export Promotion</td>
<td>11</td>
</tr>
<tr>
<td>2.1.2 Precautionary Motives</td>
<td>11</td>
</tr>
<tr>
<td>2.1.3 The Monetarist or Classical Views</td>
<td>12</td>
</tr>
<tr>
<td>2.1.4 Keynesian View on International Reserves</td>
<td>13</td>
</tr>
<tr>
<td>2.1.5 A Three-Period Model of Optimal Reserves Allocation</td>
<td>14</td>
</tr>
<tr>
<td>2.2 Empirical Literature</td>
<td>14</td>
</tr>
<tr>
<td>2.3 Limitations of Previous Studies</td>
<td>20</td>
</tr>
<tr>
<td>CHAPTER THREE: METHODOLOGY</td>
<td>23</td>
</tr>
<tr>
<td>3.0 Monetary Approach to Balance of Payments and Exchange Rate Determination</td>
<td>23</td>
</tr>
<tr>
<td>3.1 Model Specification</td>
<td>25</td>
</tr>
<tr>
<td>3.2 Pre-Estimation tests</td>
<td>30</td>
</tr>
<tr>
<td>3.2.1 Unit-Root test</td>
<td>30</td>
</tr>
<tr>
<td>Section</td>
<td>Title</td>
</tr>
<tr>
<td>---------</td>
<td>-------</td>
</tr>
<tr>
<td>3.2.2</td>
<td>Cointegration test</td>
</tr>
<tr>
<td>3.3</td>
<td>Statistical tests</td>
</tr>
<tr>
<td>3.3.1</td>
<td>R²</td>
</tr>
<tr>
<td>3.3.2</td>
<td>The t – test</td>
</tr>
<tr>
<td>3.3.3</td>
<td>The F – test</td>
</tr>
<tr>
<td>3.4</td>
<td>Econometric Procedure (Tests)</td>
</tr>
<tr>
<td>3.4.1</td>
<td>Test for Multicolinearity</td>
</tr>
<tr>
<td>3.4.2</td>
<td>Test for Autocorrelation</td>
</tr>
<tr>
<td>3.4.3</td>
<td>Test for Normality</td>
</tr>
<tr>
<td>3.4.4</td>
<td>Test for Heteroscedasticity</td>
</tr>
<tr>
<td>3.4.5</td>
<td>Regression Specification Error Test</td>
</tr>
<tr>
<td>3.5</td>
<td>Data</td>
</tr>
<tr>
<td>3.6</td>
<td>Definition of Model Variables</td>
</tr>
<tr>
<td>4.1</td>
<td>Presentation of Battery/Pre-Estimation tests</td>
</tr>
<tr>
<td>4.2</td>
<td>Presentation of Regression Results</td>
</tr>
<tr>
<td>4.3</td>
<td>Evaluation of Results</td>
</tr>
<tr>
<td>4.3.1</td>
<td>Economic (A Priori) Criteria</td>
</tr>
<tr>
<td>4.3.2</td>
<td>Statistical Criteria</td>
</tr>
<tr>
<td>4.4</td>
<td>Econometric Procedure (Tests)</td>
</tr>
<tr>
<td>4.4.1</td>
<td>Test for Multicolinearity</td>
</tr>
<tr>
<td>4.4.2</td>
<td>Test for Autocorrelation</td>
</tr>
<tr>
<td>4.4.3</td>
<td>Test for Heteroskedasticity</td>
</tr>
<tr>
<td>4.4.4</td>
<td>Normality Test</td>
</tr>
<tr>
<td>4.4.5</td>
<td>The Specification Error Test</td>
</tr>
</tbody>
</table>
4.5 Evaluation of Working Hypotheses ....................................................... 46

CHAPTER FIVE: SUMMARY, CONCLUSION AND POLICY IMPLICATIONS....... 50

5.1 Summary ................................................................................. 50

5.2 Conclusion ............................................................................... 51

5.3 Policy Implications/Recommendation ........................................... 52

REFERENCES .................................................................................. 54

APPENDIX ......................................................................................... 59
CHAPTER ONE
INTRODUCTION

1.1 Background of the Study

Foreign exchange reserves (also called Forex reserves) in a strict sense are only the foreign currency deposits and bonds held by central banks and monetary authorities. But it is more accurately termed official international reserves or international reserves. These are assets of the central bank held in different reserve currencies, mostly the US dollar, and to a lesser extent the Euro, the UK pound, and the Japanese yen, and used to back its liabilities, e.g. the local currency issued, and the various bank reserves deposited with the central bank, by the government or financial institutions (CBN 2010).

IMF(2003) defined international reserves as “consisting of official public sector foreign assets that are readily available to, and controlled by the monetary authorities, for direct financing of payment imbalances, and directly regulating the magnitude of such imbalances, through intervention in the exchange markets to affect the currency exchange rate and/or for other purposes”.

Eichengreen and Adalet(2005), affirmed that in recent decades, currency and/or financial crises accompanied by reversals in capital flows have become more frequent and severe. Therefore, with increased financial integration, countries are more vulnerable to contagion from within and outside their regions. Consequently, central banks in developing countries have accumulated reserves to cushion extreme events, the bunching of external debt maturities, or other shocks that could affect the foreign exchange market and the domestic economy. Central banks also hold reserves to back a peg or managed exchange rate system.

Calvo and Reinhart (2002), Reinhart and Rogoff, (2004) affirmed that countries classified as having a free or a managed float often resemble pegs, a “fear of floating” appears to be pervasive. Choi and Cook (2004) argued that this is true for countries with dollarized liabilities. To soften local currency volatility, central banks use reserves even in the absence of severe shocks. As a result of this, Foreign exchange reserves have clear implications for exchange rate stability, financial markets and hence for overall economic activity.
Note worthy here is that there have been divergent views about reserves holding. Some economists argue that foreign exchange reserves are useless and unutilized, while others argue that reserve holding is necessary to help smooth balance of payments imbalances (Friedman 1953, Kemal 2002). Friedman (1953) criticized the fixed exchange rate system with the argument that it contains unutilized foreign exchange reserves while, Kemal (2002), argues that foreign exchange reserves should be there to smooth out the imbalances in balance of payments. Therefore, it is believed that the concern of the critics of reserve holdings is about the cost of holding reserves which is the investment that the nations must forego in order to accumulate reserves.

However, the supporters of reserve holdings argue that the cost of reserves holding is small compared to the economic consequences of exchange rate variations. For example, depreciation in the value of the currency, caused by either financial crises or other internal or external shocks, may increase a country’s costs of paying back debt denominated in foreign currency as well as its costs of imported items. Furthermore, it also creates high inflation expectations. Choi and Cook (2004), and Frankel (2005), confirmed that many of the currency and financial crises of the last ten years have been associated with the contractionary effects of currency depreciation, with substantial output losses, especially through balance sheet channels. It is pertinent to put down here that, with adequate amount of reserves, monetary authorities can intervene at the appropriate times to help maintain the value of the domestic currency.

Landell-Mills (1989), suggests that the rationale for holding reserves include the following: Financing external imbalances, intervening in foreign exchange markets, and providing a buffer to cushion the economy against future exigencies or emergencies. However, in the past few years, reserve accumulation has mainly been associated with emerging Asian economies following the Asian financial crisis of the early 1990’s.

Today, it has become a global phenomenon traversing oil exporting nations and other non renewable resource dependent economies. In Nigeria, the period beginning from the later end of 1999 marked a turning point from a hitherto culture of fiscal indiscipline characterized by frivolous spending to a new dawn of prudent consumption and saving. Hence, this can be seen from her extraordinary accumulation in the level of reserves from USD 4.98 billion in May 1999 to USD 59.37 billion and USD40.48 billion as at March, 2007 and 2010 respectively (CBN 2007, 2010).

According to Magnus (2007), these robust domestic economic performances were occasioned by macroeconomic fundamentals like internal reforms, complemented by
favourable external conditions like the persistent and unprecedented rise in crude oil prices joined with drastic decline in external obligations like debt service.

According to Central Bank of Nigeria, the Sources of Nigeria’s external reserves are derived mainly from the proceeds of crude oil production and sales.

Other sources of external reserves in Nigeria include: income from Investing foreign reserves, repatriation of unutilized Wholesale Dutch Auction System (WDAS), interest on WDAS Accounts held by Deposit Money Banks, WDAS Purchases, Inward Money Transfer, Value Added Tax (VAT), Education Tax, Commission, etc.

These can be shown in the diagram given below:

![Diagram of Sources of Reserves](image)

*Source: Foreign Operations Department, Central Bank of Nigeria*

The data given by CBN (2010) indicates that the trend of foreign reserves in Nigeria has been fluctuating overtime. For instance, foreign reserves in Nigeria averaged USD 756.4 billion between the periods 1970 to 1974. More so, in Nigeria, the foreign reserves between 1975 and 1979 averaged USD 2650.2 billion. This indicates a rise in foreign reserve. But between 1980 and 1984, foreign reserves in Nigeria dropped to USD 2164.48 on the average. Also, the average foreign reserve in Nigeria between 1985 and 1989 is USD 5320.32 billion, indicating a rise in reserve accumulation. Furthermore, from 1990 to 1994, there was a significant rise in foreign reserves on the averaged to about USD 38179.34 billion. Moreover, Nigerian foreign reserves rose to USD 325051.8 billion between 1995 and 1999 on the average, indicating a sharp rise in foreign reserves. The reserve further rose to USD 1805737 on the average between the year 2000 and 2004. The increase in this foreign reserve was due
to improvements in the overall performance of the economy. Finally, between the year 2005 and 2009, the foreign reserve position of Nigeria averaged USD 6060636 billion.

On the same data by CBN (2010), the trend of real income in Nigeria has also not been steady. Between 1970 and 1974 average level of real income is shown to be USD 7011.4 billion. Between 1975 and 1979, real income in Nigeria averaged USD 29399.84 billion. This shows a rise in real income in Nigeria. But between 1980 and 1984, there was a sharp rise in Nigeria’s real income to about USD 161123.1 billion on the average. It also averaged USD 213683.9 billion between 1985 and 1989, also indicating a sharp increase in accumulation of real income. Further, from 1990 to 1994, it also increased on the averaged to USD 270915.7 billion. Nigeria’s real income rose also to USD 300049.8 billion between 1995 and 1999 on the average. Between the year 2000 and 2004, the real income of Nigeria averaged USD 424897.1 billion. Also, between the year 2005 and 2009, it further rose on the average to USD 636231.3 billion.

On financial openness, CBN (2010) showed that its trend in Nigeria is also not stationary. For example, from 1970 to 1974, financial openness averaged 2.9%. Between 1975 and 1979, it reduces to about 2.3% on the average. Financial openness in Nigeria rose further to about 14% on the average between 1980 and 1984. From 1985 to 1989, it also averaged about 77.6%. More so, from 1990 to 1994, it further increased to about 96.7% on the average but thereafter, it decreased on the average to about 37% between 1995 and 1999. From the year 2000 to 2004, financial openness of Nigeria averaged 57.4%, marking an increase in Nigeria’s financial openness. Finally, between 2005 and 2009, Nigeria’s financial openness decreased a bit and averaged 54.8%.

The trend of trade openness of Nigeria has also not been stable as shown by CBN (2010). From 1970 to 1974, the trade openness of Nigeria averaged 36.2%. Between 1975 and 1979, it increased to about 43.3% on the average. Trade openness in Nigeria decreased to about 38.7% on the average between 1980 and 1984 but, from 1985 to 1989, it also decreased further and averaged 34.7%. However, from 1990 to 1994, it increased to about 57.6% on the average but after this period, it rose on the average to about 70.9% between 1995 and 1999. Trade openness in Nigeria from the year 2000 to 2004 averaged about 59.6%, marking a decrease in Nigeria’s trade openness. Moreover, between 2005 and 2009, Nigeria’s trade openness in Nigeria increased a bit and averaged about 60.7%.
The rate at which exchange rate fluctuates has not been relatively stable as CBN (2010) shows. For instance, between 1970 and 1974, exchange rate of Nigerian Naira per US Dollar averaged about NGA 0.671 but between 1975 and 1979, it averaged about NGA 0.618. Further, between 1980 and 1984, the exchange rate of Nigerian Naira per US Dollar averaged about NGA 0.664 but between 1985 and 1989, it increased to about NGA 3.77 on the average. This may be as a result of the introduction of the Structural Adjustment Programme (SAP) in 1986. From 1990 to 1994, it further increased to NGA 15.8 on the average. It further averaged NGA 36.05 between the periods 1995 and 1999. It continued to increase on the average to NGA 119.6 from 2000 to 2004 and, finally to NGA 130.8 on the average between the periods 2005 and 2009.

On the interest rate differential, the trend has been relatively stable from 1970 to 1974, between 1975 and 1979, between 1980 and 1984, and between 1985 and 1989 as the data given by CBN (2010) shows. The average Nigerian interest rate differential from 1970 to 1974, between 1975 and 1979, between 1980 and 1984, and between 1985 and 1989 are, 3%, 3.3%, 3.1% and 3.41% respectively. But between 1990 and 1994, it increased to about 4.35% on the average. It further increased on the average to about 5.27% between 1995 and 1999. It continued increasing on the average to about 5.59% from the year 2000 to 2004. Thereafter, it rose further to 10.44% between 2005 and 2009.

On the benchmark stock of reserves, its trend is depicts that it also fluctuates. The benchmark stock of Nigeria’s reserves averaged USD 2795.122 billion between the periods 1970 to 1974. More so, it rose to USD 6466.245 between 1975 and 1979 on the average. But it decreased to USD 6264.89 (i.e. -6264.89) billion on the average between 1980 and 1984, it dropped further to USD 58808.2 (-58808.2) billion on the average between 1985 and 1989. Further, it dropped to USD 78138.5 billion (-78138.5) from 1990 to 1994. There was a significant rise in the benchmark stock of reserves on the averaged to about USD 420796.1 billion between 1995 and 1999. Moreover, it rose to USD 2335359 billion on the average, indicating a sharp rise in benchmark stock of reserves on the average, between the year 2000 and 2004. Finally, benchmark reserve further rose to US 5618291 between the year 2005 and 2009 on average.

On the same data by CBN (2010), the trend of demand for foreign exchange in Nigeria has also been relatively stable from 1970 to 1974, between 1975 and 1979, between 1980 and 1984, and between 1985 and 1989 as the data shows. The average Nigerian foreign
exchange demand from 1970 to 1974, 1975 to 1979, 1980 to 1984, and from 1985 to 1989 are, USD 100633.4, USD 100633.4, USD 100631.7 and 100688.3 billion respectively. But between 1990 and 1994, it increased to about USD 98876.48 billion on the average. It further increased on the average to about USD 197553.8 billion between 1995 and 1999. It continued increasing on the average to about USD 750251.2 billion from the year 2000 to 2004. Thereafter, it dropped to USD 96014.19 billion between 2005 and 2009.

The graph given below summarises the trend of all the variables.

Fr represents foreign reserves, Y represents real income, Fop represents financial openness, Top represents trade openness, Ev represents exchange rate volatility, Id represents interest rate differential, Fr* represents benchmark stock of reserves, while DFEX represents demand for foreign exchange. From the graph above, it can be seen that from years 1 to 27, all the variables remained relatively stable but thereafter, they started increasing and fluctuating. But the magnitude of increase is higher in Fr* and DFEX.

Moreover, with strong justification being provided by the proponents of reserves holding and the fact that the management of the external imbalance has been one of the most serious problems faced by the governments of developing countries including Nigeria, it is essential to analyze further the determinants of international reserves and also examine the link between macroeconomic performance and reserve accumulation in Nigeria.
1.2 Statement of the Problem

It is the desire to investigate the factors that determine international reserves in Nigeria that has led in the interest to carry out this research. Foreign exchange reserves adequacy is a key component of good macroeconomic management. Foreign exchange reserves can be used to smooth random and temporary balance of payments shocks to maintain exchange rate parity, avoid the macroeconomic costs of adjustment to temporary shocks, and smooth adjustment to the macroeconomic impact of some permanent shocks. Further, Foreign reserves can also be used to smooth exchange rate volatility in illiquid foreign exchange markets.

Prior to now, Nigeria operated the controlled system of exchange rate and therefore, needed to keep high amount of reserves in order to maintain the exchange rate at a pegged level. But later, she witnessed some flexibility in the exchange rate market. Currently, Nigeria is operating the managed-float system which means that the Central Bank of Nigeria (CBN) should intervene occasionally in the exchange rate market to prevent excessive short-term exchange rate volatility. However, for the Central Bank to perform this role effectively, adequate amount of reserves should be kept at all times.

It is observed here that Nigeria's international reserves have not been stable over the years. Some increases have been recorded but, they have not been sustainable. The reserve position of Nigeria has continuously seen some improvements since the year 1999. The Gross International Reserves of Nigeria rose from USD 4.98 billion in May 1999 to USD 59.37 billion as at March 28, 2007. According to Magnus (2007), these robust domestic economic performances were occasioned by macroeconomic fundamentals like internal reforms, complemented by favourable external conditions like the persistent and unprecedented rise in crude oil prices joined with drastic decline in external obligations like debt service.

According to the reports of the News Agency of Nigeria (2009), the foreign reserve rose to about 67 billion US dollars in mid-2008, reflecting the high demand and pricing of the crude oil in the international market, but began a free fall in the third quota of the year. However, by December 2008, Nigeria’s foreign reserve dropped to US$59 billion. Xinhua (2009), states that Nigeria's foreign reserve dropped further to US$48 billion in mid-2009. The fall in Oil prices brought a downward swing in foreign reserve of Nigeria and has continued, thereby, making the Central Bank of Nigeria (CBN) to put the country's current reserve at 48 billion US dollars, indicating a 19-billion dollar fall since mid-2008. This is because, Crude Oil is the main foreign exchange earner of Nigeria.
Moreover, CIA World Fact Book (2010), states that Nigeria’s current reserve also dropped further to 46.54 billion US dollars as at ending of December, 2009. CBN (2010), also confirmed Nigeria’s international reserves to have dropped further to USD40.48 billion as at March 2010. Nigeria’s international reserves fell down further to $36.7 billion the earlier month of October 2010, CBN said. Olukoya (2010), asserted that Nigeria’s foreign exchange reserves dropped again by 7.6 percent (i.e. to US$33.9 billion) in the month end of Oct. 2010, according to data on the Central Bank of Nigeria website, as the bank sold dollars to prop up the value of the naira. “The foreign reserve was partially depleted because the government struggled to meet huge foreign exchange demands at its twice-weekly foreign-exchange market in September”. As at October 7, 2011, the reserves stood at US$30.8 billion after shuttling between $31 billion and $32 billion, on September 26 and October 6. But, as at December 7, 2011, the nation’s foreign reserves rose to US$32.98 billion.

It is pertinent to note here that the decline in reserves increased the risk to the economy from any renewed drop in oil prices. Therefore, it can be argued that “the outlook is very bleak if our foreign reserves continue to deplete at this rate; there will be a time when nothing will be left to cover our imports”.

However, given the background above, it is observable that the management of the external imbalance has been one of the most serious problems faced by the governments of developing countries including Nigeria. The questions that readily come to mind and need to be addressed are:

(i) What are the factors that have accounted for the changes in Nigeria’s international reserves?
(ii) What is the opportunity cost of holding the reserves?
(iii) To what extent do Nigeria’s international reserves depart (vary) from the benchmark stock of reserves?

1.3 Objectives of the Study

The principal objective of this study is to analyze the determinants of international reserves in Nigeria.

Further, the specific objectives are:
• To determine factors responsible for changes in Nigeria’s international reserves.
• To evaluate the opportunity cost of holding reserves.
• To examine the extent to which Nigeria’s international reserves depart from the benchmark stock of reserves.

1.4 Statement of Hypothesis

There is need for hypothesis in order to shape the research work. Therefore, this is the core of the various aspects of the problem being studied so that the results obtained should either support or refute the arguments advanced.

Consequently, the hypotheses of the study are here under as follows:

❖ There is (are) no determinant factor(s) responsible for changes in Nigeria’s international reserves.
❖ High opportunity cost is associated with a low level of reserve holdings.
❖ Nigeria’s international reserves do not depart (vary) from the benchmark stock of reserves.

1.5 Justification of the Study

Large reserves of foreign currency allow a government to manipulate exchange rates - usually to stabilize the foreign exchange rates to provide a more favourable economic environment. In theory, the manipulation of foreign currency exchange rates can provide the stability that a gold standard provides, but in practice this has not been the case. Further, the greater a country's foreign reserves, the better position it is in to defend itself from speculative attacks on the domestic currency.

In addition, there are costs in maintaining large currency reserves. Fluctuations in exchange markets result in gains and losses in the purchasing power of reserves. Even in the absence of a currency crisis, fluctuations can result in huge losses. However, it is pertinent to put here that foreign exchange reserves are important indicators of ability to repay foreign debt, and for currency defence, and hence, relevant in determining credit ratings of nations.

1.6 Policy Relevance

Notwithstanding the importance of international reserves, at the time of this research, no serious attempt has been made to work on the determinants of international reserves in
Nigeria’s case. Consequently this study, aims at bridging the research gap by revealing the determinants of international reserves in Nigeria.

More so, this research work will inform policy makers on the policy direction to take so as to ensure a sustained increase in the reserve holdings of the country. It will also enable the managers of the Nigerian economy to smooth any balance of payments shocks that the economy may experience. Finally, the research work will also be useful as a reference point to future researchers especially, those interested in international reserves.

1.7 Scope of the Study

This work shall use Secondary data spanning a period of 40 years (that is from 1970 to 2009). The choice of this study period is because of data availability.
CHAPTER TWO
LITERATURE REVIEW

2.1 Theoretical Literature

2.1.1 Revived Bretton Woods System and Export Promotion

Dooley, Folkerts-Landau, and Garber (2003) posit that the economic emergence of a fixed exchange rate periphery in Asia has re-established the United States as the centre country in the revived Bretton Woods international monetary system. In terms of the Asian countries, i.e. the periphery, development strategy is export-led growth supported by undervalued exchange rates. However, a single-minded emphasis on export growth has been supported by a virtually unlimited demand for U.S. financial assets in the form of official reserves.

Dooley, Folkerts-Landau, and Garber (2004) extend the argument and state that the U.S. deficit, supplies international collateral to the periphery, and international collateral in turn supports two-way trade in financial assets that liberates capital formation in poor countries from inefficient domestic financial markets.

Pertinent to note here is that a rate of exchange that does nothing more than equalize price levels will not necessarily prove to be equilibrium in foreign exchange rate. Foreign trade usually includes capital and unilateral transfer movements, and this theory does not pretend to even-out with them. Adding together, nations produce many commodities that do not enter into international trade, and the prices of those domestic goods obviously cannot be equalized internationally. Furthermore, studies of European prices and exchange rates during inflationary periods indicate that internal price levels are frequently determined by rates of exchange.

2.1.2 Precautionary Motives

Aizenman and Marion (2004) argued that apart from any need to hold reserves for exchange-rate management, countries that face conditional access to global capital markets and costly tax collection will hold precautionary reserves to smooth consumption and distortions intertemporally. This helps to explain, to a large extent, the recent accumulation of reserves in Asian countries in the aftermath of financial crises.

Aizenman and Marion (2004) also state that political instability or corruption could explain why countries decide to reduce the demand for precautionary reserves.
Caballero and Krishnamurthy (2003) add that countries with underdeveloped local securities markets need higher levels of reserves. This is essentially in line with the assumption of conditional access to global capital markets in Aizenman and Marion’s (2004) argument. Aizenman and Lee (2007), state that precautionary motives may lead countries to hoard international reserves in order to mitigate the possible transmission of banking crisis to currency crisis.

However, it is less clear if uncovered interest parity holds. Under uncovered interest parity, the differential in interest rates would equal not only the forward discount, but also the expected rate of future change in the exchange rate. It is hard to measure whether this condition in fact holds, because it is hard to measure investors’ private expectations. One reason uncovered interest parity could easily fail is the existence of an foreign exchange-risk premium. If uncovered-interest parity holds, then countries can finance unlimited deficits by borrowing abroad, so long as they are willing and able to pay the going world rate of return. But if uncovered interest parity does not hold, then countries will find that the more they borrow, the higher the rate of interest they must pay.

2.1.3 The Monetarist or Classical Views

Edwards (1983) states that on the one hand, reserves movement respond to discrepancies between desired and actual reserves and on the other, according to monetary approach to balance of payments, changes in international reserves is related to excess demands or excess supplies of money.

Yin-Wong and Hiro (2006), posit that Johnson and the “global monetarists” argue that excess demand for money (that involves balance of payments surplus) needs to be complimented by an increase in international reserves whereas excess supply of money (balance of payments deficit) leads to a fall in reserve holding. This view is based on the international financial framework under the Bretton Woods system.

De Beaufort and Kapteyn (2001) referred to research on the Early Warning System, including Calvo (1996), and argued that the reserves-to-M2 ratio is a reasonable measure of reserve adequacy. Caballero and Panageas (2004) argue that reserve accumulation is not the best insurance against sudden stops. Lane and Burke (2001), posit that there is no significant association between exchange rate regime and international reserves. Yearger (1984), states that a restored gold standard would not work well and would hardly endure “if it were not accompanied by drastic restraints on government interferences in economic life”.
Aizenman and Lee (2007), state that an unintended consequence of competitive hoarding is excessive reserves, where the competitive gains are dissipated. The inefficiency associated with competitive hoarding may provide the impetus for the formation of institutions that would allow coordination. For example, an “Asian International Reserve Fund” may provide an umbrella institution that would commit the countries to refrain from competitive hoarding.

2.1.4 Keynesian View on International Reserves

To Keynes, the early twentieth century had proven the extent to which nations would resort to currency devaluation as a lever to improve their balance of trade, seldom improving in the process either their own terms of trade or the opportunities inherent in a flourishing and expanding trade network. As balance of payments accounting had become more common, many Western nations had come to believe that unilateral currency devaluation would, in the absence of reciprocal action, improve the terms of trade. It would make a nation's own exports cheaper in terms of foreign currency and would, of course, make imports equally more expensive. It was not uncommon to find, however, the price of imports rising under such an initiative to the point where the aggregate value of imported goods continued to outpace the value of the higher, newly attained level of exports.

Keynes's theoretical insight here was to recognize that in modern industrial economies, monetary policy would simply have little effect in restoring balance through price deflation. It would regulate external balance, instead, by causing unemployment, lower incomes, and decreased imports. He then seized upon the notion that exchange rate mechanism mattered far less than international liquidity. Though gold, the pound sterling, and the U.S. dollar had all proved somewhat useful in attempts at securing substantial international reserves with which to conduct increasing levels of trade, even the highly regarded British and American currencies remained vulnerable to the deflationist tendencies Keynes so abhorred.

However, Robert and Vijay (2010) argue that the fact that the reserves were held mainly in dollars allowed the US to avoid deflation, and instead run a “Keynesian” domestic policy which set the stage for an unsustainable asset and consumption boom. In short, there was a nexus connecting reserve accumulation by China and expansionary monetary and fiscal policy in the US.
2.1.5 A Three-Period Model of Optimal Reserves Allocation

The theory of optimal reserves allocation in an environment exists where governments face rollover risk. This basic model extends to a dynamic framework to provide a theory for the increase in reserves and the pattern of sudden stops in emerging countries as documented by Hur and Kondo (2011). It posits that while interim reserves, interim liquidation, and the interest rate are functions of the aggregate liquidity shock, the rollover policy is a function of both the aggregate state and the individual liquidity shock of an investor. A debt contract is resource feasible. In other words, initial reserves and invested capital cannot exceed the loan amount; and interim reserves and interim payments cannot exceed initial reserves and interim output. Obviously, the main friction here is that the government cannot lend in the interim against the future output from the initial investment. Hence, liquidation and reserves are the only resources available to make interim payments. Similarly, final output and residual reserves are the only resources available to make final payments. The model suggests a condition which requires that the interim rollover policy is to roll over the loan if and only if rolling over yields a higher payment than calling the loan in the interim.

2.2 Empirical Literature

Enormous empirical literatures exist on international reserves determination. Some of the pertinent ones are given below:

Edwards (1983) empirically investigated the movement of demand for international reserves and monetary equilibrium by estimating a dynamic equation that allows reserves movement to reflect the monetary authority’s excess demand for international reserves and the public’s excess demand for money using a sample of 23 developing countries that maintained a fixed exchange rate during the period of 1965 – 1972. He found that reserves movements respond to monetary factors and to differences between actual and desired reserves.

Lane and Burke (2001) studied the determinants of cross-country variation in the level of international reserves over the period 1981-1995. They confirm that trade openness is the most important variable. They also found that financial deepening is associated with an increase in the reserve ratio. More so, they confirmed in their work that smaller and more volatile industrial countries hold larger reserves than their larger, less volatile counterparts. In addition, more indebted developing countries tend to have smaller reserve ratios.
Abdourahmane and Sarr (2004), estimated long run relationship between foreign reserves holdings and their determinants - real GDP per capita, openness to trade (ratio of imports and exports to GDP), current account deficit to GDP, nominal short-term interest rate differential and exchange rate volatility. The study applied IMF (2003) to uncover the long run determinants of the demand for foreign exchange reserves in Tunisia and to assess the adequacy of current and projected reserves holding in light of the country’s policy choices. It also revealed that foreign exchange reserves are positively related to economic size and current account vulnerability and negatively correlated with exchange rate flexibility and the opportunity costs of holding reserves.

Xu Guangqing (2003), in a paper submitted to the Third Annual International Conference on Business in Hawaii, estimated the desired stock of reserves for China and showed that deviations of the actual stock from the desired level do trigger a process of adjustment and found that the speed of adjustment was quite high in China. The study also examined the determinants of the speed of adjustment and examined the empirical content of the hypothesis that (i) trade-off large equilibrium stocks of reserve for low speeds of adjustment; (ii) the speed of adjustment depends upon the (absolute) size of the discrepancy between desired and actual stocks; and (iii) the speed of adjustment depends upon whether the discrepancy between actual and desired stocks is positive or negative. Following previous work on the demand for foreign reserves and considering China’s special economic characteristics, especially the capital flight which happened seriously in China, the study assumed that the desired level of reserves is related to (i) a measure of scale - reflecting the value of foreign reserve transactions or of wealth; (ii) the average propensity to import - reflecting the degree of openness of the economy; (iii) the volatility of exchange rate; (iv) debt burden and (v) capital flight pressure. The study revealed that all the variables except the debt rate had significant values and also showed some special characteristics involved in China’s reserve adjustment picture: China adjusts more rapidly to reserve deficiencies than to surpluses; the speed of adjustment is negatively related to the divergence between the actual level of reserve and the target level; and when China holds abnormally large quantities of reserve it does adjust more rapidly.

Aizenman and Riera-Crichton (2006) evaluate the impact of international reserves, terms of trade shocks and capital flows on the real exchange rate (REER). The study revealed that international reserves cushions the impact of terms of trade shocks on the REER, and that this effect is important for developing but not for industrial countries. The buffer effect is especially significant for Asian countries, and for countries exporting natural resources.
Financial depth reduces the buffer role of international reserves in developing countries. Developing countries REER seem to be more sensitive to changes in reserve assets; whereas industrial countries display a significant relationship between hot money and REER.

Choi and Baek (2004) used a new classification of exchange rate arrangements developed by Reinhart and Rogoff (2004) to test whether reserve holdings decrease with increasing exchange rate flexibility. Using pooled data for 137 countries over the period 1980-2000, the study regresses international reserves variable on other variables such as per capita GDP, trade openness(measured as the ratio of exports plus imports to GDP), financial openness(defined as the ratio of gross private capital flows to GDP), interest rate, export volatility and a dummy for exchange rate regime. The study finds that the degree of exchange rate flexibility has an inverted-U relationship with the country’s reserve holdings. Exchange rate regimes with intermediate flexibility need more reserves than polar regimes (hard pegs and freely floating). Further, reserve holdings are smaller under hard pegs than under freely floating, implying that current large stockpiles of reserves in East Asian countries can be significantly reduced if they adopt a single currency. Regarding the other determinants of the demand for reserves, country size, real openness and financial openness all raise reserve holdings while the opportunity cost and export volatility are not significant variables. Finally, per capita GDP and reserve holdings also have an inverted-U relationship, thereby, showing that their correlation is negative for industrial countries, but positive for developing countries.

Lai (2004) examined the demand for international reserves by considering the financial centre status of an economy as well as factors often cited in literature such as the size of an economy, trade openness and the exchange rate regime. Using a sample of over 140 economies, the study examines the empirical evidence for the relationship between reserve holdings and financial sector development and considers how the level of foreign exchange reserves held by Hong Kong compares with the other economies considered. The results confirm that the openness and size of the financial sector are important determinants of the level of reserve holdings. After controlling for the size of the economy, trade openness and financial centre status, the level of reserves in Hong Kong does not appear to be unusually high by international standards.

Noteworthy here is that Choi and Baek (2004), and Lai (2004), used OLS but did not test for the stationarity of the series they used. However, it has been shown that running regression on non-stationary data using OLS estimation method produces spurious regression results. As a result of this, this study will use the cointegration approach and also tests for the stationarity of the series in order to avoid any spurious regression results.
Khan and Ahmed (2005) analysed the main determinants of reserves holding in Pakistan and also attempted to find the implications of structural shifts such as September 11, military take-over and the autonomy of State Bank of Pakistan for the traditional reserves demand theory and the implications of monetary approach to balance of payments for reserves holding behaviour in Pakistan. The study estimates the long run cointegration relationship between reserves variable and other determinants such as balance of payments variability, money market rate, the average propensity to import, the level of imports and workers’ remittances using quarterly data over the period 1982:1-2003:2. The study finds that there exists a stable long run reserve demand function in case of Pakistan. The estimated cointegration relationship shows that all variables except remittances are significant. The variations in balance of payments and imports have positive relationship while money market rate has a negative impact on international reserves.

Yin-Wong and Hiro (2006) conducted a comprehensive cross-country empirical analysis of the determinants of international reserves. For the sample period of 1975 to 2004, they used data from more than 100 economies, including both developed and developing economies, to examine the effects on international reserves holding of three groups of determinants, namely, traditional macro variables, financial variables, and institutional variables. They focused on the interplay of these variables and their changing roles in determining international reserves. Therefore, with a large sample of economies, they compared the behaviour of crisis-inflicted and non-crisis-inflicted economies and examine whether international reserves of these economies behave differently before and after crises. Moreover, they used the estimation results to compare and contrast the patterns of demand for international reserves of the developed and developing economies. The estimation results show that the explanatory power of the determinants changes across different time periods and also vary between developed and developing economies. The compositions of the significant determinants within each one of the three groups of explanatory variables also displayed substantial variations across subsample periods and country groups. The behaviour of crisis-inflicted economies can be identified only in some cases but not uniformly. The results also suggest that, compared with a developing economy, a developed economy tends to hold a lower level of international reserves, ceteris paribus.

Jo (2007) used a cointegration and a vector error correction approach to estimate the magnitude and sources of international reserve accumulation in Korea. The study presents further evidence to support the hypothesis that the large build up of international reserves in Korea might be the by-product of mercantilist objectives to smooth exchange rate movements
Beyond responses to perceptions of the need for greater reserve hoardings, generated by the 1997-98 Asian crises. The study finds that Korea’s recent hoarding of international reserves substantially exceeds any benchmark levels. One explanation is that the large reserve build-up is the by-product of Korea’s exchange rate policy to maintain export competitiveness. The study presents evidence that, under “managed float FX regime” since the crisis in Korea, exports have been cheap and the terms of trade have substantially declined, maintaining high export growth. Also, the main source of Korea’s reserve hoarding after the crisis has been trade surplus rather than capital inflows. In the cointegration and error correction estimation, both long-term and short-term relationship between the terms of trade and international reserve is found to be negative, which is further evidence that Korea has stockpiled reserves with heightened concern about export competitiveness. However, the results do not ignore some scope of the precautionary demand that Asian countries have built the buffers against rapid financial outflows. More so, GDP has a significantly positive relationship with foreign reserve stock implying that, from long-term point of view, as international transactions increase with economic size, reserve levels have increased with GDP levels. The variability measures of the balance of payments have positive long-term relationship with reserves, confirming that reserve holding increase with the volatility of international transactions. The exchange rate volatility shows positive long-run relationship with reserves while the openness measure shows a long run negative relationship with reserves.

Yan (2007) investigated empirically the relationship between the pattern of fiscal policy and the demand for international reserves in developing countries, and how this relationship is associated with political risk and conditional access to global capital markets. Using the Two Stage Least Squares (2SLS), the study finds that for developing countries with low political risk, countercyclical (procyclical) fiscal policies are associated with higher (lower) international reserve holdings in economic downturns. The relationship is stronger when the countries with low political risk rely heavily on external financing. For developing countries with high political risk, the link between reserves holdings and fiscal policy pattern is not clear-cut.

Adam and Leonce (2007), investigated the crowding out effect of external reserves on both public and private investment, Real GDP growth, domestic credit to public sector (for public investment) and interest rate and exchange rate expectations (for private investment) served as additional variables to external reserves. The same authors considered monetary variables such as interest rates, inflation rate, as additional variables to external reserve in
exchange rate equation and finally, only the lag value of inflation rate was added for inflation equation.

Bentum-Ennin (2008), adopted a modified version of the monetary approach to balance of payments in analyzing the link between Ghana’s international reserves and macroeconomic performance and, a buffer stock model to analyze the opportunity cost of holding reserves and how Ghana’s reserves levels depart from the benchmark stock of reserves. For him to avoid spurious regression results, he subjected the time series data to stationarity tests. He used the Johansen’s cointegration procedure to examine long run relationships that existed among the variables. The short run dynamics was examined by using an error correction model. It is found that an improvement in macroeconomic performance bring about an improvement in the reserve position of a country; increase in domestic credit also has a negative effect on international reserves but, increased openness to trade and financial openness, and increased tourism receipts have positive impacts on international reserves, while higher interest rate differential and exchange rate volatility have negative impacts on international reserves.

Suvojit, Ram, and Benito (2008), analyzed the optimal reserve holding for India during an era of flexible exchange rate and high capital mobility using the buffer stock model of Frenke and Jovanovic(1981). The evidence derived from the ARDL approach of Pesaran, Shin and Smith (1996) support the fact that the scale variable, opportunity cost variable and the volatility variable all have significant effects on the reserve demand. The evidence also shows that exchange rate flexibility does not have any significant impact on the reserve demand.

Prabheesh, Malathy, and Madhumathi (2009), empirically investigated the importance of precautionary and mercantilist approaches to international reserves in the Indian context using monthly data from 1993 to 2007. The ARDL approach to cointegration was used to estimate as in the long-run relationship between reserves and its determinants. The empirical results show that the impact of the volatility of Foreign Institutional Investment which captures the precautionary motive, and that of undervalued real exchange rate which is associated with the mercantilist view on reserves are statistically significant in the long run. Hence, they concluded that both the precautionary and mercantilist motives explain reserve accumulation in India over the study period.

Usman and Ibrahim (2010) investigated the impact of change in external reserve positions of Nigeria on domestic investment, inflation rate and exchange rate. Using a combination of ordinary least square (OLS) and vector error correction (VEC) methods, it
was observed that change in external reserves in the country only influences foreign direct investment (FDI) and exchange rates and no influence of it was found on domestic investment and inflation rates. The study suggested that there is need for broader reserve management strategies that will aim at maximizing the gains from oil export revenue by utilizing more of these resources to boost domestic investment.

It is pertinent to note here that the literature reviewed, has revealed various variables that may affect reserve holdings of any nation. Thus, this study adopts a modified version of the monetary approach to balance of payments and a buffer stock model to analyze the determinants of international reserves in Nigeria.

2.3 Limitations of Previous Studies

The major obstacles encountered by previous researchers on the process of conducting their research work are as follows:

- Most of the previous studies done on international reserves were merely done on reserve accumulation and utilisation, the demand for international reserves, the impact of reserve holding, implications for investment, inflation and so on, without looking at the factors that determine international reserve holding. Exceptions are Yin-Wong and Hiro (2006), Abdourahmane and Sarr (2004), Khan and Ahmed (2005), and Bentum-Ennin (2008), who did it for cross-country analysis, Tunisia, Pakistan, and Ghana respectively, but none has been done for Nigeria at the time this research is being carried out.

- Most works reviewed used OLS but did not test for the stationarity of the series used. Examples are Choi and Baek (2004), and Lai (2004). However, it has been shown that running regression on non-stationary data using OLS estimation method produces spurious results. This study will use the cointegration approach and also test for the stationarity of the series in order to avoid any spurious regression results.

- Most of the empirical studies such as Dhliwayo(1996), Howard & Mamingi (2002) and Nwaobi(2003) used the standard model spelt out in the monetary approach to estimate the reserve flow equation. This study, however, intends to modify the standard model by incorporating other variables that may determine international reserve.
<table>
<thead>
<tr>
<th>Years/Authors</th>
<th>Location</th>
<th>Nature of Study</th>
<th>Nature of Data</th>
<th>Methodology</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lane and Burke (2001)</td>
<td>Asia</td>
<td>Cross-Country</td>
<td>Annual Time Series Data</td>
<td>Cointegration Approach</td>
<td>Trade openness is the most important variable, financial deepening is associated with an increase in the reserve ratio, smaller and more volatile industrial countries hold larger reserves than their larger, less volatile counterparts, and that more indebted developing countries tend to have smaller reserve ratios.</td>
</tr>
<tr>
<td>Abdourahmane and Sarr (2004)</td>
<td>Tunisia</td>
<td>Country specific</td>
<td>Annual Time Series Data</td>
<td>Cointegration Approach</td>
<td>Foreign exchange reserves are positively related to economic size and current account vulnerability and negatively correlated with exchange rate flexibility and the opportunity costs of holding reserves.</td>
</tr>
<tr>
<td>Xu Guangqing (2003)</td>
<td>China</td>
<td>Country specific</td>
<td>Annual Time Series Data</td>
<td>Error-Correction Model</td>
<td>The deviations of the actual stock from the desired level do trigger a process of adjustment and found that the speed of adjustment was quite high in China.</td>
</tr>
<tr>
<td>Aizenman and Riera-Crichton (2006)</td>
<td>Asia</td>
<td>Cross-Country</td>
<td>Annual Time Series Data</td>
<td>Buffer stock model</td>
<td>International reserves cushions the impact of terms of trade shocks on the REER, and that this effect is important for developing but not for industrial countries.</td>
</tr>
<tr>
<td>Choi and Baek (2004)</td>
<td>East Asia</td>
<td>Cross-Country</td>
<td>Pooled data</td>
<td>New classification of exchange rate arrangements developed by Reinhart and Rogoff (2004)</td>
<td>The degree of exchange rate flexibility, per capita GDP and reserve holdings have an inverted-U relationship showing that their correlation is negative for industrial countries, but positive for developing countries.</td>
</tr>
<tr>
<td>Lai (2004)</td>
<td>Hong Kong</td>
<td>Cross-country</td>
<td>Annual Time Series Data</td>
<td>ARDL model</td>
<td>After controlling for the size of the economy, trade openness and financial centre status, the level of reserves in Hong Kong does not appear to be unusually high by international standards.</td>
</tr>
<tr>
<td>Khan and Ahmed (2005)</td>
<td>Pakistan</td>
<td>Country specific</td>
<td>Quarterly data</td>
<td>Cointegration Approach</td>
<td>There exists a stable long run reserve demand function in case of Pakistan, and the variations in balance of payments and imports have positive relationship while money market rate has a negative impact on international reserves.</td>
</tr>
<tr>
<td>Author(s)</td>
<td>Country</td>
<td>Methodology</td>
<td>Data</td>
<td>Findings</td>
<td></td>
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<td>Annual Time Series Data</td>
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<td></td>
</tr>
<tr>
<td>Jo (2007)</td>
<td>Korea</td>
<td>Country specific</td>
<td>Annual Time Series Data</td>
<td>Korea’s recent hoarding of international reserves substantially exceeds any benchmark levels</td>
<td></td>
</tr>
<tr>
<td>Yan (2007)</td>
<td>China</td>
<td>Cross-country analysis</td>
<td>Annual time series data</td>
<td>Developing countries with low political risk are associated with higher international reserve holdings in economic downturns, while those with high political risk, the link between reserves holdings and fiscal policy pattern are not clear-cut.</td>
<td></td>
</tr>
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<td>Adam and Leonce (2007)</td>
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<td>Country specific</td>
<td>Annual time series data</td>
<td>Only the lag value of inflation rate was added for inflation equation.</td>
<td></td>
</tr>
<tr>
<td>Bentum-Ennin (2008)</td>
<td>Ghana</td>
<td>Country specific</td>
<td>Annual time series data</td>
<td>Increase in domestic credit has a negative effect on international reserves but, increased openness to trade and financial openness, and increased tourism receipts have positive impacts on international reserves, while higher interest rate differential and exchange rate volatility have negative impacts on international reserves.</td>
<td></td>
</tr>
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<td>India</td>
<td>Country specific</td>
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<td></td>
</tr>
<tr>
<td>Prabheesh, Malathy, and Madhumath (2009)</td>
<td>India</td>
<td>Country specific</td>
<td>Annual Time Series Data</td>
<td>Both the precautionary and mercantilist motives explain reserve accumulation in India over the study period.</td>
<td></td>
</tr>
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<td>Usman and Ibrahim (2010)</td>
<td>Nigeria</td>
<td>Country specific</td>
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</tr>
</tbody>
</table>
CHAPTER THREE
METHODOLOGY

3.0 Monetary Approach to Balance of Payments and Exchange Rate Determination

The basic premise of the monetary approach is that any balance of payments disequilibrium is based on monetary disequilibrium, that is, differences existing between the amount of money people wish to hold and the amount supplied by the monetary authorities. In simple terms, if people demand more money than is being supplied by the central bank, then the excess demand for money is satisfied by inflows of money from abroad. Conversely, if the central bank is supplying more than is demanded, the excess supply of money is eliminated by outflows of money to other countries. Thus the monetary approach analysis emphasizes the determinants of money demand and money supply, since these will also determine the balance of payments and exchange rate.

The analysis is carried out for a small, open economy. The demand for money is given as:

\[ L = kPY \] ................................. (1)

Where
- \( L \) = demand for money
- \( P \) = domestic price level
- \( Y \) = real income; and
- \( k \) = a constant fraction indicating how money demand will change given a change in \( P \) or \( Y \).

The usual story is that the higher the income, the more money people will hold to buy more goods. The higher the price level, the more money is desired to buy any given quantity of goods. The demand for money should, therefore, rise with an increase in either \( P \) or \( Y \).

The money supply relationship is specified as:

\[ M = f(DC + Fr) \] ................................................................. (2)

Where
- \( M \) = money supply
- \( DC \) = domestic credit; and
- \( Fr \) = international reserves

Let denote
- \( P \) = domestic price level
- \( E \) = exchange rate; and
- \( P^* \) = foreign price level

Then, the law of one price becomes:

\[ P = EP^* \] ........................................................................................................ (3)

Therefore, the equilibrium condition becomes:
L = M ...................................................................................... (4)

Consequently, the balance of payments can be defined as:

CA + KA = Fr .............................................................................. (5)

Where, CA = current account; and

KA = capital account.

It is pertinent to note here that, if Fr < 0, then CA + KA < 0, and then, the nation is running a balance of payments deficit.

The adjustment mechanism that ensures equilibrium in Equation (4) varies with the exchange rate regime.

However, with fixed exchange rates, money supply adjusts to money demand through international flows of money via balance of payments imbalances.

With flexible exchange rates, money demand will be adjusted to a money supply set by the central bank via exchange rate changes.

In the case of a managed float, where theoretically we have floating exchange rates but the central banks intervene to keep exchange rates at desired levels, we have both international money flows and exchange rate changes.

Substituting (4) and (3) into (1) gives,

M = kEP*Y ...................................................................................... (6)

Substituting into (ii) yields,

f(DC + Fr) = kEP*Y ................................................................ (7)

Under fixed exchange rate regime, the exchange rate is not allowed to vary. International reserves must vary to maintain the parity value of the exchange rate. Hence, the balance of payments must adjust to any monetary disequilibrium. If the central bank raises DC, Money supply exceeds money demand. Therefore,

f(DC ↑ + Fr) > kEP*Y

If there is pressure for the domestic currency to depreciate, the central bank must sell FR until M = L. Consequently, this can be given as:

f(DC ↑ + Fr ↓ ) = kEP*Y

Here, there is no net impact on the monetary base and money supply as the change in Fr offset the change in DC. Under a flexible exchange rate regime, the Fr component of the monetary base does not change. Thus, exchange rate, E, will adjust to eliminate any monetary
disequilibrium. Considering the impact of an increase in DC, money supply will exceed money demand. And as a result of this we have:

\[ f(DC \uparrow + Fr) > kE P^* Y \]

Now the domestic currency must depreciate to balance money supply and money demand. And as a result, we have:

\[ f(DC \uparrow + Fr) = kE P^* Y \]

Under a managed float system, we have both international money flows and exchange rate changes. Thereby, leading to:

\[ f(DC \uparrow + Fr \downarrow ) = kE P^* Y \]

Moreover, this research will adopt the modified version of monetary approach to balance of payments in order to address the first research objective. The monetary approach to balance of payments posits that the overall balance of payments measured by international reserves is influenced by imbalances between the demand for and supply of money stock. However, the basic conclusion of the monetary approach is that, starting from an initial equilibrium position, an increase in the demand for money (or an increase in its supply) will lead to a balance of payments surplus (or vice versa). In addition to this, excess money supply induces increased expenditure, which is directed at foreign commodities. These purchases of foreign commodities by domestic residents have to be financed by running down foreign exchange reserves hence, worsening the balance of payments. More so, the outflow of foreign exchange reserves reduces money supply until it is equal to money demand, thereby restoring monetary equilibrium and halting an outflow of foreign exchange reserves. Thus, an excess demand for money leads to an opposite adjustment which in turn induces foreign exchange reserves inflow, domestic monetary expansion and eventually a restored balance of payments equilibrium position.

### 3.1 Model Specification

As stated above, the outflow of foreign exchange reserves reduces money supply until it is equal to money demand, thereby restoring monetary equilibrium and halting an outflow of foreign exchange reserves. And an excess demand for money leads to an opposite adjustment which in turn induces foreign exchange reserves inflow, domestic monetary expansion and eventually a restored balance of payments equilibrium position.

Consequently, Money supply is determined by the availability of international reserves and the level of domestic credit created by the country’s monetary reserves. Hence, this can be stated as follows:
Ms = (Fr + DC)........................................................................................ (8)

Where; Ms = money supply
    Fr = international reserves
    DC = domestic credit

Equation (8) postulates that money supply is determined by the availability of international reserves and the level of domestic credit created by the country’s monetary reserves.

Moreover, the real demand for money is also specified as follows:
Md = f(Y, P, Ir, E)........................................................................................... (9)

Where;
    Md = money demand
    Y = level of real domestic income
    P = domestic price level
    Ir = domestic rate of interest
    E = nominal exchange rate
    f = functional notation.

Equation (9) sets out the real demand for money as a function of real domestic income, domestic price level, domestic interest rate, and nominal exchange rate.

According to the monetary theory, there is a positive relationship between demand for money (money held) and income \( \frac{\partial Md}{\partial y} > 0 \) and money held and the price level \( \frac{\partial Md}{\partial P} > 0 \), and a negative relationship between money held and interest rate \( \frac{\partial Md}{\partial Ir} < 0 \).

Moreover, if the cost of holding a domestic currency increases relative to the cost of holding foreign currency, say due to a higher inflation rate for domestic currency, then demand will shift away from domestic currency to foreign currency if the two currencies are substitutes. As a result, the domestic currency would depreciate even more than before the inflation differential between the two currencies. However, with the depreciation of the domestic currency (an increase in exchange rate), people hold more foreign currency (i.e. substitute foreign currency for domestic currency) in order to prevent further loss of value of their currency and thus, the demand for domestic currency (demand for money) will decrease. The opposite holds true for an appreciation of the domestic currency (i.e. a fall in exchange rate). Therefore, \( \frac{\partial Md}{\partial E} < 0 \).
Equilibrium in the money market requires that supply of money equals demand. Consequently, this can be specified as:

\[ Ms = M = Md \]  \[ (10) \]

Where:

- \( Ms \) = money supply
- \( Md \) = money demand
- \( M \) = equilibrium stock of money.

Equation (10) is the equilibrium condition in the money market.

Combining Equations (1), (2), and (3) and isolating reserves as the dependent variable, yields equation (4) below:

\[ Fr = h(Y, P, Ir, E, DC) \]  \[ (11) \]

Where; variables in equation (4) remain the same as defined above.

\[ h \] = functional notation.

To take care of the growth rate of the international reserves and its determinants we have to transform the variables to their logarithmic forms. Therefore, the natural log transformation of equation (4) is given as follows:

\[ \ln Fr = \alpha_0 + \alpha_1 \ln Y + \alpha_2 \ln P + \alpha_3 Ir + \alpha_4 \ln E + \alpha_5 \ln DC + \mu \]  \[ (12) \]

\[ \alpha_1 > 0, \quad \alpha_2 > 0, \quad \alpha_3 < 0, \quad \alpha_4 > 0, \quad \alpha_5 < 0 \]

Where, \( \mu \) = the white noise error.

Note that interest rate (\( Ir \)) is not logged because it is already transformed to a rate.

Furthermore, to examine other potential determinants of international reserves especially, the opportunity cost of holding reserves and the extent to which Nigeria’s international reserves depart from the benchmark stock of reserves, a modified version of the buffer stock model will be employed.

More so, Nigeria like any other country holds reserves as a buffer against unforeseen exigencies. In addition to this, the managed float system operated in Nigeria requires that the Central Bank occasionally intervenes in the exchange rate market to prevent excessive exchange rate volatility. For the Central Bank to perform this role effectively, adequate amount of reserves should be kept at all times. As a result of this, a modified version of the inventory model or the buffer stock model will be employed following Heller (1966), Frenkel and Jovanovic (1981), and Bahmani-Oskooee (1985), which are traditional studies on the demand for international reserves.
Also, Aizenman and Marion (2004), Aizenman and Lee (2006), Aizenman et al (2007), which are recent studies, attempted to identify the determinants for the large reserve hoarding in East Asia using a buffer stock model. This is because, the buffer stock approach suggests that central banks rationally choose a level of reserves by comparing the opportunity cost of holding reserves with the macroeconomic adjustment cost in a case of reserves shortage.

Under the conventional model, reserves holding mainly depend on economic size, trade openness, balance of payment volatility, and opportunity cost of holding reserves. Hence, this can be written as:

\[ Fr_t = a_1 + a_2 GDP_t + a_3 TOPEN_t + a_4 BOP_t + a_5 OPCOST_t + \mu \] \hspace{1cm} \text{Equation (13)}

Where,  
\( Fr = \) international reserves
\( GDP = \) Gross Domestic Products
\( TOPEN = \) trade openness
\( BOP = \) balance of payment volatility
\( OPCOST = \) opportunity cost of holding reserve
\( \mu = \) the white noise error.

Equation (13) is the benchmark specification of reserve holdings based on a buffer stock model.

Flood and Marion (2001), and Disyatat and Mathieson (2001), have considered additional variables. For instance, they found that the volatility of the effective exchange rate (exchange rate volatility) is an important determinant. Therefore, the choice of exchange rate regime should affect international reserve holdings. This is because, greater exchange rate flexibility should reduce the demand for reserves since central banks no longer need a large reserve stockpile to maintain a peg or enhance the peg’s credibility. Hence, the coefficient of exchange rate volatility should be negative. Consequently, the buffer stock model will be employed with some additional variables.

Following the IMF (2003), which used a standard buffer stock model based on Aizenman and Marion (2004), the international reserves holdings can be specified as follows:

\[ \ln Fr = b_0 + b_1 \ln Y + b_2 \text{DID} + b_3 \ln Ev + b_4 \ln FOp + b_5 \ln TOp + b_6 DFr^* + b_7 \ln DEx + \mu \] \hspace{1cm} \text{Equation (14)}

Where,  
\( Fr = \) international reserves
\( Y = \) Gross Domestic Products
\( \text{DID} = \) dummy for interest rate differential which is a measure of opportunity cost (i.e. 1 when interest rate differential is positive and, 0 otherwise)
\( \text{Ev} = \) exchange rate volatility
Fop = financial openness
Top = trade openness
DFr* = dummy for benchmark stock of reserves (i.e. 1 when FR is positive and, 0 otherwise)
DFex = demand for foreign exchange
µ = the white noise error.

From equation (14), the right hand side variables are chosen as potential determinants of reserves on the basis of previous empirical studies (this solves problem (i)). Moreover, problem (ii) will be solved using the coefficient of interest rate differential (b₂), while problem (iii) will be solved by graphing foreign reserves (Fr) and the benchmark stock of reserves to show the extent of disparity between them.

The Error Correction Model (ECM) which represents the deviation from the long run steady state relations among the variables will be conducted once a long-run relationship is shown to exist. Therefore, the short run dynamics will be examined by means of an error-correction model. This is given as:

\[ \Delta y_t = \sum_{i=1}^{k} \phi_i \Delta y_{t-i} + \sum_{i=1}^{k} \beta_i \Delta X_{t-i} + \theta ECM_{t-1} + \nu_t \]  \hspace{1cm} (15)

Where,
- \( y_t \) and \( x_t \) = the series of cointegrated variables.
- \( \phi_i \) and \( \beta_i \) = parameters of the model
- \( ECM_{t-1} \) = the lagged value of the estimated error term from the cointegrated equation(s) or the deviation from the long run steady state relations among the variables (The error correction mechanism).
- \( \theta \) = the speed of adjustment or the rate with which the long run error is being corrected annually in the short run.
- \( \nu_t \) = white noise error term.
- \( k \) = the number of lagged first difference term.
- \( \Delta \) = the difference operator.

Pertinent to note here is that an error correction specification works with stationary data. The merits of error correction model are that it does not put apriori restrictions on the model and that it separates long run and short-run effects. Thus before running the model above, pre-estimation tests have to be conducted.
3.2 Pre-Estimation tests

3.2.1 Unit-Root test

In empirical research on time series data, there always exist problem of nonstationarity which renders the traditional tools of econometrics (like OLS and 2SLS) inappropriate. To overcome this problem of Unit-Root, the first strategy here will be to test for the stationarity of the series since time-series data will be used. There are many tests that have been developed to test for stationarity. These include the Dickey Fuller test, Augmented Dickey-Fuller test, Phillips-Perron test, Sarghan Bhanga Dubbin Watson (SBDW). Among all, the Augmented Dickey-Fuller test, denoted conventionally as ADF is widely regarded as the most efficient test for integration and it is at present the most widely used in practice. Thus, the ADF test will be used in this research work and this can be specified as follows:

\[
\Delta Y_t = a_0 + a_1 Y_{t-1} + \sum_{i=1}^{k} b_i \Delta Y_{t-i} + \mu_t
\]  

\[\text{................................................. (16)}\]

Where,

- \(Y_t\) = a vector of all variables of the model
- \(a_i\) and \(b_i\) = parameters of the model
- \(\mu_t\) = white noise error term
- \(k\) and \(\Delta\) remain as defined above.

The null hypothesis here is that \(Y_t\) has a unit root (that is, nonstationary) and the alternative is that there is no unit root (that is, stationary). If the variables turn out to contain unit roots it implies they are non-stationary. Stationarity could however be achieved by first differencing of the levels if the series are integrated of order one or I (1).

3.2.2 Cointegration test

Further, the next step will be to test for the existence of a stable long-run relationship among the variables. The concept of cointegration can be used to test for the existence of a stable or, as is sometimes claimed, long run equilibrium relationship among economic variables. The cointegration test examines whether some linear combination of the nonstationary series in the regression produces a white noise process or not. The ADF cointegration test will be utilized in this study. Hence, once a long-run relationship is shown to exist, the short run dynamics will be examined by means of an error-correction model given in equation (8) above.
3.3 Statistical tests

3.3.1 $R^2$: This is used to measure the goodness of fit of the estimated regression models. $\overline{R}^2$ (which is adjusted to the degrees of freedom) can also be used for this purpose.

3.3.2 The $t$-test: This will be used to test the significance of the individual parameter estimates of the model.

3.3.3 The $F$-test: This will be used to test the overall significance of all the parameter estimates of the model.

3.4 Econometric Procedure (Tests)

3.4.1 Test for Multicollinearity

This is used to test for the linear collinearity among the explanatory variables. Therefore, the Correlation Matrix will be used for this test.

3.4.2 Test for Autocorrelation

This is used to test whether the errors corresponding to different observations are uncorrelated. This means testing for the randomness of the error term. Hence, the Durbin–Watson (DW) method will be used for testing this. Koutsoyiannis (1977) posits that this provides estimates which have asymptotic properties and are more efficient for samples of all size.

3.4.3 Test for Normality

The Jarque–Bera (JB) test of normality will be employed here to test whether the residuals are normally distributed.

3.4.4 Test for Heteroscedasticity

This will be used to test whether the variance of the error term is constant. It can arise because of the presence of outliers, incorrect data transformation, incorrect functional form, incorrect specification of the regression model, etc. Therefore, the White Heteroscedasticity test will be adopted for this purpose.

3.4.5 Regression Specification Error Test

This is employed to know if the model is well-specified. This is because often times, specification biases arise accidentally maybe from our inability to formulate the model as
precisely as possible because the underlying theory is weak or because we do not have the right kind of data to test the model. Here, the Ramsey’s reset test will be adopted. It posits that the lower the F-test of the Ramsey’s reset test, the more ideal the model is (i.e. if the F-statistics is significant, the model is said to be mis-specified).

3.5 Data

The data for this study will be a time series data obtained from secondary sources. Therefore, annual data covering the period 1970 to 2009 will be utilized. The data will be obtained from the Central Bank of Nigeria Statistical Bulletin.

Following IMF (2003), income variable (Y) will be measured by real GDP, financial openness (FOp) will be measured by the ratio of external debt to GDP, openness to trade (TOp) calculated as ratio of imports plus exports to GDP, exchange rate volatility (Ev) calculated as the standard deviation of Naira/US dollar rate, and opportunity cost of holding reserves (DID) is a dummy measured by the difference between domestic and foreign interest rates (i.e 1 when interest rate differential is positive and, 0 otherwise). Foreign reserves (Fr) will be measured by real reserves minus gold. Demand for foreign exchange (DFex) will be measured using the demand of foreign exchange figures bought at Bureaux-de-Change (BDC) (uncovered years will be extrapolated).

The benchmark international reserves (optimal reserves) variable (DFr*) will be generated using two approaches namely; the cointegration approach and the Hodrick-Prescott Filter method which is a smoothing method that is widely used among macroeconomists to obtain a smooth estimate of the long-term trend component of a series. It is also used as a dummy measured by the difference between foreign reserves and benchmark stock of international reserves (1 when FR is positive and, 0 otherwise).

3.6 Definition of Model Variables

i. International Reserves

International reserves include (a) foreign currency assets of the monetary authority (b) Special Drawing Rights (c) Reserve position in the Fund (d) Gold.
Edwards (1985), Landell and Mills (1989) used the International Financial Statistics definition of total Reserves of the monetary authorities minus gold. Gold is excluded because there is some question whether central banks consider gold to be as liquid as say foreign currency holdings to be used as an intervention asset. Central Banks seem to regard gold as a reserve that is truly “of last resort” to be sold only as a last measure.

ii. **Scaling factors**

The scaling variable measures the size of international transactions and can be represented by GDP, GDP per capita, or population size. International transactions increase with economic size, and therefore reserves are expected to increase with real GDP per capita and population.

Aizenman and Marion (2004) suggest that reserve holdings should increase with the size of international transactions. Thus we expect $b_1 > 0$ in Eq(7).

iii. **Opportunity cost of holding reserves**

The opportunity cost variable plays an important role in theoretical models. The standard measure of the opportunity cost in empirical studies is the differential between the country’s own-interest rate and the interest rate on comparable US treasuries.

Flood and Marion (2002), IMF (2003), Aizenman and Marion (2004), most recent empirical studies, do not find a significant negative effect for the opportunity cost hence, they point out that the opportunity cost variable may not be properly measured since the composition of reserves is not adequately reflected, and until the early 1990s, most emerging markets did not have market determined domestic interest rates. In addition, the standard measure does not take into account the cost of acquiring international currencies for building up reserves, which importantly depends on the country-risk premium and access to international capital markets. We expect $b_2 < 0$ in Eq(7).

iv. **Exchange rate flexibility**

Disyatat (2001), Flood and Marion (2002), Aizenman and Marion (2004) argued that conventional wisdom holds that greater flexibility in the exchange rate should reduce the demand for reserves since central banks do not need a large reserve stockpile to maintain a peg or to enhance the peg’s credibility.

Heller and Mohsin, (1978), also posit that more flexible exchange rate regimes can better accommodate shocks to the economy, and hence need smaller liquidity buffers. However, the need for reserves may increase with exchange rate flexibility to temper exchange rate movements if capital flows are volatile.
Frankel and Dornbusch, (1995), and Dooley, Michael P., Folkerts-Landau, David, and Peter Garber (2004), posit in addition to the above, that central banks, in an attempt to dampen the appreciation of their currencies, may accumulate reserves.

v. **Financial and Trade Openness**

With increased financial integration and open capital accounts, the scope of international reserve management has expanded over time and includes not just moderating volatility in the exchange rate and facilitating the export and import of goods and services, but now also encompasses a wide variety of cross-border asset transactions. Due to this trend, sovereign liquidity management has gained in importance and is increasingly perceived as a key element in reducing the vulnerability to international financial shocks.

To capture changes in the financial openness of an economy, empirical studies use *de jure* financial integration measures based on policies to promote capital account liberalization or *de facto* measures based on actual capital flows.

Prasad, Eswar S., Kenneth S. Rogoff, Shang-Jin Wei, and Ayhan Kose, (2003), and Lane and Milesi-Ferretti (2006) suggest *de facto* measures of financial integration.

Reserves should also be built up with the vulnerability of both real and financial external shocks such as terms-of-trade shocks and the currency and financial crises. To the extent that a country is more open in the real side as well as in the financial side, it is more vulnerable to such shocks. Thus real and financial-side openness both should be positively correlated with reserve holdings, that is, \( b_4 > 0 \) and \( b_5 > 0 \).

vi. **Demand for Foreign Exchange**

The demand and/or supply of foreign currencies may be said to be derived from that of the items bought and sold with it. The demand for and/or supply of foreign exchange rates takes on the characteristics of the goods, services, and capital that it is desired to acquire or that gave rise to the supply. The supply of foreign exchange of a given country stems from the sale of foreign merchandise, services, and capital to that country. When foreigners want to buy a country's exports, they must purchase its currency with their own. Thus the supply of one country's currency available to a second country is closely related to the demand for the second country's currency. Consequently, if the supply of a country's currency increases, the value of the currency decreases in relation to other currencies and more money is (demanded) required to buy the foreign exchanges. Hence, \( b_7 > 0 \).
CHAPTER FOUR
EMPIRICAL RESULTS

4.1 Presentation of Pre-Estimation tests

The battery tests conducted in this research work shows that all the variables (LOG(FR), LOG(Y), DID, LOG(EV), LOG(FOP), LOG(TOP), DFr* and LOG(DFex)) are all integrated of order one. This is because the absolute value of the computed ADF test Statistics are greater than the absolute value of the tabulated ADF Critical Values of the variables at 5% level of significance (this is based on the ADF unit root test which was conducted on the variables). The unit root was tested with trend and intercept at level form but the results indicated that both trend and intercepts are insignificant except that of LOG(FR). LOG(FR) was not stationary at level but, at first difference, it became stationary hence, it is integrated of order one (i.e. LOG(FR)~I(1)). For others, “none” (i.e. no intercept and trend) was chosen to test again for the presence of unit root at level but, the results showed that each of the variables is not stationary. However, at first difference, each of them became stationary. Therefore, each of the variables are integrated of order one. This can be seen in summary as shown in table 4.1.1 below (see Appendix for full print out).

Table 4.1.1: The Summary Results of Unit Root Test

<table>
<thead>
<tr>
<th>Variable</th>
<th>ADF t-Statistics</th>
<th>5% Critical Values</th>
<th>Order of Integration</th>
</tr>
</thead>
<tbody>
<tr>
<td>D(LOG(FR(-1)))</td>
<td>-5.228219</td>
<td>-3.5348</td>
<td>Order one (i.e. I(1))</td>
</tr>
<tr>
<td>D(LOG(Y(-1)))</td>
<td>-4.517220</td>
<td>-2.9422</td>
<td>Order one (i.e. I(1))</td>
</tr>
<tr>
<td>D(DID(-1))</td>
<td>-4.777675</td>
<td>-1.9514</td>
<td>Order one (i.e. I(1))</td>
</tr>
<tr>
<td>D(LOG(EV(-1)))</td>
<td>-2.945823</td>
<td>-1.9501</td>
<td>Order one (i.e. I(1))</td>
</tr>
<tr>
<td>D(LOG(FOP(-1)))</td>
<td>-3.492774</td>
<td>-1.9501</td>
<td>Order one (i.e. I(1))</td>
</tr>
<tr>
<td>D(LOG(TOP(-1)))</td>
<td>-5.147303</td>
<td>-1.9501</td>
<td>Order one (i.e. I(1))</td>
</tr>
<tr>
<td>D(DFr*(-1))</td>
<td>-4.487746</td>
<td>-1.9501</td>
<td>Order one (i.e. I(1))</td>
</tr>
<tr>
<td>D(LOG(DFEX(-1)))</td>
<td>-4.939411</td>
<td>-1.9501</td>
<td>Order one (i.e. I(1))</td>
</tr>
</tbody>
</table>

Moreover, from the ADF cointegration test conducted on the variables at 5% level of significance, it was also observed that the absolute value of the computed ADF test Statistic (-5.200947) is greater than the absolute value of the tabulated ADF Critical Value (-1.9498) at 5% level of significance hence, making all the variables have long run relationship (i.e. they are cointegrated). (Also see Appendix for full print out).
4.2 Presentation of Regression Results

The modified version of the buffer stock model given in equation (7) of chapter three can be seen in summary in table 4.2.1 below:

Table 4.2.1: Summary Results of the Buffer Stock Model

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coefficients</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>-7.007895</td>
<td>2.501762</td>
<td>-2.801184</td>
<td>0.0086</td>
</tr>
<tr>
<td>LOG(Y)</td>
<td>0.888138</td>
<td>0.153583</td>
<td>5.782787</td>
<td>0.0000</td>
</tr>
<tr>
<td>DID</td>
<td>-0.249014</td>
<td>0.700460</td>
<td>-0.355501</td>
<td>0.7245</td>
</tr>
<tr>
<td>LOG(EV)</td>
<td>1.184641</td>
<td>0.105664</td>
<td>11.21140</td>
<td>0.0000</td>
</tr>
<tr>
<td>LOG(FOP)</td>
<td>-0.838012</td>
<td>0.125533</td>
<td>-6.675608</td>
<td>0.0000</td>
</tr>
<tr>
<td>LOG(TOP)</td>
<td>0.637820</td>
<td>0.500729</td>
<td>1.273785</td>
<td>0.2119</td>
</tr>
<tr>
<td>DFr*</td>
<td>0.085270</td>
<td>0.335254</td>
<td>0.254343</td>
<td>0.8009</td>
</tr>
<tr>
<td>LOG(DFEX)</td>
<td>0.306895</td>
<td>0.106310</td>
<td>2.886794</td>
<td>0.0069</td>
</tr>
</tbody>
</table>

R-squared = 0.969494, Adjusted R-squared = 0.962821, F-statistic = 145.2818, Durbin-Watson stat = 1.50 2455

However, controlling for Heteroskedasticity (using White Heteroskedasticity-Consistent Standard Errors & Covariance) in the modified version of the buffer stock model yields the results given in table 4.2.2 below:

Table 4.2.2: Summary Results of the Buffer Stock Model Controlling for Heteroskedasticity

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coefficients</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>-7.007895</td>
<td>2.425874</td>
<td>-2.888812</td>
<td>0.0069</td>
</tr>
<tr>
<td>LOG(Y)</td>
<td>0.888138</td>
<td>0.163398</td>
<td>5.435418</td>
<td>0.0000</td>
</tr>
<tr>
<td>DID</td>
<td>-0.249014</td>
<td>0.294600</td>
<td>-0.845260</td>
<td>0.4042</td>
</tr>
<tr>
<td>LOG(EV)</td>
<td>1.184641</td>
<td>0.106040</td>
<td>11.17165</td>
<td>0.0000</td>
</tr>
<tr>
<td>LOG(FOP)</td>
<td>-0.838012</td>
<td>0.138807</td>
<td>-6.037229</td>
<td>0.0000</td>
</tr>
<tr>
<td>LOG(TOP)</td>
<td>0.637820</td>
<td>0.682402</td>
<td>0.934670</td>
<td>0.3570</td>
</tr>
<tr>
<td>DFr*</td>
<td>0.085270</td>
<td>0.398299</td>
<td>0.214084</td>
<td>0.8318</td>
</tr>
<tr>
<td>LOG(DFEX)</td>
<td>0.306895</td>
<td>0.089195</td>
<td>3.440733</td>
<td>0.0016</td>
</tr>
</tbody>
</table>

R-squared = 0.969494, Adjusted R-squared = 0.962821, F-statistic = 145.2818, Durbin-Watson stat = 1.50 2455

However, because there exists evidence of cointegration among the variables, the deviation from the long run steady state relations among the variables has to be conducted. This means estimating the model given in equation (8) of chapter three. Therefore, the short run dynamics (Error-Correction Model) is examined and the results can be seen as given summarily below in table 4.2.3.
Table 4.2.3: Parsimonious Regression Results

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coefficients</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0.007659</td>
<td>0.108804</td>
<td>0.070396</td>
<td>0.9443</td>
</tr>
<tr>
<td>D(LOG(Y))</td>
<td>0.624919</td>
<td>0.264030</td>
<td>2.366848</td>
<td>0.0067</td>
</tr>
<tr>
<td>D(DID)</td>
<td>-0.601850</td>
<td>0.184362</td>
<td>-3.264500</td>
<td>0.0027</td>
</tr>
<tr>
<td>D(LOG(EV))</td>
<td>1.335498</td>
<td>0.443081</td>
<td>3.014115</td>
<td>0.0052</td>
</tr>
<tr>
<td>D(LOG(FOP))</td>
<td>-0.804604</td>
<td>0.272019</td>
<td>-2.957900</td>
<td>0.0060</td>
</tr>
<tr>
<td>D(LOG(TOP))</td>
<td>0.738346</td>
<td>0.474153</td>
<td>1.557190</td>
<td>0.1299</td>
</tr>
<tr>
<td>D(DFr*)</td>
<td>0.625889</td>
<td>0.212243</td>
<td>2.948926</td>
<td>0.0041</td>
</tr>
<tr>
<td>D(LOG(DFEX))</td>
<td>0.210022</td>
<td>0.101738</td>
<td>2.064336</td>
<td>0.0477</td>
</tr>
<tr>
<td>ECM(-1)</td>
<td>-0.751739</td>
<td>0.262117</td>
<td>-2.867957</td>
<td>0.0075</td>
</tr>
</tbody>
</table>

R-squared = 0.703927, Adjusted R-squared = 0.671640, F-statistic = 3.809364, Durbin-Watson stat = 1.824031

Furthermore, in order to examine the extent of the disparity between foreign reserves and benchmark stock of reserves, both foreign reserves and benchmark stock of reserves are graphed as can be seen below in figure 4.2.1;

Figure 4.2.1 A Graph Showing the Extent to which Foreign Reserves (Fr) Depart From the Benchmark Stock of Reserves (Fr*)

From the graph, it can be seen clearly that both foreign reserves (Fr) and benchmark stock of reserves (Fr*) maintained a zero (USD0) level but tend towards the same direction as the year increased from 1 to 27. Thereafter, both of them increased to about USD1000000 as the year increased from 28 to 31. After this point, there exists a disparity between them - as Fr* increased continually with a gentle slope, Fr decreased a bit and increased sharply with a very steep slope from about USD1000000 to about USD5500000 as the year raised from 31 to 35.
After this period, Fr fall a step further but increased gently from about USD5500000 to about USD 7000000 as the year increased from 36 to 38. Thereafter, Fr declined while Fr* increased continually with a gentle slope without any sign of decline.

4.3 Evaluation of Results

The results of the model are evaluated based on Economic (a priori), Statistical and Econometric criteria.

4.3.1 Economic (A Priori) Criteria

The buffer stock model (equation (7) in chapter three) which was employed to determine the potential determinants of reserves (to solve problem (i)), and to evaluate the opportunity cost of holding reserves (to solve problem (ii)), indicates that all the variables conformed to their a priori expectations except exchange rate volatility (Ev) which assumed positive instead of negative sign. This is surprising since it is expected that a rise in exchange rate volatility leads to a reduction in foreign reserves (Fr). However, this implies in Nigeria’s case that the more volatile the exchange rate, the more Nigeria will need to accumulate more reserves to smooth the volatility in exchange rate.

Moreover, it can be seen that a percentage increase in foreign debt stock (Financial Openness (FOp)) and a unit change in interest rate differential (DID), have negative impact on (decreases) foreign reserves (Fr) by about 84%, and 0.25 units respectively. On the other hand, a percentage increase in real income (Y), exchange rate volatility (Ev), openness to trade (Top), demand for foreign exchange (DFex), and a unit increase in the benchmark stock of international reserves (Optimal reserves (DFr*)) have positive impact on (increases) Nigeria’s foreign reserves by about 89%, 118%, 64%, 31%, and 0.09 units respectively. The constant term is negatively related to foreign reserve and a unit increase in it decreases foreign reserve by about 7.007895 units (i.e. -7.007895).

However, controlling for heteroskedasticity in the model brings about an improvement in the standard errors and t-statistics of the model though; the a priori expectations and the coefficients of the model remained the same. This can be seen in table 4.2.2 (also see Appendix for full print out).

Furthermore, because of the evidence of cointegration among the variables of the model, the buffer stock model (equation (7)) transcends into Error correction model (ECM) seen in equation (8) of chapter three. The ECM was also conducted by controlling for
heteroskedasticity using White Heteroskedasticity-Consistent Standard Errors & Covariance. This helps in the improvement of the Standard Errors and t-statistics of the model.

From the model, it can be seen that all the variables maintained their a priori expectations as have already been described above except the constant term which assumed positive instead of negative sign. This is because of the introduction of the error correction mechanism.

Consequently, an improvement in macroeconomic performance will bring about an improvement in the reserve position of Nigeria hence, it can be seen from the model that a percentage increase in foreign debt stock (Financial Openness (FOp)) and a unit rise in interest rate differential (DID), have negative impact on (decreases) foreign reserves (Fr) by about 80%, and 0.60 units respectively. On the other hand, a percentage increase in real income (Y), exchange rate volatility (Ev), openness to trade (Top), demand for foreign exchange (DFex), and a unit increase in the benchmark stock of international reserves (Optimal reserves (DFr*)) have positive impact on (increases) Nigeria’s foreign reserves by about 62%, 134%, 74%, 21%, and 0.63 units respectively. The Error Correction Mechanism (ECM (-1)) shows that the speed of adjustment is as high as about 75%. This conforms to its a priori expectation (i.e. it has negative a priori sign). This means that D(LOG(Fr)) will be negative to restore the equilibrium. Consequently, if Fr is above its equilibrium value, it will start falling in the next period to correct the equilibrium error. The constant term is also positively related to foreign reserve but it is statistically not different from zero.

4.3.2 Statistical Criteria

(i) $R^2$ and $\bar{R}^2$

The values of $R^2$ and $\bar{R}^2$ (adjusted for the loss in the degrees of freedom) for the buffer stock model (both the one heteroskedasticity is not controlled for and the one it is controlled for) are 0.969494 and 0.962821. This shows that there is goodness of fit. This means that all the explanatory variables [LOG(Y), LOG(EV), LOG(FOp), LOG(Top), LOG(DFex), DID, and DFr*] explain about 97% (for $R^2$) and/or 96% (for $\bar{R}^2$) of the total variations in Nigeria’s foreign reserves. More so, that of the error correction model shows that the values of $R^2$ and $\bar{R}^2$ are 0.703927 and 0.671640 respectively. This also implies good fit and that all the explanatory variables [D(LOG(Y)), D(LOG(EV)), D(LOG(FOp)), D(LOG(Top)), D(LOG(DFex)), D(DID), D(DFr*), and ECM(-1)] explain about 70% of the total variations in Nigeria’s foreign reserves.
(ii) The t-test

The hypothesis here is that;

H$_0$: $\alpha_i = 0$ (statistically insignificant)

H$_1$: $\alpha_i \neq 0$ (statistically significant)

Where $\alpha_i =$ parameter estimates of the explanatory variables in the model

Level of significance = 5% and for n-k degrees of freedom.

Where, n = the number of observation (40 and 39, i.e. for the buffer stock model and the ECM)

K = the number of parameter estimates (8 and 9, i.e. for the buffer stock model and the ECM)

**Decision Rule:** Reject null hypothesis (H$_0$) if $-t_{cal} < -t_{a/2}$ or if $t_{cal} > t_{a/2}$ and accept the null hypothesis otherwise. This holds for two tailed test. Hence, $t_{a/2}(n-k)df = t_{0.05/2} = t_{0.025}(40-8) = t_{0.025}(32)$ = 2.042

Looking at the t-Statistic of the buffer stock model (both the one heteroskedasticity is not controlled for and the one it is controlled for), it can be observed from the model that all the variables (the constant term (C), LOG(Y), LOG(EV), LOG(FOP), and LOG(DFEX)) except LOG(TOP), DID and DFr*, are statistically significant (i.e. -2.801184 or -2.888812 < -2.042, 5.782787 or 5.435418 > 2.042, 11.21140 or 11.17165 > 2.042, -6.675608 or -6.037229 < -2.042, 2.886794 or 3.440733 > 2.042, while 1.273785 or 0.934670 < 2.042, -0.355501 or -0.845260 > -2.042, and 0.254343 or 0.214084 < 2.042).

Consequently, this suggests that in the long run, growth in Nigeria’s foreign reserves is not influenced by trade openness (Top), the opportunity cost of holding reserves (DID) and the benchmark stock of reserves but by other determinants such as the constant term, real Gross Domestic Products (Y), exchange rate volatility (Ev), financial openness (Fop), and the demand for foreign exchange (DFEx).
Moreover, the t-Statistic of the error correction (the short run) model indicates that all the variables \([D(\text{LOG}(Y)), D(\text{LOG}(EV)), D(\text{LOG}(FOP)), D(\text{LOG}(DFEX)), D(DID), D(DFr^*) \text{ and } \text{ECM(-1)}]\) except \(\text{LOG(TOP)}\), are statistically significant [i.e. 2.366848 > 2.042, 3.014115 > 2.042, -2.957900 < -2.042, 2.064336 > 2.042, -3.264500 < -2.042, 2.948926 > 2.042, and -2.867957 < 2.042 while 1.557190 < 2.042]. Here, the constant term is statistically not different from zero (i.e. 0.070396 < 2.042).

As a result, this empirical evidence suggests that in the short run, growth in Nigeria’s foreign reserves is not influenced by the constant term and trade openness (Top), but by other determinants such as real Gross Domestic Products (Y), exchange rate volatility (Ev), financial openness (Fop), the demand for foreign exchange (DFex), the opportunity cost of holding reserves (DID), the benchmark stock of reserves (DFr*), and the error correction mechanism (ECM(-1)).

(iii) The F-test

The test for the overall significance of the parameters of the model can be given as follows;

\[H_0: \alpha_i = 0 \text{ (statistically insignificant)}\]

\[H_1: \alpha_i \neq 0 \text{ (statistically significant)}\]

Where \(\alpha_i = \) parameter estimates of the explanatory variables in the model

Where \(i = 0, 1, \ldots, 9\)

Level of significance = 5%

**Decision Rule:** Reject the null hypothesis if the computed F-statistic (\(F_{\text{cal}}\)) exceeds the tabulated F value (\(F_{\text{tab}}\)) at 5% level of significance with \((k-1)(V_1), (n-k)(V_2)\) degrees of freedom. That is; reject \(H_0\) if \(F_{\text{cal}} > F_{\text{tab}}(k-1, n-k)\) otherwise, do not reject it.

Where, \(K\) and \(n\) remain as defined above.
The long run (buffer stock) model indicates that at 5% level of significance, the model’s degree of freedom is (8-1, 40-8) (i.e. (7, 32)). Thus, the value of \( F_{\text{tab}} = F_{0.05}(7, 32) = 2.33 \). Therefore, it can be seen from the model that the computed F – statistic (\( F_{\text{cal}} \)) exceeds the tabulated F-value (\( F_{\text{tab}} \)) (i.e. \( 145.2818 > 2.27 \)). This implies that there exists an overall significance of the regression model (i.e. the model is statistically significant and hence, it has a good fit). In other words, they are statistically different from zero (i.e. not all \( \alpha_i \)’s are zero).

Hence, at 5% level of significance, the short run (ECM) model’s degree of freedom is (9-1, 39-9) (i.e. (8, 30)). Thus, the value of \( F_{\text{tab}} = F_{0.05}(8, 30) = 2.27 \). Therefore, it can be seen from the model that the computed F – statistic (\( F_{\text{cal}} \)) exceeds the tabulated F-value (\( F_{\text{tab}} \)) (i.e. \( 3.809364 > 2.27 \)). This implies that there exists an overall significance of the regression model (i.e. the model is statistically significant and hence, it has a good fit). In other words, they are statistically different from zero (i.e. not all \( \alpha_i \)’s are zero).

### 4.4 Econometric Procedure (Tests)

Since all the variables of the model are cointegrated (i.e. they have long run relationship), the analysis will henceforth be based on the short run (error correction) model in order to take care of the short run dynamics.

#### 4.4.1 Test for Multicolinearity

To test for linear collinearity between the variables of the model, the correlation matrix is employed and this can be seen as given below:
Table 4.4.1: Correlation Matrix

<table>
<thead>
<tr>
<th>Variables</th>
<th>D(LOG(Y))</th>
<th>D(DID)</th>
<th>D(LOG(EV))</th>
<th>D(LOG(FOp))</th>
<th>D(LOG(TOP))</th>
<th>D(DFr*)</th>
<th>D(LOG(DFex))</th>
<th>ECM(-1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D(LOG(Y))</td>
<td>1.000000</td>
<td>-0.0034876</td>
<td>0.1079275</td>
<td>-0.0819349</td>
<td>0.0277250</td>
<td>-0.0013485</td>
<td>0.0156864</td>
<td>0.3846851</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4581402</td>
<td>256357</td>
<td>9623962</td>
<td>3540954</td>
<td>9510451</td>
<td>7936451</td>
<td>038468510</td>
</tr>
<tr>
<td>D(DID)</td>
<td>-0.003487</td>
<td>1.000000</td>
<td>-0.097070</td>
<td>-0.0308859</td>
<td>-0.0781107</td>
<td>0</td>
<td>-0.0322600</td>
<td>0.1912688</td>
</tr>
<tr>
<td></td>
<td>1402</td>
<td>7079709</td>
<td>797079</td>
<td>1946619</td>
<td>3117731</td>
<td></td>
<td>8669855</td>
<td>80936451</td>
</tr>
<tr>
<td>D(LOG(EV))</td>
<td>-0.107927</td>
<td>0.0970701</td>
<td>1.000000</td>
<td>0.4829885</td>
<td>0.1192280</td>
<td>-0.0592879</td>
<td>0.0111960</td>
<td>0.0739470</td>
</tr>
<tr>
<td></td>
<td>57</td>
<td>797079</td>
<td>57</td>
<td>4734563</td>
<td>6</td>
<td>9623962</td>
<td>4510451</td>
<td>701654</td>
</tr>
<tr>
<td>D(LOG(FOp))</td>
<td>-0.081934</td>
<td>0.0308859</td>
<td>0.4829885</td>
<td>1.000000</td>
<td>-0.0736337</td>
<td>0.1627416</td>
<td>0.5297759</td>
<td>-0.0764658</td>
</tr>
<tr>
<td></td>
<td>9623962</td>
<td>146619</td>
<td>4734563</td>
<td></td>
<td>23</td>
<td>9603549</td>
<td>9337968</td>
<td>4634669</td>
</tr>
<tr>
<td>D(LOG(TOP))</td>
<td>0.027725</td>
<td>-0.0781107</td>
<td>0.1192280</td>
<td>-0.0736337</td>
<td>1.000000</td>
<td>-0.2710105</td>
<td>0.1873050</td>
<td>0.2935526</td>
</tr>
<tr>
<td></td>
<td>9340457</td>
<td>117731</td>
<td>6</td>
<td>23</td>
<td></td>
<td>42</td>
<td>555556</td>
<td>6555565</td>
</tr>
<tr>
<td>D(DFr*)</td>
<td>-0.001348</td>
<td>0</td>
<td>0.1016274</td>
<td>10.1627416</td>
<td>0.1057707</td>
<td>0.1057707</td>
<td>0.0794353</td>
<td>0.1853956</td>
</tr>
<tr>
<td></td>
<td>9510451</td>
<td></td>
<td>09986655</td>
<td>39824908</td>
<td>418556</td>
<td>092418</td>
<td>7134671</td>
<td>000007</td>
</tr>
<tr>
<td>D(LOG(DFex))</td>
<td>0.015686</td>
<td>-0.0322600</td>
<td>0.0111960</td>
<td>0.5297759</td>
<td>0.1873050</td>
<td>0.1057707</td>
<td>0.0794353</td>
<td>0.1853956</td>
</tr>
<tr>
<td></td>
<td>4510451</td>
<td>986655</td>
<td>9809659</td>
<td>39824908</td>
<td>18057072</td>
<td>418556</td>
<td>7134671</td>
<td>000007</td>
</tr>
<tr>
<td>ECM(-1)</td>
<td>0.384685</td>
<td>0.1912688</td>
<td>0.0739470</td>
<td>0.2935526</td>
<td>0.1853956</td>
<td>0.0794353</td>
<td>0.1853956</td>
<td>0.1057707</td>
</tr>
<tr>
<td></td>
<td>109310</td>
<td>093</td>
<td>16554</td>
<td>655556</td>
<td>7134671</td>
<td>000007</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The results given in table 4.4.1 suggest the absence of multicollinearity among the variables of the model. However, a mild but positive correlation exists between financial openness (FOp) and the demand for foreign exchange (DFex) (i.e. 0.529775933798). This is true since a rise in financial openness will trigger off a rise in the demand for foreign exchange.
4.4.2 Test for Autocorrelation

This is carried out in this work using the Durbin Watson t-Statistic. Thus, the hypothesis tested is as given below:

$H_0$: No autocorrelation

$H_1$: Autocorrelation exists

Level of significance $= 0.05$

**Decision Rule:** The summary of the decision rule is presented in table 4.4.2 as given below:

**Table 4.4.2 Durbin-Watson d Test: Decision Rules**

<table>
<thead>
<tr>
<th>Null Hypothesis</th>
<th>Decision</th>
<th>If</th>
</tr>
</thead>
<tbody>
<tr>
<td>No positive autocorrelation</td>
<td>Reject</td>
<td>$0 &lt; d &lt; d_L$</td>
</tr>
<tr>
<td>No positive autocorrelation</td>
<td>No decision</td>
<td>$d_L \leq d \leq d_u$</td>
</tr>
<tr>
<td>No negative correlation</td>
<td>Reject</td>
<td>$4 - d_L &lt; d &lt; 4$</td>
</tr>
<tr>
<td>No negative correlation</td>
<td>No decision</td>
<td>$4 - d_u \leq d \leq 4 - d_L$</td>
</tr>
<tr>
<td>No autocorrelation, positive</td>
<td>Do not reject</td>
<td>$d_u &lt; d &lt; 4 - d_u$</td>
</tr>
<tr>
<td>or negative</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From table 4.2.3 above, it can be observed that the Durbin – Watson statistic, $d = 1.824031$. Also, the significance points of $d_L$ and $d_U$ at 0.05 level of significance are; $d_L = 0.970$ while $d_u = 2.098$ (from Durbin – Watson table with 9 degrees of freedom and $n = 39$).

Therefore, we have; $d_L \leq d \leq d_u$

$\therefore 0.970 \leq 1.824031 \leq 2.098$

However, from the result above, it can be observed that $0.970 \leq 1.824031 \leq 2.098$. Hence, we say that the test is inconclusive. Therefore, there is no decision.
4.4.3  Test for Heteroskedasticity

This is employed to find out if the error term exhibits constant variance. It follows $\chi^2$ (Chi-square) distribution. This can be given as follows:

$H_0 : b_i = 0$ (Homoskedasticity)

$H_1 : b_i \neq 0$ (Heteroskedasticity)

Decision Rule: Reject $H_0$ if $\chi^2_{cal} > \chi^2_{tab}(k-1)$ and accept it otherwise. Or if $\chi^2_{cal} < \chi^2_{tab}(k-1)$, accept $H_0$ and reject it otherwise. Hence,

$\chi^2_{cal} = n.R^2$

Where $n = 39, R^2 = 0.362203, \text{ and } K = 15.$

$\chi^2_{cal} = 39 \times 0.362203 = 14.125917$

$\chi^2_{tab}(k-1) = \chi^2_{0.05}(17-1) = \chi^2_{0.05}(16) = 27.5871$

Therefore, since $\chi^2_{cal} (14.125917) < \chi^2_{0.05}(17) (27.5871)$, we accept the null hypothesis and conclude that the variance of the error term is homoskedastic.

4.4.4  Normality Test

This is employed to find out if the error term is normally distributed. It is distributed at 2 degrees of freedom. Thus, Jarque – Bera test of normality is given as shown below;

$H_0 : \mu_i = 0$ (Error term is normally distributed)

$H_1 : \mu_i \neq 0$ (Error term is not normally distributed)

Level of significance = 0.05

Decision Rule: If $\chi^2_{cal} < \chi^2_{tab}$, accept the null hypothesis ($H_0$) otherwise, reject it. $\chi^2_{cal} = 0.064484$ while $\chi^2_{tab(0.05)(2)} = 5.99147$

Therefore, since $\chi^2_{cal} (0.064484) < \chi^2_{0.05}(2) (5.99147)$, we accept the null hypothesis ($H_0$) and conclude that the error term is normally distributed. Also, looking at the histogram of residuals (see Appendix), it can also be observed that the residual is normally distributed.
4.4.5 The Specification Error Test

This test is employed to find out if there exists specification error in the model used. That is, to know whether the model used is mis-specified. The Ramsey Reset test employed for this purpose follows F-distribution (see appendix for full print out). This can be conducted as follows;

H₀: \( \alpha_i = 0 \) (statistically insignificant)

H₁: \( \alpha_i \neq 0 \) (statistically significant)

Where \( \alpha_i \) = parameter estimates of the explanatory variables in the model

Where \( i = 0,1,...,9 \)

Level of significance = 5%

Decision Rule: If F- statistic (Fₘₐₖ) > F value (Fₜₐₖ) (i.e. if F value is statistically significant), accept the null hypothesis that the model is mis-specified otherwise, reject it.

Hence, Fₜₐₖ(0.05) (m, n-k) = F₀.₀₅(1, 30) = 4.17

Where, m = the number of regressors omitted from the model = 1

\( n = \) number of observations = 39

\( K = \) number of parameter estimates = 9

\( Fₘₖ = 1.203713 \)

Hence, since Fₘₖ (1.203713) is less than F₀.₀₅(1, 30) = 4.17, we reject the null hypothesis and conclude that the model is well-specified (i.e. it is statistically significant).

4.5 Evaluation of Working Hypotheses

The results of the model indicate that all the variables conformed to their a priori expectations except exchange rate volatility (Ev) which assumed positive instead of negative sign. This is surprising since it is expected that a rise in exchange rate volatility leads to a reduction in foreign reserves (Fr). However, this implies in Nigeria’s case that the more volatile the exchange rate, the more Nigeria will need to accumulate more reserves to smooth the volatility in exchange rate.
Moreover, it can be seen that a percentage increase in foreign debt stock (Financial Openness (FOp)) and a unit rise in interest rate differential (DID), have negative impact on (decreases) foreign reserves (Fr) by about 84%, and 25 units respectively. On the other hand, a percentage increase in real income (Y), exchange rate volatility (Ev), openness to trade (Top), demand for foreign exchange (DFex), and a unit increase in the benchmark stock of international reserves (Optimal reserves (DFr*)) have positive impact on (increases) Nigeria’s foreign reserves by about 89%, 118%, 64%, 31%, and 9 units respectively. The constant term is negatively related to foreign reserve and a unit increase in it decreases foreign reserve by about 7.007895 units (i.e. -7.007895).

However, controlling for heteroskedasticity in the model brings about an improvement in the standard errors and t-statistics of the model though; the a priori expectations and the coefficients of the model remained the same.

Furthermore, because of the evidence of cointegration among the variables of the model, the buffer stock model was transformed into Error correction model (ECM). The ECM was also conducted by controlling for heteroskedasticity using White Heteroskedasticity-Consistent Standard Errors & Covariance. This helps in the improvement of the Standard Errors and t-statistics of the model.

All the variables in the ECM model maintained their a priori expectations as have described above except the constant term which assumed positive instead of negative sign. This is because of the introduction of the error correction mechanism. As a result, an improvement in macroeconomic performance will bring about an improvement in the reserve position of Nigeria hence, looking at the model a percentage increase in foreign debt stock (Financial Openness (FOp)) and a unit rise in interest rate differential (DID), have negative impact on (decreases) foreign reserves (Fr) by about 80%, and 60 units respectively. On the other hand, a percentage increase in real income (Y), exchange rate volatility (Ev), openness to trade (Top), demand for foreign exchange (DFex), and a unit rise in the benchmark stock of international reserves (Optimal reserves (DFr*)) have positive impact on (increases) Nigeria’s foreign reserves by about 62%, 134%, 74%, 21%, and 63 units respectively. The Error Correction Mechanism (ECM (-1)) shows that the speed of adjustment is as high as about 75%. This conforms to its a priori expectation (i.e. it has negative a priori sign). This means that D(LOG(Fr)) will be negative to restore the equilibrium. Consequently, if Fr is above its equilibrium value, it will start falling in the next period to correct the equilibrium error. The constant term is also positively related to foreign reserve but it is statistically not different from zero.
Moreover, the test for the overall significance of the model (F-test) shows that the variables combined together has a significant impact on foreign reserves. This implies that all the variables of the model \([D(\text{LOG}(Y)), D(\text{LOG}(EV)), D(\text{LOG}(\text{FOP})), D(\text{LOG}(\text{TOP})), D(\text{LOG}(\text{DFEX})), D(\text{DID}), D(\text{DFr*}), \text{and ECM(-1)}] \) determine \(D(\text{LOG}(Fr))\). Though individually, \(D(\text{LOG}(\text{TOP})) \) does not.

Consequently, given the working hypotheses that:

- There is (are) no determinant factor(s) responsible for changes in Nigeria’s international reserves.
- High opportunity cost is associated with a low level of reserve holdings.

It is therefore found that the first null hypothesis is rejected hence, the conclusion is that in the long run Nigeria’s foreign reserves is not determined by trade openness (Top), the opportunity cost of holding reserves (DID) and the benchmark stock of reserves but by other determinants such as the constant term, real Gross Domestic Products (Y), exchange rate volatility (Ev), financial openness (Fop), and the demand for foreign exchange (DFex). This empirical evidence suggests further that in the short run, growth in Nigeria’s foreign reserves is not determined by the constant term and trade openness (Top), but by other determinants such as real Gross Domestic Products (Y), exchange rate volatility (Ev), financial openness (Fop), the demand for foreign exchange (DFex), the opportunity cost of holding reserves (DID), the benchmark stock of reserves (DFr*), and the error correction mechanism (ECM(-1)).

Furthermore, given the second hypothesis, it is also found that the opportunity cost of holding reserves is about 2.5% (i.e. -0.0249014 units) in the long run, and about 6.0% (i.e - 0.0601850 units) in the short run. This implies that higher interest rate differential (DID), reduces Nigeria’s foreign reserves by about 2.5% and 6.0% both in the short and long run respectively. Consequently, the null hypothesis of the second objective is rejected hence; low opportunity cost is associated with high level of reserve holdings (both in the short and long run respectively) in Nigeria’s case.

Moreover, on the third hypothesis, foreign reserves (Fr) and the benchmark stock of reserves was graphed to show the extent of disparity between them. The graph indicates that there exists a disparity between them – as Fr* increased continually with a gentle slope, Fr decreased a bit and increased sharply with a very steep slope from about USD1000000 to about USD5500000 as the year increased from 31 to 35. After this period, Fr fell a step further but increased gently from about USD5500000 to about USD 7000000 as the year
increased from 36 to 38. Thereafter, Fr declined while Fr* increased continually with a gentle slope without any sign of decline.
CHAPTER FIVE
SUMMARY, CONCLUSION AND POLICY IMPLICATIONS

5.1 Summary

This research work focused on the determinants of foreign reserves in Nigeria. Thus, modelling Nigeria foreign reserves (Fr) against real gross domestic product (Y), exchange rate volatility (Ev), financial openness (Fop), trade openness (Top), demand for foreign exchange (DFex), interest rate differential which is a measure of opportunity cost (DID), the benchmark stock of reserves (DFr*), and the deviation from the long run steady state relations among the variables (ECM(-1)) has given the insight to the factors that really determine Nigeria’s foreign reserves.

However, it was found that in the long run (see the modified version of the buffer stock models in the appendix) Nigeria’s foreign reserves is not determined by trade openness (Top), the opportunity cost of holding reserves (DID) and the benchmark stock of reserves but by other determinants such as the constant term, real Gross Domestic Products (Y), exchange rate volatility (Ev), financial openness (Fop), and the demand for foreign exchange (DFex). Further, it was empirically found in this research that in the short run, growth in Nigeria’s foreign reserves is not determined by trade openness (Top), but by other determinants such as real Gross Domestic Products (Y), exchange rate volatility (Ev), financial openness (Fop), the demand for foreign exchange (DFex), the opportunity cost of holding reserves (DID), the benchmark stock of reserves (DFr*), and the error correction mechanism (ECM(-1)).

It is also found that both in the long run and short run, the opportunity cost of holding reserves is about 2.5% (i.e. -0.0249014), and about 6.0% (i.e -0.0601850). This implies that higher interest rate differential (DID), reduces Nigeria’s foreign reserves by about 2.5% and 6.0% both in long run and the short respectively thereby, implying that low opportunity cost is associated with high level of reserve holdings (both in the short and long run respectively) in Nigeria’s case.

However, another crucial finding unravelled in this work is on the a priori sign of the exchange rate volatility (Ev) which assumed positive instead of negative sign. This is surprising since it is expected that a rise in exchange rate volatility leads to a reduction in foreign reserves (Fr). This by implication implies that in Nigeria’s case, the more volatile the
exchange rate, the more Nigeria will need to accumulate more reserves to smooth the volatility in exchange rate.

Foreign reserves (Fr) and the benchmark stock of reserves were also graphed to show the extent of disparity between them. The graph indicates in this work that there exists a disparity between them and this is determined by the changing character of the forces of demand and supply in the money market.

5.2 Conclusion

It has been seen that Foreign exchange reserves adequacy is a key component of good macroeconomic management. The modified version of the buffer stock model was applied to assess the determinants of foreign reserve in Nigeria’s case. The study regressed international reserve variable on macroeconomic variables: real income, interest rate differential (a measure of opportunity cost), exchange rate volatility, financial openness, openness to trade (a measure of current account vulnerability), benchmark stock of reserves, and the demand for foreign exchange. In order to avoid any spurious regression results, the time series data was subjected to stationarity tests. The ADF cointegration procedure was used to examine if there exists any potential long run relationships. The result indicated that the variables are cointegrated together. Hence, the short run dynamics was examined by means of an error correction model.

Empirical evidence also shows that low opportunity cost is associated with high level of reserve holdings (both in the short and long run respectively) in Nigeria’s case thereby, making it possible for Nigeria to accumulate and hold more reserves to help smoothen exchange rate volatility.

The graph of foreign reserves (Fr) and the benchmark stock of reserves (Fr*) indicates that there exists a disparity between them and it is determined by the changing character of the forces of demand and supply in the money market. The insight here is that the more (less) people demand for money in the money market, the more (less) money will be supplied and the more (less) foreign reserves (Fr) is depleted hence, leading to a reduction (or an increase) in benchmark stock of reserves (Fr*). Therefore, a reasonable amount of foreign reserves must be kept at all times to help smoothen the volatility in exchange rate.

In sum, the econometric tests conducted showed that there is no evidence of linear co-linearity between the variables of the model, autocorrelation test is inconclusive therefore, no
decision was taken. There is also no evidence of Heteroskedasticity. The error term is also normally distributed, and the specification error test showed that the model is well-specified.

5.3 Policy Implications/Recommendations

Finally, the results indicate that Nigerian government need to reconsider her reserve management strategies as the result shows that reserves holding by this country cannot be justified by trade openness (TOp). As a result, Nigeria should liberalize its trade though, with some restrictions (such as imposition of tax on imported luxury goods) in order to help in more reserve accumulation.

Since the risk in reserve holding (opportunity cost of holding reserves (DID)) both in the long and short run is very low, management strategies that will aid in more reserve accumulation should be reconsidered by Nigerian government. More so, strategies with a broader economic development policy framework should also be aimed at in order to maximize the gains from oil export revenues (as it is the major foreign exchange earner of Nigeria). Consequently, this will aid in more reserve accumulation.

Moreover, since in the long run the benchmark stock of reserves does not affect Nigeria’s foreign reserves (but does affect it in the short run), Nigerian government should make sure that adequate amount of reserves must be kept at all times (not only in the short run but also, in the long run) to help smooth the volatility in exchange rate.

In addition to this, since exchange rate volatility has strong positive impact, adequate (more) reserves have to be accumulated to help smoothen the volatility in the exchange rate not only in the short run but also, in the long run.

In the end, the graph of foreign reserves (Fr) and the benchmark stock of reserves (Fr*) indicates that there exists a disparity between them and it is determined by the changing character of the forces of demand and supply in the money market hence, Nigerian government should adopt management strategies that will equilibrate the two of them at least, in the short run. For instance, managers of Nigeria’s foreign reserves should encourage the monitoring of the use of scarce foreign exchange resources to ensure that foreign exchange disbursements and utilization are in line with economic priorities and within the annual foreign exchange budget. This will help to ensure availability of a regular and comfortable
balance of payments position as well as the stability of the Naira and hence, go a long way in equilibrating foreign reserves (Fr) and the benchmark stock of reserves (Fr*). Further, Nigeria reserve managers should invest heavily in infrastructural development in order to create the enabling environment for a non-oil economy. In this regard, the provision of steady power and water supplies as well as good road and communication networks is very crucial. In this way, more foreign reserves (Fr) and the benchmark stock of reserves (Fr*) will be accumulated and thus, lead to their equilibrium, at least in the short run. Finally, reserve managers should also train and retain highly skilled personnel who could measure and control the associated risks/costs of reserve holding. Though, these staff in view are highly demanded in the private sector due to their skills but, they should offer higher prices than the private sector. This will also go a long way in equilibrating foreign reserves (Fr) and the benchmark stock of reserves (Fr*).
REFERENCES


Aizenman and Jaewoo (2007) Financial versus Monetary Mercantilism-Long-run View of Large International Reserves Hoarding UCSC and the NBER; IMF


Caballero, Ricardo J. and Stavros Panageas (2004) Insurance and Reserves Management in a Model of Sudden Stops, manuscript, MIT.


http://www.eusanz.org/pdf/conf04/choi_baek.pdf


CIA World Fact Book (2010) Economy of Nigeria,


Edwards (1985) On the Interest – Rate Elasticity of the Demand for International Reserves:


Kemal (2002) Optimal Level of Reserves in Developing Economies, with Special Reference to Pakistan, Pakistan Institute of Development Economics, Islamabad, (Public Policy Papers No.1)


Landell-Mills (1989) The Demand for International Reserves and their Opportunity Cost,


Robert and Vijay (2010) Keynes, Global Imbalances, and International Monetary Reform,
Rebalancing the Global Economy: A Primer for Policymaking by Stijn Claessens, Simon Evenett and Bernard Hoekman (eds), Wednesday, June 23.


APPENDIX

UNIT ROOT TESTS

LOG(FR) ~ I(1)

<table>
<thead>
<tr>
<th>ADF Test Statistic</th>
<th>-5.228219</th>
</tr>
</thead>
<tbody>
<tr>
<td>1% Critical Value*</td>
<td>-4.2242</td>
</tr>
<tr>
<td>5% Critical Value</td>
<td>-3.5348</td>
</tr>
<tr>
<td>10% Critical Value</td>
<td>-3.1988</td>
</tr>
</tbody>
</table>

*MacKinnon critical values for rejection of hypothesis of a unit root.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LOG(FR),2)
Method: Least Squares
Date: 03/10/12 Time: 10:12
Sample(adjusted): 1973 2009
Included observations: 37 after adjusting endpoints

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>D(LOG(FR(-1)))</td>
<td>-1.328335</td>
<td>0.254070</td>
<td>-5.228219</td>
<td>0.0000</td>
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<tr>
<td>D(LOG(FR(-1)),2)</td>
<td>0.207429</td>
<td>0.171117</td>
<td>1.212208</td>
<td>0.2340</td>
</tr>
<tr>
<td>C</td>
<td>0.376583</td>
<td>0.289648</td>
<td>1.300143</td>
<td>0.2026</td>
</tr>
<tr>
<td>@TREND(1970)</td>
<td>8.18E-05</td>
<td>0.011961</td>
<td>0.006837</td>
<td>0.9946</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.567339</td>
<td>Mean dependent var</td>
<td>-0.012787</td>
<td></td>
</tr>
<tr>
<td>Adjusted R-squared</td>
<td>0.528006</td>
<td>S.D. dependent var</td>
<td>1.130159</td>
<td></td>
</tr>
<tr>
<td>S.E. of regression</td>
<td>0.776440</td>
<td>Akaike info criterion</td>
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<tr>
<td>Sum squared resid</td>
<td>19.89436</td>
<td>Schwarz criterion</td>
<td>2.607765</td>
<td></td>
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<tr>
<td>Log likelihood</td>
<td>-41.02182</td>
<td>F-statistic</td>
<td>14.42404</td>
<td></td>
</tr>
<tr>
<td>Durbin-Watson stat</td>
<td>1.996499</td>
<td>Prob(F-statistic)</td>
<td>0.000004</td>
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</tbody>
</table>

LOG(Y) ~ I(1)

<table>
<thead>
<tr>
<th>ADF Test Statistic</th>
<th>-4.517220</th>
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</thead>
<tbody>
<tr>
<td>1% Critical Value*</td>
<td>-3.6171</td>
</tr>
<tr>
<td>5% Critical Value</td>
<td>-2.9422</td>
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<tr>
<td>10% Critical Value</td>
<td>-2.6092</td>
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*MacKinnon critical values for rejection of hypothesis of a unit root.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LOG(Y),2)
Method: Least Squares
Date: 03/10/12 Time: 10:17
Sample(adjusted): 1973 2009
Included observations: 37 after adjusting endpoints

<table>
<thead>
<tr>
<th>Variable</th>
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<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
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<td>D(LOG(Y(-1)))</td>
<td>-1.066310</td>
<td>0.236055</td>
<td>-4.517220</td>
<td>0.0001</td>
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<tr>
<td>D(LOG(Y(-1)),2)</td>
<td>0.111751</td>
<td>0.170433</td>
<td>0.655691</td>
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<td>C</td>
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<td>0.067270</td>
<td>2.138246</td>
<td>0.0398</td>
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<td>R-squared</td>
<td>0.486282</td>
<td>Mean dependent var</td>
<td>0.000744</td>
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<tr>
<td>Adjusted R-squared</td>
<td>0.456063</td>
<td>S.D. dependent var</td>
<td>0.488853</td>
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<td>S.E. of regression</td>
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<td>Akaike info criterion</td>
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<td>Schwarz criterion</td>
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<td>F-statistic</td>
<td>16.09208</td>
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<td>Durbin-Watson stat</td>
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<td>Prob(F-statistic)</td>
<td>0.000012</td>
<td></td>
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</table>
**DID~ I(1)**

ADF Test Statistic  -4.777675   1% Critical Value* -2.6344
                     5% Critical Value -1.9514
                     10% Critical Value -1.6211

*MacKinnon critical values for rejection of hypothesis of a unit root.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LOG(DID),2)
Method: Least Squares
Date: 03/10/12   Time: 10:21
Sample(adjusted): 1973 2009
Included observations: 33
Excluded observations: 4 after adjusting endpoints

<table>
<thead>
<tr>
<th>Variable</th>
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<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>D(DID(-1))</td>
<td>-1.500847</td>
<td>0.314137</td>
<td>-4.777675</td>
<td>0.0000</td>
</tr>
<tr>
<td>D(DID(-1),2)</td>
<td>-0.003686</td>
<td>0.182368</td>
<td>-0.020211</td>
<td>0.9840</td>
</tr>
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</table>

R-squared 0.745783
Mean dependent var 0.035720

**LOG(Ev) ~ I(1)**

ADF Test Statistic  -2.945823   1% Critical Value* -2.6261
                     5% Critical Value -1.9501
                     10% Critical Value -1.6205

*MacKinnon critical values for rejection of hypothesis of a unit root.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LOG(EV),2)
Method: Least Squares
Date: 03/10/12   Time: 10:22
Sample(adjusted): 1973 2009
Included observations: 37 after adjusting endpoints

<table>
<thead>
<tr>
<th>Variable</th>
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<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>D(LOG(EV(-1)))</td>
<td>-0.574293</td>
<td>0.194952</td>
<td>-2.945823</td>
<td>0.0057</td>
</tr>
<tr>
<td>D(LOG(EV(-1)),2)</td>
<td>-0.146116</td>
<td>0.168688</td>
<td>-0.866191</td>
<td>0.3923</td>
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</tbody>
</table>

R-squared 0.745783
Mean dependent var 0.035720
LOG(Fop) \sim I(1)

ADF Test Statistic   -3.492774  1% Critical Value\* -2.6261
                      5% Critical Value  -1.9501
                      10% Critical Value -1.6205

*MacKinnon critical values for rejection of hypothesis of a unit root.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LOG(FOP),2)
Method: Least Squares
Date: 03/10/12   Time: 10:25
Sample(adjusted): 1973 2009
Included observations: 37 after adjusting endpoints

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>D(LOG(FOP(-1)))</td>
<td>-0.698562</td>
<td>0.200002</td>
<td>-3.492774</td>
<td>0.0013</td>
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<td>D(LOG(FOP(-1)),2)</td>
<td>-0.006370</td>
<td>0.167817</td>
<td>-0.037961</td>
<td>0.9699</td>
</tr>
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</table>

R-squared 0.353131
Mean dependent var -0.004238
Adjusted R-squared 0.334649
S.D. dependent var 0.681180
S.E. of regression 0.558632
Akaike info criterion 1.715118
Sum squared resid 10.80545
Schwarz criterion 1.802194
Log likelihood -29.72968

LOG(Top) \sim I(1)

ADF Test Statistic   -5.147303  1% Critical Value\* -2.6261
                      5% Critical Value  -1.9501
                      10% Critical Value -1.6205

*MacKinnon critical values for rejection of hypothesis of a unit root.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LOG(TOP),2)
Method: Least Squares
Date: 03/10/12   Time: 10:26
Sample(adjusted): 1973 2009
Included observations: 37 after adjusting endpoints

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>D(LOG(TOP(-1)))</td>
<td>-1.449570</td>
<td>0.281617</td>
<td>-5.147303</td>
<td>0.0000</td>
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<tr>
<td>D(LOG(TOP(-1)),2)</td>
<td>0.042734</td>
<td>0.168588</td>
<td>0.253485</td>
<td>0.8014</td>
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R-squared 0.694656
Mean dependent var -0.001375
Adjusted R-squared 0.685932
S.D. dependent var 0.408561
S.E. of regression 0.228965
Akaike info criterion -0.057958
Sum squared resid 1.834872
Schwarz criterion 0.029119
Log likelihood 3.072224

Durbin-Watson stat 1.975479

Durbin-Watson stat 1.992020
LOG(DFEX) ~ I(1)

ADF Test Statistic -4.939411  
1% Critical Value* -2.6261  
5% Critical Value -1.9501  
10% Critical Value -1.6205

*MacKinnon critical values for rejection of hypothesis of a unit root.

Augmented Dickey-Fuller Test Equation  
Dependent Variable: D(LOG(DFEX),2)  
Method: Least Squares  
Date: 04/16/12 Time: 13:43  
Sample(adjusted): 1973 2009  
Included observations: 37 after adjusting endpoints

<table>
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<th>Prob.</th>
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</thead>
<tbody>
<tr>
<td>D(LOG(DFEX(-1)))</td>
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<td>D(LOG(DFEX(-1)),2)</td>
<td>0.195873</td>
<td>0.171573</td>
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<td>0.497896</td>
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<td>S.D. dependent var</td>
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<td>S.E. of regression</td>
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<td>Akaike info criterion</td>
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<td>Sum squared resid</td>
<td>39.51568</td>
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<td>3.098841</td>
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<td>Log likelihood</td>
<td>-53.71765</td>
<td>Durbin-Watson stat</td>
<td>1.944173</td>
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</table>

DFr* ~ I(1)

ADF Test Statistic -4.487746  
1% Critical Value* -2.6261  
5% Critical Value -1.9501  
10% Critical Value -1.6205

*MacKinnon critical values for rejection of hypothesis of a unit root.

Augmented Dickey-Fuller Test Equation  
Dependent Variable: D(DFr*,2)  
Method: Least Squares  
Date: 04/16/12 Time: 13:48  
Sample(adjusted): 1973 2009  
Included observations: 37 after adjusting endpoints

<table>
<thead>
<tr>
<th>Variable</th>
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<th>t-Statistic</th>
<th>Prob.</th>
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</thead>
<tbody>
<tr>
<td>D(DFr*(-1))</td>
<td>-1.263158</td>
<td>0.281468</td>
<td>-4.487746</td>
<td>0.0001</td>
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<td>D(DFr*(-1),2)</td>
<td>0.052632</td>
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<td>0.277350</td>
<td>0.7831</td>
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<td>R-squared</td>
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<td>0.589474</td>
<td>S.D. dependent var</td>
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<td>S.E. of regression</td>
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<td>Akaike info criterion</td>
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<td>0.988564</td>
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<td>Durbin-Watson stat</td>
<td>2.013881</td>
<td></td>
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</table>
Cointegration Test

ADF Test Statistic

-5.200947

1% Critical Value* -2.6243
5% Critical Value -1.9498
10% Critical Value -1.6204

*MacKinnon critical values for rejection of hypothesis of a unit root.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(RESID01)
Method: Least Squares
Date: 04/16/12 Time: 14:11
Sample(adjusted): 1972 2009
Included observations: 38 after adjusting endpoints

<table>
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<tr>
<th>Variable</th>
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<th>t-Statistic</th>
<th>Prob.</th>
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<tbody>
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<td>RESID01(-1)</td>
<td>-1.010032</td>
<td>0.194202</td>
<td>-5.200947</td>
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<tr>
<td>D(RESID01(-1))</td>
<td>0.258799</td>
<td>0.154767</td>
<td>1.672181</td>
<td>0.1032</td>
</tr>
</tbody>
</table>

R-squared 0.459940
Adjusted R-squared 0.444383
S.E. of regression 0.560680
Sum squared resid 11.31704
Log likelihood -30.90540

Model of Equation (7): The modified version of the buffer Stock Model

Dependent Variable: LOG(FR)
Method: Least Squares
Date: 04/13/12 Time: 10:04
Sample: 1970 2009
Included observations: 40

<table>
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<tr>
<th>Variable</th>
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<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
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<td>LOG(Y)</td>
<td>0.888138</td>
<td>0.153583</td>
<td>5.782787</td>
<td>0.0000</td>
</tr>
<tr>
<td>DID</td>
<td>-0.249014</td>
<td>0.700460</td>
<td>-0.35501</td>
<td>0.7245</td>
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<td>LOG(EV)</td>
<td>1.184641</td>
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<td>0.0000</td>
</tr>
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<td>LOG(FOP)</td>
<td>-0.838012</td>
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<tr>
<td>LOG(TOP)</td>
<td>0.637820</td>
<td>0.500729</td>
<td>1.273785</td>
<td>0.2119</td>
</tr>
<tr>
<td>DFr*</td>
<td>0.085270</td>
<td>0.335254</td>
<td>0.254343</td>
<td>0.8009</td>
</tr>
<tr>
<td>LOG(DFEX)</td>
<td>0.306895</td>
<td>0.106310</td>
<td>2.886794</td>
<td>0.0069</td>
</tr>
</tbody>
</table>

R-squared 0.969494
Adjusted R-squared 0.962821
S.E. of regression 0.660475
Sum squared resid 13.95927
Log likelihood -35.70283
Durbin-Watson stat 1.502455

Mean dependent var 0.015165
S.D. dependent var 0.752566
Akaike info criterion 1.731863
Schwarz criterion 1.818052
Log likelihood -30.90540
F-statistic 145.2818
Prob(F-statistic) 0.000000
Controlling for Heteroscedasticity in the modified version of the buffer Stock Model

Dependent Variable: LOG(FR)
Method: Least Squares
Date: 04/16/12   Time: 14:18
Sample: 1970 2009
Included observations: 40
White Heteroskedasticity-Consistent Standard Errors & Covariance

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>-7.007895</td>
<td>2.425874</td>
<td>-2.888812</td>
<td>0.0069</td>
</tr>
<tr>
<td>LOG(Y)</td>
<td>0.888138</td>
<td>0.163398</td>
<td>5.435418</td>
<td>0.0000</td>
</tr>
<tr>
<td>DID</td>
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<td>0.294600</td>
<td>-0.845260</td>
<td>0.4042</td>
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<td>LOG(EV)</td>
<td>1.184641</td>
<td>0.106040</td>
<td>11.17165</td>
<td>0.0000</td>
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<tr>
<td>LOG(FOP)</td>
<td>-0.838012</td>
<td>0.138807</td>
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<td>LOG(TOP)</td>
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<tr>
<td>DFr*</td>
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<td>0.214084</td>
<td>0.8318</td>
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<tr>
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<td>0.089195</td>
<td>3.440733</td>
<td>0.0016</td>
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R-squared 0.969494  Mean dependent var 10.21794
Adjusted R-squared 0.962821  S.D. dependent var 3.425360
S.E. of regression 0.660475  Akaike info criterion 2.185142
Sum squared resid 13.95927  Schwarz criterion 2.522918
Log likelihood -35.70283  F-statistic 145.2818
Durbin-Watson stat 1.502455  Prob(F-statistic) 0.000000

Error Correction Model

Dependent Variable: D(LOG(FR))
Method: Least Squares
Date: 04/16/12   Time: 14:28
Sample(adjusted): 1971 2009
Included observations: 39 after adjusting endpoints
White Heteroskedasticity-Consistent Standard Errors & Covariance

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0.007659</td>
<td>0.108804</td>
<td>0.070396</td>
<td>0.9443</td>
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<tr>
<td>D(LOG(Y))</td>
<td>0.624919</td>
<td>0.264030</td>
<td>2.366848</td>
<td>0.0067</td>
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<td>D(DID)</td>
<td>-0.601850</td>
<td>0.184362</td>
<td>-3.264500</td>
<td>0.0027</td>
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<tr>
<td>D(LOG(EV))</td>
<td>1.335498</td>
<td>0.443081</td>
<td>3.014115</td>
<td>0.0052</td>
</tr>
<tr>
<td>D(LOG(FOP))</td>
<td>-0.804604</td>
<td>0.272019</td>
<td>-2.957900</td>
<td>0.0060</td>
</tr>
<tr>
<td>D(LOG(TOP))</td>
<td>0.738346</td>
<td>0.474153</td>
<td>1.557190</td>
<td>0.1299</td>
</tr>
<tr>
<td>D(DFr*)</td>
<td>0.625889</td>
<td>0.212243</td>
<td>2.948926</td>
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<tr>
<td>D(LOG(DFEX))</td>
<td>0.210022</td>
<td>0.101738</td>
<td>2.064336</td>
<td>0.0477</td>
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<tr>
<td>ECM(-1)</td>
<td>-0.751739</td>
<td>0.262117</td>
<td>-2.867957</td>
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R-squared 0.703927  Mean dependent var 10.21794
Adjusted R-squared 0.671640  S.D. dependent var 3.425360
S.E. of regression 0.589245  Akaike info criterion 1.979226
Sum squared resid 10.41630  Schwarz criterion 2.363125
Log likelihood -29.59490  F-statistic 143.2910
Durbin-Watson stat 1.502455  Prob(F-statistic) 0.000000
A Graph Showing the Extent to which Foreign Reserves (Fr) Depart From the Benchmark Stock of Reserves (Fr*)

![Graph showing the extent to which foreign reserves depart from the benchmark stock.](image)

Correlation Matrix

<table>
<thead>
<tr>
<th>Variables</th>
<th>D(LOG(Y))</th>
<th>D(DID)</th>
<th>D(LOG(EV))</th>
<th>D(LOG(FOP))</th>
<th>D(LOG(TOP))</th>
<th>D(LOG(DFr*))</th>
<th>D(LOG(DFex))</th>
<th>ECM(-1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D(LOG(Y))</td>
<td>1.000000</td>
<td>-</td>
<td>0.107927526357</td>
<td>-</td>
<td>0.0277250935</td>
<td>-</td>
<td>0.01568647</td>
<td>0.384685101031</td>
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<tr>
<td>D(DID)</td>
<td>0.00348764581402</td>
<td>1.000000</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.03226009</td>
<td>0.1912688093</td>
</tr>
<tr>
<td>D(LOG(EV))</td>
<td>-0.107927526357</td>
<td>0.0970701797079</td>
<td>1.000000</td>
<td>0.482988547436</td>
<td>0.11922880490</td>
<td>-</td>
<td>0.059287936482</td>
<td>0.01111980144209</td>
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<tr>
<td>D(LOG(FOP))</td>
<td>-0.0819349962373</td>
<td>-0.0308859146619</td>
<td>0.482988547436</td>
<td>1.000000</td>
<td>0.0736337761823</td>
<td>-</td>
<td>0.162741603996</td>
<td>0.52977593798</td>
</tr>
<tr>
<td>D(LOG(TOP))</td>
<td>-0.0272250935404</td>
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<td>0.1192328040016</td>
<td>-0.0303633761823</td>
<td>1.000000</td>
<td>-</td>
<td>0.271010505242</td>
<td>0.187353055696</td>
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<tr>
<td>D(DFr*)</td>
<td>-0.0013485045951</td>
<td>0.00222600986655</td>
<td>-0.092879396482</td>
<td>0.162741603996</td>
<td>-0.0736105052</td>
<td>1.000000</td>
<td>0.105770725418</td>
<td>0.185395600292</td>
</tr>
<tr>
<td>D(LOG(DFex))</td>
<td>0.015686479391</td>
<td>0.0222600986655</td>
<td>0.011960144209</td>
<td>0.52977593798</td>
<td>0.18735055969</td>
<td>0.105770725418</td>
<td>1.000000</td>
<td>0.0794353436717</td>
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<tr>
<td>ECM(-1)</td>
<td>0.384685101031</td>
<td>0.1912688093</td>
<td>0.0739470701823</td>
<td>-0.076465834665</td>
<td>0.29355260655</td>
<td>-</td>
<td>0.0794353436717</td>
<td>1.000000</td>
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</table>
Heteroskedasticity test

White Heteroskedasticity Test:
F-statistic 0.780859  Probability 0.690290
Obs*R-squared 14.12593  Probability 0.589333

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 04/16/12  Time: 14:42
Sample: 1971 2009
Included observations: 39

White Heteroskedasticity-Consistent Standard Errors & Covariance

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0.086799</td>
<td>0.176838</td>
<td>0.490840</td>
<td>0.6284</td>
</tr>
<tr>
<td>D(LOG(Y))</td>
<td>0.387360</td>
<td>0.847647</td>
<td>-0.43795</td>
<td>0.6552</td>
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<tr>
<td>(D(LOG(Y)))^2</td>
<td>-0.019675</td>
<td>0.449243</td>
<td>-0.43795</td>
<td>0.6552</td>
</tr>
<tr>
<td>D(DID)</td>
<td>0.126677</td>
<td>0.200207</td>
<td>0.632734</td>
<td>0.5334</td>
</tr>
<tr>
<td>(D(DID))^2</td>
<td>-0.265570</td>
<td>0.180697</td>
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<td>0.1558</td>
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<tr>
<td>D(LOG(EV))</td>
<td>1.179999</td>
<td>1.150669</td>
<td>1.025490</td>
<td>0.3163</td>
</tr>
<tr>
<td>(D(LOG(EV)))^2</td>
<td>-0.763327</td>
<td>0.726521</td>
<td>-1.050661</td>
<td>0.3048</td>
</tr>
<tr>
<td>D(LOG(FOP))</td>
<td>-0.696007</td>
<td>0.473018</td>
<td>-1.471417</td>
<td>0.1553</td>
</tr>
<tr>
<td>(D(LOG(FOP)))^2</td>
<td>0.595104</td>
<td>0.379637</td>
<td>1.567561</td>
<td>0.1313</td>
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<tr>
<td>D(LOG(TOP))</td>
<td>0.230042</td>
<td>0.339782</td>
<td>0.677029</td>
<td>0.5054</td>
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<tr>
<td>(D(LOG(TOP)))^2</td>
<td>-0.370134</td>
<td>0.678641</td>
<td>-0.545045</td>
<td>0.5910</td>
</tr>
<tr>
<td>D(DFr*)</td>
<td>0.395915</td>
<td>0.321943</td>
<td>1.229768</td>
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<tr>
<td>(D(DFr*))^2</td>
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<td>0.4744</td>
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<tr>
<td>D(LOG(DFEX))</td>
<td>0.124414</td>
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<td>0.723856</td>
<td>0.4768</td>
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<tr>
<td>(D(LOG(DFEX)))^2</td>
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<td>0.058258</td>
<td>-1.577149</td>
<td>0.1290</td>
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<tr>
<td>ECM(-1)</td>
<td>0.019252</td>
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<td>0.8954</td>
</tr>
<tr>
<td>ECM(-1)^2</td>
<td>0.049501</td>
<td>0.203161</td>
<td>0.243654</td>
<td>0.8098</td>
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</table>

R-squared 0.362203  Mean dependent var 0.267085
Adjusted R-squared -0.101649  S.D. dependent var 0.391545
S.E. of regression 0.410964  Akaike info criterion 1.358654
Sum squared resid 3.715612  Schwarz criterion 2.083796
Log likelihood -9.493746  F-statistic 0.780859
Durbin-Watson stat 1.935157  Prob(F-statistic) 0.690290

Normality test

Series: Residuals
Sample 1971 2009
Observations 39

Mean -3.84E-17
Median -0.006048
Maximum 1.260922
Minimum -1.295913
Std. Dev. 0.523558
Skewness 0.087804
Kurtosis 3.094044

Jarque-Bera 0.064849  Probability 0.968727
Specification error Test

Ramsey RESET Test:

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>F-statistic</td>
<td>1.203713</td>
<td>0.281608</td>
</tr>
<tr>
<td>Log likelihood ratio</td>
<td>1.586092</td>
<td>0.207885</td>
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Test Equation:
Dependent Variable: D(LOG(FR))
Method: Least Squares
Date: 04/16/12   Time: 15:01
Sample: 1971 2009
Included observations: 39

White Heteroskedasticity-Consistent Standard Errors & Covariance

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>-0.040748</td>
<td>0.118277</td>
<td>-0.344511</td>
<td>0.7329</td>
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<tr>
<td>D(LOG(Y))</td>
<td>0.459970</td>
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</tr>
<tr>
<td>D(DID)</td>
<td>-0.389552</td>
<td>0.434385</td>
<td>-0.897709</td>
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</tr>
<tr>
<td>D(LOG(EV))</td>
<td>1.105607</td>
<td>0.440015</td>
<td>2.512658</td>
<td>0.0178</td>
</tr>
<tr>
<td>D(LOG(FOP))</td>
<td>-0.682391</td>
<td>0.232190</td>
<td>-2.938930</td>
<td>0.0064</td>
</tr>
<tr>
<td>D(LOG(TOP))</td>
<td>0.649066</td>
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<td>1.291230</td>
<td>0.2068</td>
</tr>
<tr>
<td>D(DFr*)</td>
<td>0.523767</td>
<td>0.305170</td>
<td>1.716311</td>
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<tr>
<td>D(LOG(DFEX))</td>
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<td>FITTED^2</td>
<td>0.288976</td>
<td>0.227256</td>
<td>1.271589</td>
<td>0.2136</td>
</tr>
</tbody>
</table>

R-squared 0.523697  Mean dependent var 0.282364
Adjusted R-squared 0.375878  S.D. dependent var 0.743348
S.E. of regression 0.587255  Akaike info criterion 1.989839
Sum squared resid 10.00118  Schwarz criterion 2.416393
Log likelihood -28.80186  F-statistic 3.542840
Durbin-Watson stat 1.738558  Prob(F-statistic) 0.004508