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Exchange Market Pressures in Egypt: Logit and Probit Early Warning Systems

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Abstract

This paper investigates the nature of exchange market pressures in Egypt, monetary policy responses as well as the effectiveness of monetary interventions in the foreign exchange market. Empirical analysis revealed that the exchange market in Egypt has been exposed to persistent downward pressures, which has been exacerbated starting from 2011. The monetary authority in Egypt used to play an active role in the foreign exchange market to ensure both liquidity and stability in the market in around 69 percent of the sample period considered. However, around 46 percent of monetary policy interventions have been effective in relieving pressures in the foreign exchange market. Moreover, both upward and downward pressures on domestic currency can have a significant negative long run effect on the absorptive capacity of monetary interventions. Finally, logit and probit early warning systems can be useful in predicting exchange market pressures in Egypt.

Keywords: *Exchange Market Pressures, ARDL, NARDL, Logit, Probit.*

1. Introduction

The exchange rate policy has become one of the most controversial issues in the Egyptian economy with the public, academicians and policy makers. The economy has been exposed to significant exchange market pressures after the January 25^{th} revolution as a result of a plunge in its main macroeconomic indicators; which should have been reflected in the market exchange rate. Nevertheless, the Central Bank of Egypt (CBE) tried to stabilize the exchange rate of the Egyptian pound vis-à-vis other currencies mainly for social and political purposes.

Since July 2013, the Egyptian pound has stabilized within a 2% band against the U.S. dollar. This trend continued through April 2014, Egypt's de facto exchange rate arrangement has been reclassified from a "crawl like" to a "stabilized arrangement", effective July 3, 2013. The stabilization policies implemented by the monetary authority and continuous interventions in the foreign exchange market should not have been expected to be sustainable, as the Egyptian pound has been overvalued for a prolonged time period and the achievement of this target necessitates the existence of sufficient official international reserves to enable the monetary authority to ensure its grip on the market (IMF, 2014); this is not the case; that's why, the CBE has opted to adopt a free float exchange rate regime starting from November 2016.

The lack of sufficient international reserves and the plunge in inflows of foreign currencies from traditional sources hindered the ability of the monetary authority to maintain its exchange rate policy, whereby market expectations fueled transactions in the parallel market due to sustainability concerns related to such policy.

Real exchange rate depreciation has been recommended in the literature as an effective policy to improve the competitiveness of the economy's exports in global markets, as real exchange rate misalignments are expected to be detrimental to economic growth and competitiveness. Nevertheless, external competitiveness issues can't be easily addressed by altering the exchange rate level per se, as the national currency might be satisfying the short-run equilibrium at any point in time, but drifting away from the long-term sustainable equilibrium levels that are supported by economic fundamentals. Thus, changes in the exchange rate should be justifiable by the macroeconomic fundamentals.

There is a consensus among policy makers and academicians that the Egyptian pound has been overvalued for a prolonged time period. (Hosni & Rofael, 2015) investigated Real Exchange Rate (RER) misalignments in Egypt over (1999-2012), and they concluded that the Egyptian Pound has been recently overvalued, with a growing trend in the relative prices in favor of Egypt's trading partners. They recommended narrowing down these misalignments and devaluing the Egyptian pound by a range of 9 to 13 percent in order for the Egyptian products not to lose their competitiveness in the international markets. However, no recent empirical studies have investigated the evolution of exchange market pressures in Egypt, the nature of monetary policy reactions to such pressures as well as the effectiveness of such interventions in stabilizing the foreign exchange market.

The contribution of this paper is: ***Firstly:*** Investigating the main characteristics of the exchange market pressures in Egypt, ***Secondly:*** Identifying the features of monetary policy responses to exchange market pressures, ***Thirdly:*** Assessing the effectiveness of monetary policy interventions in the foreign exchange market, ***Fourthly:*** Analyzing potential asymmetries in monetary policy responses to foreign exchange market pressures in Egypt, ***Fifthly:*** Assessing the ability of logit and probit early warning systems (EWSs) to predict exchange market pressures in Egypt.

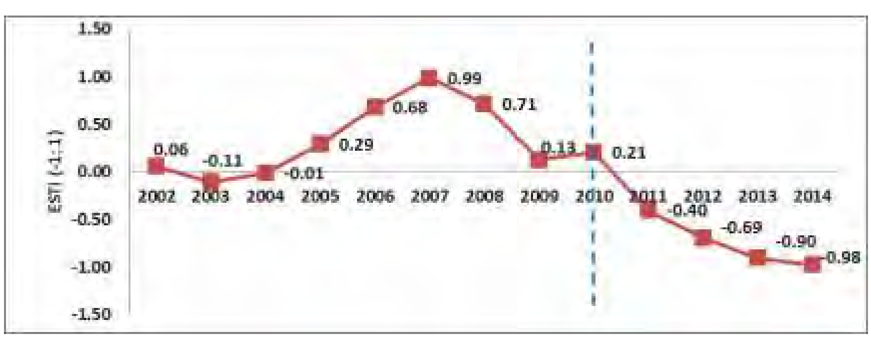
The rest of the paper is organized as follows: ***Section Two: The Egyptian Economy: Stylized Facts:*** Highlights the developments of macroeconomic stability and the main challenges facing the Egyptian economy. ***Section Three: Exchange Market Pressures: Theoretical Overview:*** Provides an overview of the definition of exchange market pressures and the empirical approaches used to measure both exchange market pressures as well as the degree of monetary policy intervention in the foreign exchange market. ***Section Four: Econometric Analysis:*** Introduces the econometric methodologies used in empirical analysis, data and empirical results. ***Section Five: Conclusion:*** Comprises the conclusion and policy implications.

2. The Egyptian Economy: Stylized Facts

This section highlights the evolution of macroeconomic stability and the challenges facing the Egyptian economy. The Egyptian economy has witnessed a gradual buildup of economic stability risks as depicted by the Economic Stability Trend Index (ESTI) (Figure 1), which switched to the negative direction starting from 2011 as real GDP growth rates over the period (2008-2014) recorded an average of about 3.6 percent, while growth rates exhibited a significant fall starting from 2011 as the average real GDP growth rate during (2008-2010) was around 5.7 percent, also real GDP per capita declined after 2011. Both national saving-to-GDP ratio and total investment-to-GDP ratio declined after 2011 and recorded around 13.2 percent and 14 percent in 2014, respectively, in tandem with a significant increase in structural budget deficit-to- potential GDP ratio, which increased from 8.3 percent in 2010 to 13 percent in 2014. Unemployment rate has also increased from 8.3 percent in 2010 to 13 percent in 2014.

The aforementioned indicators reflect the size of economic challenges facing the Egyptian economy which should be reflected in the foreign exchange market and equilibrium exchange rate. That's why structural economic reforms should be undertaken to put the economy on a sustainable path to economic growth.

Figure (1): Egypt's Economic Stability Trend Index (ESTI) (2002-2014)



Source: Researcher's Calculations.

3. Exchange Market Pressures: Theoretical Overview:

This section provides an overview of the definition of exchange market pressures and the empirical approaches used to measure both exchange market pressures as well as the degree of monetary policy intervention in the foreign exchange market to lay the ground for the empirical analysis in the rest of the paper.

- **Literature Review:**

Exchange market pressure is defined as money market disequilibrium that occurs as a result of non-zero excess demand or supply of domestic currency in the foreign exchange market (Taslim, 2003). Such pressure in the foreign exchange market is not directly observable. However, it is measured by changes in the macroeconomic variables that could be used to restore equilibrium in the money market. Under fixed exchange rate regimes, exchange market pressures are reflected in changes in official international reserves. On the other hand, under a free float exchange rate regime, changes in the market exchange rate reflect the extent of foreign exchange market disequilibrium. In a managed float or intermediate exchange rate regime, simultaneous changes in both exchange rate and official international reserves reflect the extent of disequilibrium at the foreign exchange market.

(Girton & Roper, 1977) first derived an Exchange Market Pressure index using the monetary approach to the balance of payments. It refers to the volume and degree of intervention required to restore equilibrium at the foreign exchange market, mainly through money market operations and exchange rate changes under both fixed and free float exchange rate regimes, respectively. Under a managed float, both money market operations and exchange rate changes are employed to absorb exchange market pressures and ensure equilibrium at the foreign exchange market.

(Weymark, 1995) made a notable contribution to the literature related to exchange market pressures. She introduced a macroeconomic model for deriving the weights assigned to the components of exchange market pressure index. Numerous empirical studies have applied the (Weymark, 1995) approach to investigate exchange market pressures and monetary policy reactions to such pressures in several economies. These studies include (Poso & Spolander, 1997) to Finland, (Kohlscheen, 2002) to Chile, (Taslim, 2003) to (Australia, Akiba, & Ida, 2004) to Singapore (Jeisman, 2005) to Australia. (Kohlscheen, 2002) slightly modified Weymark's (1995) approach to account for the Chilean policy of reserve requirements on foreign capital inflows. Empirical evidence revealed that Central Banks usually intervene in the foreign exchange market to avoid undesirable exchange rate volatility and ensure long run stability at the foreign exchange market.

In this paper, we will employ Weymark's (1995) approach to assess the extent and direction of exchange market pressures and evaluate the nature of monetary authority responses by constructing both an Exchange Market Pressure Index (EMPI) and a Monetary Policy Intervention Index (MPII).

The models of currency crisis include two main methodologies that have been extensively used in empirical studies. The first approach is the Signals approach, which is a non-parametric approach, and the second approach is the limited dependent variable regression (Probit and Logit models), which is a parametric approach that facilitates the anticipation of a currency crisis.

The signals approach was introduced by Kaminsky et al. (1998), and further developed by Edison (2003). Kaminsky et al. (1998) investigated the evolution of several indicators with a view to assessing their importance in predicting currency crises. Thus, the macroeconomic fundamentals of the economy should be tracked as when a particular indicator exceeds a given threshold, it might be interpreted as a warning signal indicating that a currency crisis or exchange market pressures may take place.

Limited dependent variable regression models can be used to estimate the probability of a currency crisis. The currency crisis indicator is modeled as a zero-one variable and the prediction of the model is interpreted as the probability of a crisis to occur, more specifically, in line with the probit regression analysis put forward by Frenkel and Rose (1996). The study of Van Rijckeghem and Weder (2003) uses probit regression to examine the role of a common lender channel in triggering crisis events. Other studies used other sophisticated versions of logit and probit models; Comelli (2014) employed fixed effects logit and probit models to compare the performance of logit and probit early warning systems in anticipating currency crises for a panel of emerging market economies. Comelli (2014) investigated the episodes of currency crises that took place in 29 emerging markets between January 1995 and December 2012; the paper concluded that higher real GDP growth rates and higher net foreign assets can significantly reduce the probability of experiencing a currency crisis, while high levels of credit to the private sector increase it. Moreover logit and probit EWSs out-of-sample performances were broadly similar, and the paper confirmed that their performance can be sensitive to the size of the estimation sample, and to the crisis definition employed.

- **Modeling Exchange Market Pressure:**

In this part, we will introduce the methodology used by Weymark's (1995) to model exchange market pressure and monetary policy reactions. The Weymark's (1995) model consists of the following equations:

$m_t^d = P_t + \beta_1 Y_t - \beta_2 i_t + \varepsilon_t$	β_1 and $\beta_2 > 0$	(3.1)
$P_t = \alpha_0 + \alpha_1 P_t^* + \alpha_2 S_t$	α_1 and $\alpha_2 > 0$	(3.2)
$i_t = i_t^* + E_t S_{t+1} - S_t$		(3.3)
$m_t^s = m_{t-1}^s + \Delta d_t + \Delta f_t$		(3.4)
$\Delta f_t = -\rho \, \Delta S_t$		(3.5)

Equation (3.1) explains that an increase in real income (Y_t) increases the demand for nominal money balances (m_t^d), while an increase in nominal interest rate (i_t) raises the opportunity cost of holding money and thus reduces the demand for money. Equation (3.2) characterizes the evolution of domestic price level, whereby domestic prices are affected by changes in foreign price levels as well as the nominal exchange rate fluctuations "pass-through effect". Equation (3.3) is the Uncovered Interest Rate Parity condition, which states that any divergence between domestic (i_t) and foreign interest rates (i_t^*) should be reflected in expected exchange rate changes, and $E_t S_{t+1}$ denotes the value that rational agents expect in period *t*+1 given the information in period *t.* Equation (3.4) defines money supply at period t (m_t^s) as the sum of inherited money stock (m_{t-1}^s), domestic credit (Δd_t) and foreign exchange reserve (Δf_t). Equation (3.5) is the monetary authority's reaction function to exchange rate fluctuations.

Substituting equations (3.2) and (3.3) in (3.1), and taking the difference of the resulting equation, combining it with the Central Bank's reaction function and re-arranging the resulting equation yields:

$$\Delta S_t = \frac{-\{(\alpha1\ \Delta Pt{*}+\beta1\ \Delta Yt - \beta2\ \Delta\ it{*}\ + \varepsilon t - \Delta dt - \ \beta2\ \Delta\ Et\ St{+}1) + \Delta ft\}}{\alpha2 + \beta2} \qquad (3.6)$$

Equation (3.6) shows that changes in foreign prices, domestic income, foreign interest rate, and domestic credit, expected changes in the spot exchange rate and official international reserves determine changes in exchange rate. The elasticity of the exchange rate with respect to official international reserves (η) is given by equation (3.7):

$$\eta = \frac{-\,\partial\Delta\, St}{\partial\Delta\, ft} = \frac{-1}{\alpha2 +\ \beta2} \qquad (3.7)$$

The Exchange market pressure index indicates how exchange market pressures reflect changes in market exchange rate and official international reserves, respectively, whereby, positive (negative) values of the index depict downward (upward) pressures on domestic currency. The Exchange market pressure index (EMPI) is defined by the equation (3.8), while the monetary policy intervention index (MPII) indicates the percentage of exchange market pressure absorbed through changes in official international reserves "monetary operations". The MPII is defined by equation (3.9).

$$EMPI_t = \Delta S_t + \eta \Delta f_t \qquad (3.8)$$

$$MPII_t = \frac{\eta\Delta ft}{EMPIt} = \frac{\eta\Delta ft}{\Delta St + \eta\Delta ft} = \frac{\Delta ft}{\left(\frac{1}{\eta}\right)\Delta St + \Delta ft} \qquad (3.9)$$

The values of the (MPII) are expected to range between ($-\infty < MPII_t < \infty$), where there are five different possibilities as follows: 1- *When $MPII_t$ equals to zero:* it means the central bank fully abstained from intervention in the foreign exchange market, implying the existence of a full float exchange rate regime. 2- *When $MPII_t$ equals to one:* It means the existence of a one–to-one proportional relationship between both exchange market pressures and changes in international reserves under a fixed exchange rate regime. 3-*When $MPII_t$ ranges between zero and one:* It means that exchange market pressures are absorbed through changes in both exchange rate and international reserves. 4- *When $MPII_t < 0$:* it means that the central bank is leaning with the wind; which means that the central bank purchases foreign currency during periods of downward pressures on domestic currency. 5- *When $MPII_t > 1$:* it means that the central bank's reaction to exchange market pressures is more than that warranted by the magnitude of such pressures.

The relative effectiveness of monetary policy interventions in stabilizing the foreign exchange market and containing pressures could be evaluated by comparing actual exchange rate (S) with potential exchange rate (S^*) that could have prevailed in the absence of monetary interventions, where (S^*) is calculated using equation (3.10). Then the exchange rate gap (SGAP) can be calculated as the relative deviation of actual exchange rate from its potential level using equation (3.11).

$$S^*_t = S_{t-1} \times (1 + EMPI_t) \qquad (3.10)$$

$$SGAP_t = \{(S_t - S^*_t)/(S^*_t)\} \times 100 \qquad (3.11)$$

4 - Econometric Analysis

- **Methodology:**

The econometric methodology employed in this section will enable us to answer the following five questions: ***Firstly:*** What are the main characteristics of exchange market pressures in Egypt? ***Secondly:*** What are the main features of monetary policy responses to exchange market pressures? ***Thirdly:*** To what extent, monetary policy interventions in the foreign exchange market are effective? ***Fourthly:*** Do asymmetries exist in monetary policy responses to foreign exchange market pressures in Egypt? ***Fifthly:*** Can logit and probit EWSs be useful in predicting exchange market pressures in Egypt?

In this section, we will estimate both the exchange market pressure index (EMPI) and monetary policy intervention index (MPII), using the methodology explained in section three with the Autoregressive Distributed Lag (ARDL) model, to be able to answer the first three questions aforementioned. Then, the Nonlinear Autoregressive Distributed Lag (NARDL) model will be used to answer the fourth question; finally logit and probit models will be used to answer the fifth question. The ARDL, NARDL as well as logit and probit models will be introduced below.

- **Auto Regressive Distributed Lag (ARDL) Model:**

The ARDL approach is useful to investigate the existence of long-run and short-run relationships, as it allows us to describe the existence of an equilibrium relationship in terms of long-run and short-run dynamics without losing long-run information. The analysis using this approach necessitates testing the existence of a co-integration "equilibrium" long run relationship between the variables, which could be conducted using the following equation.

$$\Delta Ln(Y_t) = \alpha_0 + \sum_{i=1}^{n} \beta i\, \Delta Ln(Y)_{t-i} + \sum_{i=0}^{n} \gamma i\, \Delta Ln(X1)_{t-i} + \sum_{i=0}^{n} \delta i\, \Delta Ln(X2)_{t-i} \qquad (4.1)$$
$$\sum_{i=0}^{n} \phi\, i\, \Delta Ln(X3)_{t-i} + \mu_1 Ln(Y)_{t-1} + \mu_2 Ln(X_1)_{t-1} + \mu_3 Ln(X_2)_{t-1} + \mu_4 Ln(X_3)_{t-1} + \varepsilon_i$$

The parameters βi, γi, δi and ϕi capture the short-run dynamics of the model whereas the parameters µ1 , µ2, µ3 and µ4 represent the long-run relationship. We can test for the existence of a long run relationship between the variables of the model using the following hypothesis:

$$H_0: \mu_1 = \mu_2 = \mu_3 = \mu_4 = 0$$
$$H_1: \mu_1 \neq \mu_2 \neq \mu_3 \neq \mu_4 \neq 0$$

We perform the bounds test to investigate the possibility of a long-run relationship between variables. For this, we perform F-test for the null hypothesis of no co-integration against the alternative one. The computed values of F-statistic should be compared with both lower and upper bounds of the critical values. In the bounds testing procedure there are three possibilities: First, the computed F-statistic falls below the lower bound of the critical value, so we fail to reject the null hypothesis of no co-integration. Second, the computed F-statistic lies above the upper bound of the critical value, so we reject the null hypothesis of no co-integration and conclude that there is a long-run relationship between the variables. Third, if the test statistic falls in between the lower and upper bounds of the critical values, then the result is indecisive.

If the bounds testing procedure confirms the existence of a long-run relationship, then the following long-run model will be estimated:

$$\Delta Ln(Y_t) = \alpha_0 + \sum_{i=1}^{n} \beta i\, Ln(Y)_{t-i} + \sum_{i=0}^{n} \gamma i\, Ln(X1)_{t-i} + \sum_{i=0}^{n} \delta i\, Ln(X2)_{t-i} \qquad (4.2)$$
$$\sum_{i=0}^{n} \phi\, i\, Ln(X3)_{t-i} + \varepsilon_i$$

After estimating the parameters that capture the long run relationship between variables, the Error Correction Model (ECM) could be estimated as follows:

$$\Delta Ln(Y_t) = \alpha_0 + \sum_{i=1}^{n} \beta i\, \Delta Ln(Y)_{t-i} + \sum_{i=0}^{n} \gamma i\, \Delta Ln(X1)_{t-i} + \sum_{i=0}^{n} \delta i\, \Delta Ln(X2)_{t-i} \qquad (4.3)$$
$$\sum_{i=0}^{n} \phi\, i\, \Delta Ln(X3)_{t-i} + \pi_1 (ECT)_{t-1} + \varepsilon_i$$

Diagnostic tests should be used to ensure the goodness of fit of the ARDL model; also stability tests as well as serial correlation, hetroskedasticity, normality and ARCH effect tests should be conducted to ensure the reliability of empirical results obtained.

- **The Asymmetric Nonlinear ARDL (NARDL) Model:**

The methodology used in this paper imports its origin from the autoregressive distributed lag ARDL model which was first introduced in (Pesaran & Shin, 1998) and (Pesaran, Shin ,& Smith, 2001). The ARDL model has been proved to be an efficient technique to investigate whether co-integrating long run relationships exist between variables in small samples, regardless of the order of integration or the stationarity properties of the variables.

The non-linear autoregressive distributed lag (NARDL) model is an asymmetric extension of the linear ARDL. The NARDL model uses partial sum decompositions to allow for non-linearity in the responses of the regressand to changes in regressors. Both short-run and long-run asymmetries can be considered in the transmission process as NARDL allows for modelling the long-run relationship as well as the dynamic adjustment pattern. The asymmetric co-integrating relationship is expressed as follows:

$$Y_t = \beta^+ X_t^+ + \beta^- X_t^- + \varepsilon_t \qquad (4.4)$$

where X_t is a (k ×1) vector of regressors, where X_t^+ and X_t^- are partial sum processes of positive and negative changes in X_t , which can be calculated as expressed by equations (4.5) and (4.6). β^+ and β^- are the asymmetric long-run parameters.

$$X_t^+ = \sum_{j=1}^{t} \Delta X_j^+ = \sum_{j=1}^{t} \max(\Delta X_j , 0) \qquad (4.5)$$

$$X_t^- = \sum_{j=1}^{t} \Delta X_j^- = \sum_{j=1}^{t} \min(\Delta X_j , 0) \qquad (4.6)$$

The asymmetric error correction representation of the NARDL (p, q) can be expressed by equation (4.7) and β+ = (-θ+/ρ) and β- = (-θ-/ρ).

$$\Delta Y_t = \rho Y_{t-1} + \theta^+ X^+_{t-1} + \theta^- X^-_{t-1} + \sum_{j=1}^{p-1} \phi \,\Delta Y_{t-j} + \sum_{j=0}^{q} (\pi^+ \Delta X^+_{t-j} + \pi^- \Delta X^-_{t-j}) + \varepsilon_t \qquad (4.7)$$

This approach has several advantages over regime-switching models. ***Firstly:*** once the regressors, X_t, are decomposed into X_t^+ and X_t^- equation (4.4) can be estimated by the OLS method. ***Secondly:*** the co-integration test is the null hypothesis expressed by equation (4.8), where co-integration exists when we reject the null hypothesis. ***Thirdly:*** Asymmetries in both the long and short run are tested using the null hypotheses expressed by equations (4.9) and (4.10) respectively, where asymmetries exist when we reject the null hypotheses. ***Fourthly:*** The NARDL model not only enables us to assess both short run (impact) and long run (reaction) asymmetries, but also it allows us to investigate adjustment asymmetry using the cumulative dynamic multiplier expressed by equation (4.11), the latter indicates the adjustment patterns from the initial equilibrium to a new equilibrium point after an economic perturbation. It is noteworthy that as the time horizon (h) approaches ∞, $\mathbf{m}^+_h$ and $\mathbf{m}^-_h$ will converge to the asymmetric long run parameters "β^+ and β^-", respectively.

$$H_0: \rho = \theta^+ = \theta^- = 0 \qquad (4.8)$$

$$H_0: (-\theta^+/\rho) = (-\theta^-/\rho) = 0 \text{ or } \beta^+ = \beta^- = 0 \qquad (4.9)$$

$$H0: \sum^{q}_{j=0} \pi^+ = \sum^{q}_{j=0} \pi^- = 0 \qquad (4.10)$$

$$m^+_h = \sum_{j=0}^{h} (\partial Y_{t+j} / \partial X^+_t),\ m^-_h = \sum_{j=0}^{h} (\partial Y_{t+j} / \partial X^-_t), \quad h = 0,1,2,\ldots\ldots \qquad (4.11)$$

- **Logit and Probit models:**

Logit and probit regression models are among the class of Limited dependent variable regression models that can be used to estimate the probability of a particular event to occur. Exchange market pressures in the paper will be modeled as a zero-one variable for upward and downward pressures respectively, and the predicted probabilities of the model will be interpreted as the probability of a downward pressure to exist.

Exchange market pressure will be modeled under these models as the forward-looking pressure variable (Y_t), where it equals to 1 if a downward pressure on domestic currency is observed, and to 0 otherwise. We define Pr (Y_t =1) as the probability of a downward pressure on domestic currency to exist, which will be estimated using logit and probit models. Formally, the probability of a downward pressure to occur is expressed as a nonlinear function of a set of explanatory variables (X), as expressed by equations (4.12) and (4.13) for both models respectively, where $\Lambda(X'\beta)$ is the cumulative distribution function (cdf) of the logistic distribution, and $\Phi(X'\beta)$ is the cumulative distribution function (cdf) of the normal distribution.

$$(\Pr Y_t = 1) = \Lambda(X'\beta) = \frac{e^{X\beta}}{1+e^{X\beta}} \qquad (4.12)$$

$$(\Pr Y_t = 1) = \Phi(X'\beta) = \int_{-\infty}^{X'B} \phi(z)\,dz \qquad (4.13)$$

The diagnostic power of logit and probit models can be evaluated using selected criteria such as the sensitivity[2], specificity[3], false positive rate[4], false negative rate[5], total misspecification error[6], and area under ROC curve[7].

The forecasting performance of the model can be evaluated using both in- sample and out-of-sample forecasting. In case of in-sample forecasting the model is estimated using all data points available and then the predicted probabilities will be compared with actual cases, while in case of out-of-sample forecasting the model is estimated utilizing the dataset up to a particular data point and then this model is used to forecast the post model building period to compare the predicted probabilities with actual observations.

Empirical Estimation

- **Data and Variables:**

Data used for econometric analysis include: Broad money in local currency (m^d), consumer price index (P) (2010=100), domestic lending interest rate (i), domestic output deflated by the GDP deflator (Y), nominal exchange rate of the Egyptian pound vis-à-vis the U.S dollar (S), and the consumer price index in the united states (P*) (2010=100). Other variables for the Egyptian economy included GDP growth rate (GDPG), foreign direct investment, net FDI inflows (% of GDP) (FDI), exports of goods and services (% of GDP) (EXP), imports of goods and services (% of GDP) (IMP), Short-term debt (% of total reserves) (SDEBTRES), and domestic credit to private sector (% of GDP) (DCREDPRIV). Annual data for all variables were obtained from the World Bank, World Development Indicators database over the period (1980-2015).

- **Stationarity Tests:**

Augmented Dickey Fuller (ADF) unit root test was employed to test for the stationarity of all variables included in the analysis and the results of these tests are summarized in Table (1).

Table (1): Results of Stationarity Tests using ADF Unit Root Test

Variable	Test Statistic	Order of Integration
Ln (M/P)	-4.500753*	I(1)
i	-3.846537**	I(1)
Y	-3.358487***	I(1)
Ln (P)	-3.751215**	I(0)
Ln (P*)	-3.208636***	I(0)
S	-3.976158**	I(0)
EMPI	-4.913128*	I(0)
MPII	-5.336528*	I(0)

Source: Author's Calculations.

*Note: *, **, *** denotes significance at 1%, 5%, 10%, respectively. EMPI and MPII are estimated by the author.*

In order to assess the extent of exchange market pressures and monetary policy intervention, the ARDL models expressed by equations (4.14) and (4.15) should be estimated, after testing for co-integration between the variables. Then the elasticity of the exchange rate with respect to official international reserves (η) will be calculated as expressed by equation (3.7) and both the exchange market pressure index (EMPI) and the monetary policy intervention index (MPII) will be calculated according to equations (3.8) and (3.9), respectively.

$$\Delta \text{Ln}\,(m_t^d / P_t) = \alpha_0 + \sum_{i=1}^{n} \beta i\, \Delta(Y)_{t-i} + \sum_{i=0}^{n} \gamma i\, \Delta(i)_{t-i} + \pi_1\, (ECT)_{t-1} + \varepsilon_i \qquad (4.14)$$

$$\Delta \text{Ln}\,(P_t) = \alpha_0 + \sum_{i=1}^{n} \beta i\, \Delta \ln(P*)_{t-i} + \sum_{i=0}^{n} \gamma i\, \Delta(S)_{t-i} + \pi_1\, (ECT)_{t-1} + \varepsilon_i \qquad (4.15)$$

We tested for the existence of co-integration between the variables included in equation (4.14) using the Bounds Test; results revealed the existence of a stable long run relationship between them at 10% significance level (Table 2). The Akaike information criterion revealed that an ARDL (1, 2, 2) model is appropriate, and the error correction representation of the ARDL model is available in Table (3). Also, the variables included in equation (4.15) were tested for co-integration, and results revealed the existence of a stable long run relationship between them at 5% significance level (Table 4). The Akaike information criterion revealed that an ARDL (5, 0, 0) model is appropriate, the error correction representation of the ARDL model is available in Table (5).

The elasticity of the exchange rate with respect to official international reserves (η) was found to equal -0.1581, and both the exchange market pressure index (EMPI) and the monetary policy intervention index (MPII) were calculated over the period (1981-2015).

Table (2): ARDL Bounds Test

Test Statistic	Value	K
F- Statistic	3.665096****	2
	Critical Value Bounds:	
Significance Level	**Lower Bound**	**Upper Bound**
10%	2.63	3.35
5%	3.1	3.87
2.5%	3.55	4.38
1%	4.13	5

Source: Author's Calculations.
*Note: *, **, ***, **** denotes significance at 1%, 2.5%, 5%, 10%, respectively.*

Table (3): The Error Correction Representation for the ARDL Model (1, 2, 2)

	Dependent Variable: Δ Ln (m_t^d/ P_t)	
	Short Run	
Variable	**Coefficient**	**P-value**
Δ i	-0.022569***	0.0507
Δ i(-1)	0.026163**	0.0128
Δ Y	0.0000	0.3355
Δ Y(-1)	-0.000001*	0.0057
ECT_{t-1}	-0.001992*	0.0004
	Long Run	
i	-6.277292	0.9820
Y	-0.000009	0.9836
C	148.3278	0.9810

Source: Author's Calculations.
*Note: *, **, *** denotes significance at 1%, 5%, 10%, respectively.*

Table (4): ARDL Bounds Test

Test Statistic	Value	K
F- Statistic	4.298633***	2
	Critical Value Bounds:	
Significance Level	**Lower Bound**	**Upper Bound**
10%	2.63	3.35
5%	3.1	3.87
2.5%	3.55	4.38
1%	4.13	5

Source: Author's Calculations.
*Note: *, **, ***, **** denotes significance at 1%, 2.5%, 5%, 10%, respectively.*

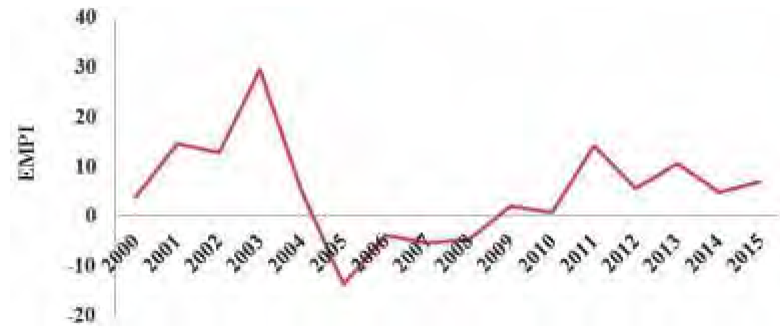
Table (5): The Error Correction Representation for the ARDL Model (5, 0, 0)

	Dependent Variable: ΔLn P_t	
	Short Run	
Variable	**Coefficient**	**P-value**
Δ Ln P(-1)	0.234350	0.1669
Δ Ln P(-2)	0.240169	0.1698
Δ Ln P(-3)	0.169707	0.3375
Δ Ln P(-4)	0.389341*	000382
Δ Ln P*	0.333268	0.4581
Δ S	0.015594	0.2426
ECT_{t-1}	-0.228745*	0.0005
	Long Run	
Ln P*	2.987351*	0.0000
S	0.047701	0.3485
C	-9.534736*	0.0000

Source: Author's Calculations.
*Note: *, **, *** denotes significance at 1%, 5%, 10%, respectively.*

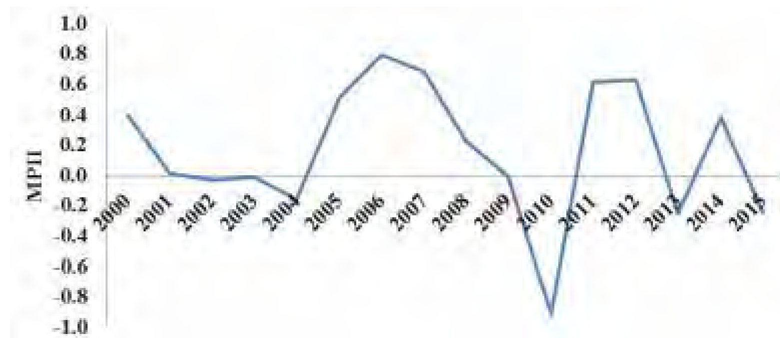
It can be easily visualized from Figure (2) that the exchange market in Egypt has been exposed to persistent downward pressures on domestic currency starting from 2009 onwards, which has been exacerbated starting from 2011 due to the economic slowdown and deterioration of macroeconomic fundamentals after the outbreak of the January 25th revolution. The monetary authority in Egypt used to play an active role in the foreign exchange market to ensure both liquidity and stability in the market, which is evident in figures (3 & 4), where the central bank continued to absorb exchange market pressures through a "leaning against the wind policy" in around 69 percent of the sample period considered in the analysis (Figure 5). It is noteworthy that the Egyptian pound has been exposed to downward pressures in around 63 percent of the sample period considered (Figure 6).

Figure (2): The Exchange Market Pressure Index for Egypt, (2000-2015)



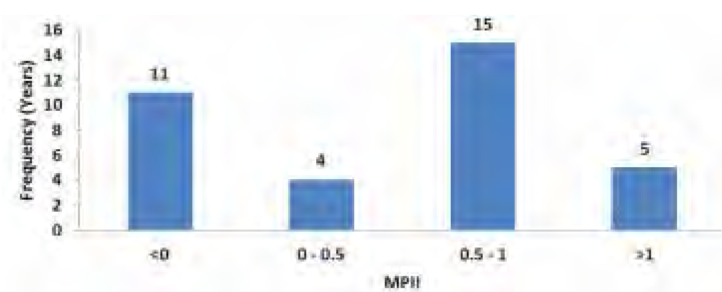
Source: Author's Calculations.

Figure (3): The Monetary Policy Intervention Index for Egypt, (2000-2015)



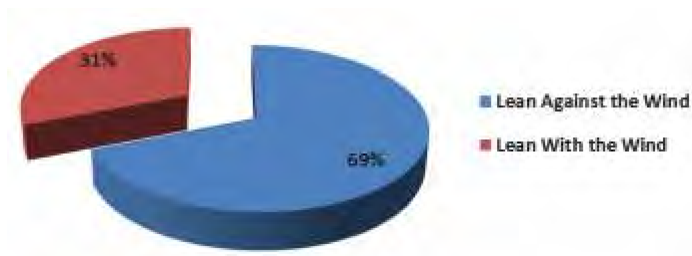
Source: Author's Calculations.

Figure (4): The Frequency of Monetary Interventions in Egypt's Foreign Exchange Market, (1981-2015)



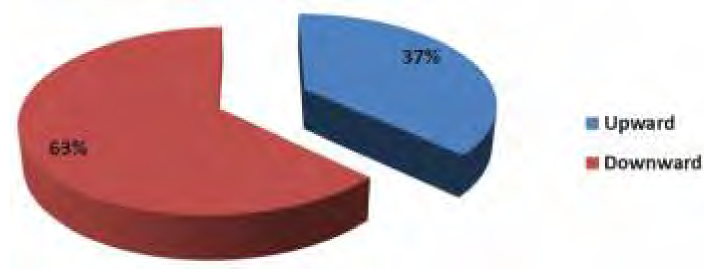
Source: Author's Calculations.

Figure (5): The Relative Distribution of Monetary Policy Responses to Exchange Market Pressures in Egypt, (1981-2015)



Source: Author's Calculations.

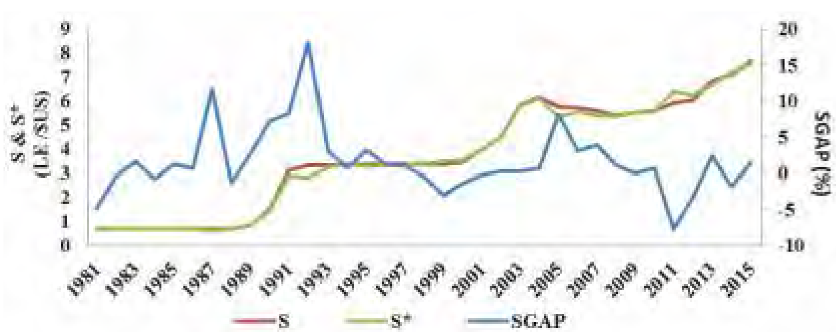
Figure (6): The Relative Distribution of Exchange Market Pressures in Egypt, (1981-2015)



Source: Author's Calculations.

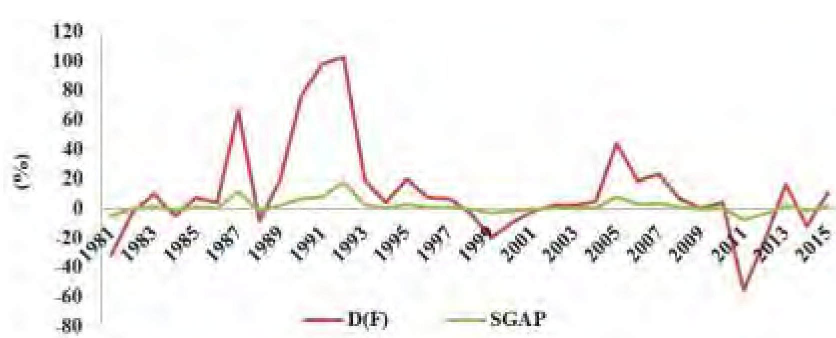
In order to assess the extent to which monetary policy interventions have been successful in stabilizing the foreign exchange market, we estimated potential exchange rates (S*) which could have prevailed in the absence of active monetary interventions; also the exchange rate gap (SGAP) was calculated (Figure 7). Monetary interventions in Egypt's foreign exchange market were effective to a certain extent in relieving market pressures and resulting in negative exchange rate gaps. Nonetheless, this came at the cost of highly volatile official international reserves due to a relatively inelastic exchange rate gap with respect to changes in international reserves (0.1369) (Figures 8 &9). To sum up, the Central Bank of Egypt has implemented active monetary interventions in 69 percent of the sample period considered. However, the exchange rate gaps have been negative only in 11 years over the sample period, implying that only 46 percent of these interventions have been effective in relieving pressures in the foreign exchange market (Figure 10).

Figure (7): Actual Versus Potential Exchange Rate Levels, (1981-2015)



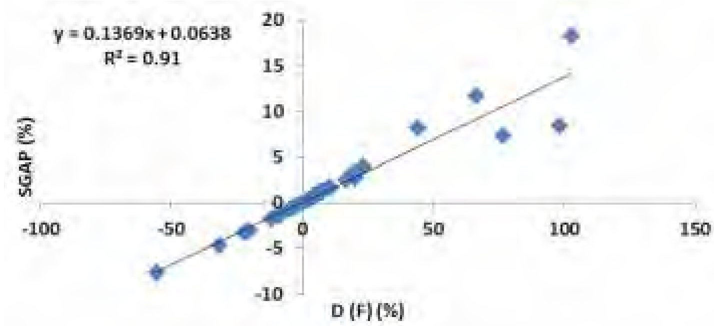
Source: Author's Calculations.

Figure (8): Relationship Between Exchange Rate Gap and International Reserves, (1981-2015)



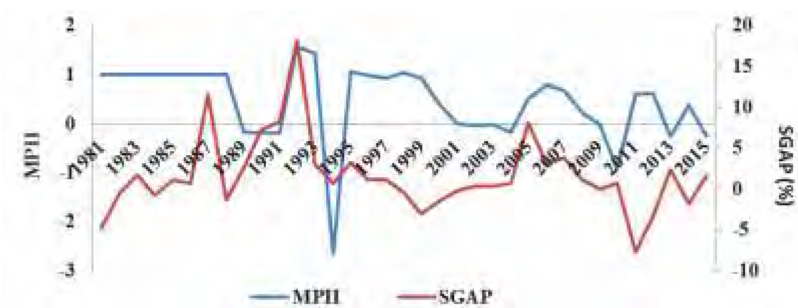
Source: Author's Calculations.

Figure (9): The Response of Exchange Rate Gap to Changes in International Reserves, (1981-2015)



Source: Author's Calculations.

Figure (10): Monetary Policy Interventions and Exchange Rate Gaps, (1981-2015)



Source: Author's Calculations.

So far, the first three questions mentioned earlier have been answered. In order to answer the fourth question, the asymmetric error correction representation of the NARDL (p, q) model represented by equation (4.1) should be estimated.

$$\Delta MPII_t = \rho MPII_{t-1} + \theta^{+} EMPI^{+}_{t-1} + \theta^{-} EMPI^{-}_{t-1} + \sum_{j=1}^{p-1} \phi \, \Delta MPII_{t-j} + \sum_{j=0}^{q} (\pi^{+} \Delta EMPI^{+}_{t-j} + \pi^{-} \Delta EMPI^{-}_{t-j}) + \varepsilon_t \qquad (4.16)$$

We tested for the existence of co-integration between the variables included in equation (4.16) using the Bounds Test; results revealed the existence of a stable long run relationship between them at 5% significance level (Table 6). The lag length of the model has been determined based upon the Akaike information criterion, and the error correction representation of the ARDL model is available in Table (7).

Two models were estimated, where in model (A), we allowed for asymmetry in both the short and long run. However, tests confirmed that asymmetry exists only in the long run. Hence, model (B) was estimated to allow for short (long) run symmetric (asymmetric) responses of monetary policy interventions to exchange market pressures. The long run parameters (β^{+} and β^{-}) for model (B) revealed that both upward and downward pressures on domestic currency have a significant negative effect on the ability of the monetary authority to intervene in the exchange market. Downward pressures were found to have a relatively high significant negative effect on the absorptive capacity of the monetary authority, as higher downward pressures on domestic currency would be expected to limit the room and scope of effective and sizeable monetary policy interventions, which was also confirmed by the cumulative dynamic multipliers (Figure 11). It is noteworthy that diagnostic tests were used to ensure that the model does not suffer serial correlation, normality, hetroskedasticity and ARCH effect problems (Table 7).

Table (6): ARDL Bounds Test

Test Statistic	Value	K
F- Statistic	4.353363***	2
	Critical Value Bounds:	
Significance Level	Lower Bound	Upper Bound
10%	2.63	3.35
5%	3.1	3.87
2.5%	3.55	4.38
1%	4.13	5

Source: Author's Calculations.
*Note: *, **, ***, **** denotes significance at 1%, 2.5%, 5%, 10%, respectively.*

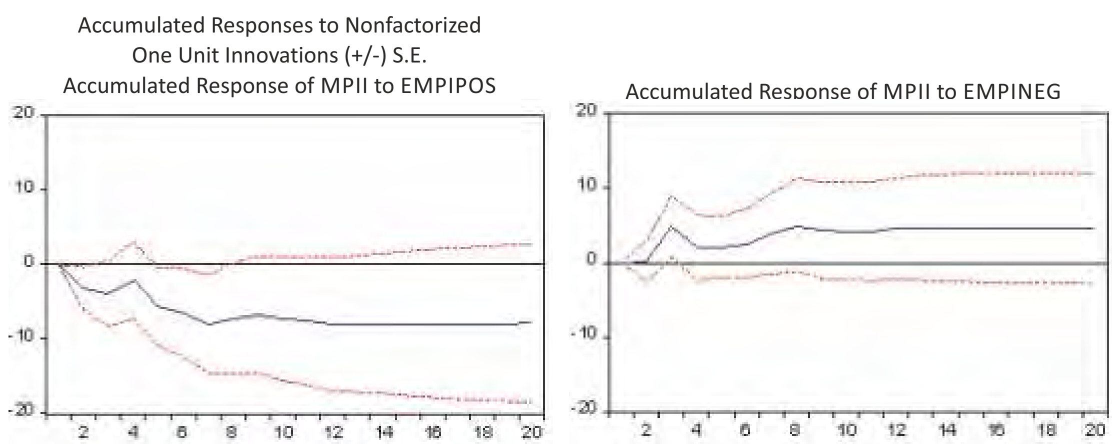
Table (7): The Error Correction Representation for the NARDL Model

Model:(A)			Model:(B)	
Dependent Variable: $\Delta MPII_t$			Dependent Variable: $\Delta MPII_t$	
Short Run			Short Run	
Variable	Coefficient	P-value	Coefficient	P-value
Δ MPII(-1)	0.269739	0.2913	0.294309	0.2113
Δ MPII(-2)	0.117701	0.4594	0.110095	0.4524
$\Delta EMPI^{+}$	-1.864990	0.2094	-	-
$\Delta EMPI^{+}$ (-1)	1.269907	0.6802	-	-
$\Delta EMPI^{+}$ (-2)	0.919773	0.7431	-	-
$\Delta EMPI^{-}$	-2.026924	0.1538	-	-
$\Delta EMPI^{-}$(-1)	-0.444176	0.6452	-	-
$\Delta EMPI^{-}$(-2)	2.887172*	0.0006	-	-
Δ EMPI	-	-	-1.593054*	0.0079
Δ EMPI(-1)	-	-	0.102167	0.8733
Δ EMPI(-2)	-	-	2.594099*	0.0002
Long Run			Long Run	
MPII (-1)	-1.381080*	0.0010	-1.379276*	0.0003
$EMPI^{+}$(-1)	-3.049654	0.1890	-3.010761*	0.0024
$EMPI^{-}$(-1)	-2.478278	0.2877	-2.412175*	0.0070
C	122.8134**	0.0328	125.3862*	0.0024
Diagnostic Tests and Statistics			Diagnostic Tests and Statistics	
R^2	0.854029	-	0.844001	-
Adjusted R^2	0.769519	-	0.789741	-
F- Statistic	10.10570*	0.0000009	15.55463*	0.000000

β^+	-2.20817		-2.18286*	0.0022
β^-	-1.79445		-1.74887*	0.0098
LR Asymmetry (F)	8.247565*	0.0098	-	-
SR Asymmetry (F)	0.000394	0.9844	-	-
Jarque Bera Test	1.789389*	0.408733	0.251589*	0.881796
Serial Correlation LM test	0.435213*	0.7308	0.474071*	0.7038
ARCH Effects Test	0.278267*	0.8405	0.516465*	0.6747
Breusch-Pagan- Godfrey Hetroskedasticity Test	0.637121*	0.7763	0.862055*	0.5610

Source: Author's Calculations.
*Note: *, **, *** denotes significance at 1%, 5%, 10%, respectively.*

Figure (11): Dynamic Multiplier Effects of Exchange Market Pressures on Monetary Policy Interventions



Source: Author's Calculations.

The fifth question is important as Early Warning Systems (EWSs) aim at the anticipation of potential exchange market pressures to avoid excessive upward and downward pressures on domestic currency which may have negative effects on the country's competitiveness in global markets for the first case or lead to an increase in the cost of imports and the depletion of international reserves under pegged or managed exchange rate systems for the latter case.

Limited dependent variable regression models can be used to estimate the probability of a downward pressure on domestic currency to occur. The exchange market pressure in this case is modeled as a zero-one variable for upward and downward pressures respectively, and the predicted probabilities of the model are interpreted as the probability of a downward pressure to exist.

In order to know whether logit and probit EWSs can be useful in predicting exchange market pressures in Egypt, the exchange market pressure index (EMPI) estimated by the author was used to construct the dependent variable (EMPIDUM) in logit and probit models, which takes the value of one in case of downward pressures on domestic currency and zero otherwise. The explanatory variables in the models included GDP growth rate (GDPG), foreign direct investment, net FDI inflows (% of GDP) (FDI), exports of goods and services (% of GDP) (EXP), imports of goods and services (% of GDP) (IMP), Short-term debt (% of total reserves) (SDEBTRES), and domestic credit to private sector (% of GDP) (DCREDPRIV). Data for the explanatory variables aforementioned were obtained from the World Bank, World Development Indicators database over the period (1981-2015).

Logit and probit EWSs were estimated and the results of these models are summarized in tables (8&9). The results of both logit and probit models revealed that exports, GDP growth, FDI and short term debt-to-total reserves ratio can significantly reduce the likelihood of the Egyptian pound to be susceptible to downward pressures, while high imports and domestic credit to the private sector can raise the likelihood of the Egyptian pound to be susceptible to downward pressures as reflected by the marginal effects estimated from the models. Model adequacy criteria confirmed the diagnostic power for both models as reflected by the sensitivity, specificity, false positive rate, false negative rate, total misspecification error, and area under ROC curve. The forecasting performance of logit and probit EWSs was evaluated in terms of both in-Sample and Out-of Sample perspectives; for the latter test both models were estimated over the period (1981-2010) to compare predicted probabilities (EMPILOGIT-OUT & EMPIPROBIT-OUT) with actual observations (EMPIDUM). The predicted probabilities confirmed that both models performed well in terms of both in-Sample and Out-of Sample forecasting (Figures: 12 to15).

Table (8): Logit EWS of Exchange Market Pressures in Egypt

Dependent variable: EMPIDUM			
Coefficient Estimates			
Variable	**Coefficient**	**Test Statistic (Z)**	**P-Value**
GDPG	-1.502***	-1.83	0.067
FDI	-0.677	-1.55	0.120
EXP	-1.525**	-2.30	0.021
IMP	1.868**	2.23	0.026
SDEBTRES	-0.291**	-2.12	0.034
DCREDPRIV	0.226**	2.01	0.044
Constant	-16.887***	-1.95	0.052
Marginal Effects			
Variable	**dy/dx**	**Test Statistic (z)**	**P-Value**
GDPG	-0.141**	-2.36	0.018
FDI	-0.064***	-1.89	0.059
EXP	-0.144*	-3.93	0.000
IMP	0.176*	3.55	0.000
SDEBTRES	-0.003*	-3.09	0.002
DCREDPRIV	0.021**	2.83	0.005
Model Adequacy Criteria			
Criterion	**In-Sample**	**Out-of Sample**	
Sensitivity (%)	90.91	88.24	
Specificity (%)	76.92	100	
False Positive Rate (%)	23.08	0	
False Negative Rate (%)	9.09	11.76	
Total Misspecification Error (%) (TME) (%)	32.17	11.76	
Area under ROC Curve	0.944	0.937	
Observations	35	30	

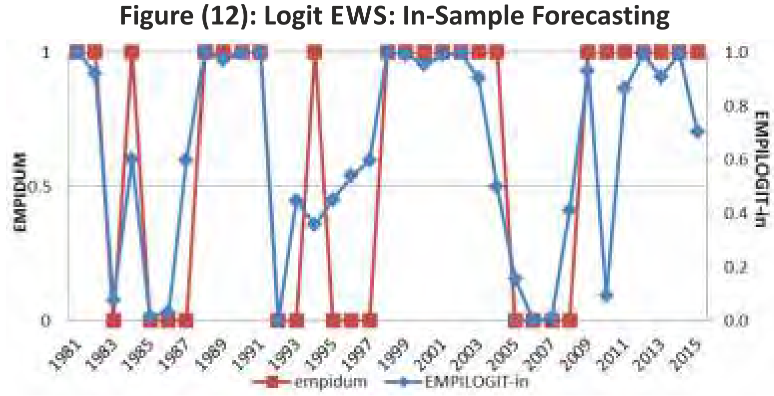
Source: Author's Calculations.
*Note: *, **, *** denotes significance at 1%, 5%, 10%, respectively.*

Table (9): Probit EWS of Exchange Market Pressures in Egypt

Dependent variable: EMPIDUM			
Coefficient Estimates			
Variable	**Coefficient**	**Test Statistic (Z)**	**P-Value**
GDPG	-0.823***	-1.95	0.052
FDI	-0.383	-1.58	0.114
EXP	-0.866**	-2.49	0.013
IMP	1.049**	2.44	0.015
SDEBTRES	-0.017**	-2.27	0.023
DCREDPRIV	0.125**	2.10	0.035
Constant	-9.239**	-2.07	0.038
Marginal Effects			
Variable	**dy/dx**	**Test Statistic (z)**	**P-Value**
GDPG	-0.131**	-2.46	0.014
FDI	-0.061***	-1.86	0.063
EXP	-0.138*	-4.35	0.000
IMP	0.167*	4	0.000
SDEBTRES	-0.003*	-3.47	0.001
DCREDPRIV	0.019**	2.82	0.005
Model Adequacy Criteria			
Criterion	**In-Sample**	**Out-of Sample**	
Sensitivity (%)	86.36	88.24	
Specificity (%)	76.92	84.62	
False Positive Rate (%)	23.08	15.38	
False Negative Rate (%)	13.64	11.76	
Total Misspecification Error (TME) (%)	36.72	27.14	
Area under ROC Curve	0.937	0.937	
Observations	35	30	

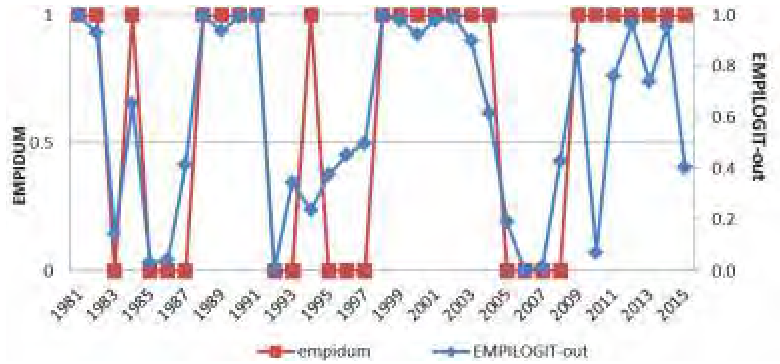
Source: Author's Calculations.
*Note: *, **, *** denotes significance at 1%, 5%, 10%, respectively.*

Figure (12): Logit EWS: In-Sample Forecasting



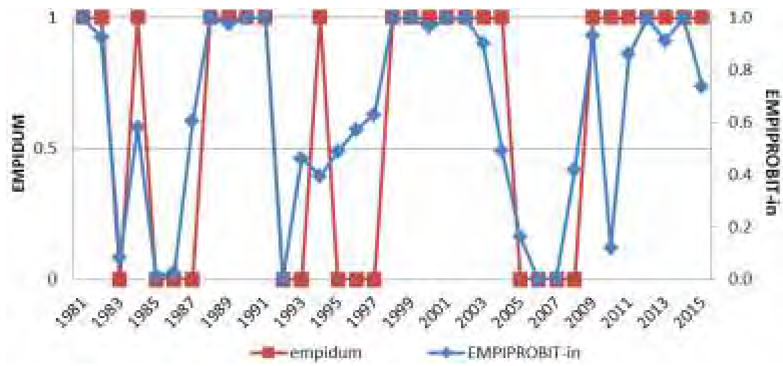
Source: Author's Calculations.

Figure (13): Logit EWS: Out-of Sample Forecasting



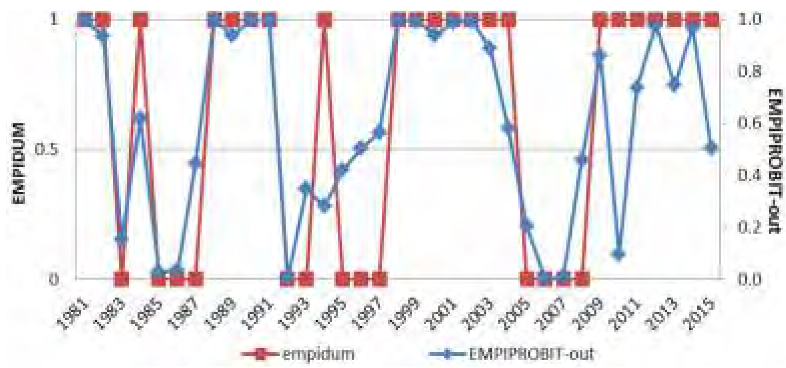
Source: Author's Calculations.

Figure (14): Probit EWS: In-Sample Forecasting



Source: Author's Calculations.

Figure (15): Probit EWS: Out-of Sample Forecasting



Source: Author's Calculations.

5 Conclusion

The Egyptian economy has been exposed to significant exchange market pressures after the outbreak of the January 25th revolution in 2011 as a result of a plunge in its main macroeconomic indicators; which should have been reflected in the market exchange rate. Nevertheless, the Central Bank of Egypt (CBE) tried to stabilize the exchange rate of the Egyptian pound vis-à-vis other currencies mainly for social and political purposes.

Since July 2013, the Egyptian pound has stabilized within a 2% band against the U.S. dollar. This trend continued through April 2014; Egypt's de facto exchange rate arrangement has been reclassified from a “crawl like” to a “stabilized arrangement”, effective July 3, 2013. However, without the availability of sufficient official international reserves, the monetary authority should not have been expected to maintain a sustainable fine tuning of the foreign exchange market. That's why the CBE has opted to adopt a free float exchange rate regime starting from November 2016.

The econometric methodology employed in this paper enabled us to answer the following five questions: ***Firstly:*** What are the main characteristics of exchange market pressures in Egypt? ***Secondly:*** What are the main features of monetary policy responses to exchange market pressures? ***Thirdly:*** To what extent, monetary policy interventions in the foreign exchange market are effective? ***Fourthly:*** Do asymmetries exist in monetary policy responses to foreign exchange market pressures in Egypt? ***Fifthly:*** Can logit and probit EWSs be useful in predicting exchange market pressures in Egypt?

The Autoregressive Distributed Lag (ARDL) model was employed to answer the first three questions aforementioned. Then, the Non-linear Autoregressive Distributed Lag (NARDL) model was used to answer the fourth question. Finally, logit and probit models were employed to answer the fifth question.

The main results of empirical analysis can be summarized as follows:

- The exchange market in Egypt has been exposed to persistent downward pressures on domestic currency starting from 2009 onwards, which has been exacerbated starting from 2011 due to the economic slowdown and deterioration of macroeconomic fundamentals after the outbreak of the January 25th revolution. It is noteworthy that the Egyptian pound has been exposed to downward pressures in around 63 percent of the sample period considered.
- The monetary authority in Egypt used to play an active role in the foreign exchange market to ensure both liquidity and stability in the market, where the central bank continued to absorb exchange market pressures through a "leaning against the wind policy" in around 69 percent of the sample period considered in the analysis.
- Monetary interventions in Egypt's foreign exchange market were effective to a certain extent in relieving market pressures and resulting in negative exchange rate gaps. Nonetheless, this came at the cost of highly volatile official international reserves due to relatively inelastic exchange rate gap with respect to changes in international reserves. Specifically, around 46 percent of monetary policy interventions have been effective in relieving pressures in the foreign exchange market.
- Both upward and downward pressures on domestic currency can have a significant negative long run effect on the ability of the monetary authority to intervene in the exchange market, downward pressures were found to have a relatively high significant negative effect on the absorptive capacity of the monetary authority, as higher downward pressures on domestic currency would be expected to limit the room and scope of effective and sizeable monetary policy interventions, which was confirmed by the cumulative dynamic multipliers.
- Logit and probit EWSs revealed that exports, GDP growth, FDI and short term debt-to- total reserves ratio can significantly reduce the likelihood of the Egyptian pound to be susceptible to downward pressures, while high imports and domestic credit to the private sector can raise the likelihood of the Egyptian pound to be susceptible to downward pressures.
- Logit and probit models can be useful in predicting exchange market pressures in Egypt.

From the aforementioned results we can conclude that economic policies going forward should focus on structural economic reforms to strengthen the macroeconomic fundamentals and ensure the stability of the exchange rate without the need for excessive artificial interventions to strengthen the Egyptian pound. Moreover, attention should be paid to developing a business enabling environment and encouraging both domestic and foreign investment to promote economic growth, hence limiting imports and reducing potential pressures on the domestic currency. Transparency and communication are important to build credibility and anchor market expectations. Finally, EWSs should be built and updated on a regular basis to be able to track and anticipate potential exchange market pressures.

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[1] *The Economic Stability Trend Index (ESTI) ranges between (-1: 1), where -1 reflects the buildup of economic vulnerabilities in the system and 1 reflects higher levels of economic stability. This index was built using the standardization method and the variables used included FDI-to-GDP ratio, Inflation rate, GDP per capita growth rate, savings-to-GDP ratio, total investment-to-GDP ratio, unemployment rate, current account balance- to- GDP ratio and general government gross domestic debt-to-GDP ratio. Annual data series for these variables over the period (2002-2014) were obtained from the World Bank World Development Indicators and the IMF World Economic Outlook databases. Details are available upon request.*

[2] *Sensitivity is defined as the true positive rate, which can be expressed as the number of true positive cases detected divided by the sum of true positives and false negatives.*

[3] *Specificity is defined as the true negative rate, which can be expressed as the number of true negative cases detected divided by the sum of true negatives and false positives.*

[4] *The False positive rate is the number of false positive cases to the total number of actual negatives in percentage terms.*

[5] *The False negative rate is the number of false negative cases to the total number of actual positives in percentage terms.*

[6] *Total Misspecification Error (TMS) is the sum of false positive and false negative rates, respectively.*

[7] *The Receiver Operating Characteristics (ROC) curve is one of the criteria that reflect the diagnostic power of limited dependent variable models and the power of the model in detecting positive outcomes, as reflected by the area under the curve. ROC curve plots sensitivity versus (1-specificity).*

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