UNDERSTANDING THE DYNAMICS OF FOREIGN RESERVE MANAGEMENT:

The Central Bank Intervention Policy and the Exchange Rate Fundamentals

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Abstract

The aim of this study is to examine the behaviour of central banks in managing their foreign exchange reserves. This includes measuring the effects of macroeconomic fundamentals on intervention and the effectiveness of intervention in managing exchange rates. First, the paper focuses on measuring central bank reaction functions to assess the response of central banks to exchange rate volatility in both emerging economies (EE) and advanced economies (AE). Then, it proposes alternative approach for the closest obtainable approximation for official intervention. Then, the Propensity Score Matching (PSM) technique is applied to test whether proposed foreign exchange intervention has causal effects on exchange rates. Results show that central banks in both EE and AE respond more aggressively to appreciation. Data from official foreign reserves provide enough evidence for detecting policy changes and reveal central bank intervention. The intervention model is improved once we include other central bank incentives such as sterilisation, trade balance and the growth of reserves in relation to the growth of output. PSM results show that the central bank interventions are meaningful and they show causal inference for the behaviour of exchange rates in EE.

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Key Words: Foreign Exchange Intervention, Central Bank Policy, Foreign Exchange Reserves, Sterilised Interventions, Propensity Score Matching.

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1. Introduction

The ultimate objective, according to Friedman (1953), is a world in which exchange rates are free floating and at the same time highly stable. Exchange rate stability apparently underlies the desirability of the intervention policy. The basic rationale behind the intervention framework is determined by whether the markets are efficient or not. When the markets are efficient, the prices fully reflect available information and the exchange rates have the correct rates that is when forward exchange rates are equal to future spot exchange rates. Nevertheless, authorities believe that the markets are inefficient due to irrational market behaviour and exchange rates have the wrong rates causing misallocation of resources. Speculation due to excessive risk aversion and bandwagon effects result in moving exchange rates from its fundamentals towards misalignments. Intervention in instances of market inefficiency does not claim that central banks need to know the correct rate. It, nevertheless, presupposes that markets can not be relied upon to achieve stability and therefore central bank intervention has a stabilising effect (Pilbeam, 1991). Reserve holdings, which averaged about 5 percent of GDP in the 1980s, have doubled every decade since, reaching some 25 percent of GDP by in 2010 (Gosh et.al. 2012, p.3). Increased intervention activity has coincided with higher exchange rate variability. This suggests that authorities have intervened more in the face of greater exchange rate movements, without eliminating fluctuations (Domanski et al., 2016).

The scale and the frequency of the intervention highly depends on the prolonged and substantial accumulation of foreign reserve in that country. The source of foreign reserve accumulation may vary either due to the discovery of a real resource, as in the case of Saudi Arabia and Norway, or due to the foreign exchange interventions, as in the case of China and other emerging market. Since the latter case is more likely to cause accumulation of foreign reserves, it is important analyse the motivation behind reserve accumulation thereby determining the reasons for central bank intervention. There are basically two motivations behind foreign reserve accumulation: the precautionary motive and the mercantilist motive. According to Green and Torgerson (2007), the major reasons for the precautionary motive is to insure against shocks; to intervene in non-crisis times with the intent to reduce volatility,

maintain a target exchange rate or be used as a tool for deflation; to serve, as lender of last resort to banks with high levels of foreign currency liability; and to use reserves for day-to-day transactions such as the purchase of foreign goods or payment of obligations to international organisations. For the mercantilist motive, the foreign reserve accumulation is used to pursue policy objectives related to the exchange rate and competitiveness, to stimulate growth or to eliminate rising commodity prices. Most studies focus on the volatility of the exchange rates for either the precautionary motive or the mercantilist motive. There is also the prevalent belief that emerging market economies, mainly in Asia, hold more than enough reserves for financial safeguard purposes with the desire to prevent currencies from appreciating significantly[2]. As a result, this belief was the cause of massive foreign reserve accumulation together with on-going global macroeconomic imbalances[3].

The reserve accumulation is important since it affects the policy choice of monetary authorities and the level of foreign exchange intervention. The available literature provides a range of analyses of foreign reserve accumulation and its determinants based on the self-insurance motivation (Aizenman and Marion, 2003; IMF, 2003; Mendoza, 2004; Aizenman et al., 2004). The IMF (2003) tests various determinants of foreign reserve holdings, finding most of the macroeconomic determinants to be statistically significant[4]. An additional established area of interest is seen to be the testing of reserve adequacy, such as in the analyses of Bird and Rajan (2003), Aizenman and Marion (2003), Edison (2003), Ruiz-Arranz and Zavadjil (2008), Williams (2005), Park and Estrada (2009), IMF (2011), and Ghosh et al. (2012).

Pontines and Rajan (2011) used central bank intervention reaction to find evidence of fear of appreciation. They concluded that Asian central banks react more strongly to currency appreciations than they do to depreciations. For the mercantilist motive, export competitiveness is the development strategy for foreign reserve holders aiming to prevent appreciation of domestic currencies against the US dollar and to promote export-led growth. Some studies, such as Hviding, Nowak, and Ricci (2004); and Dooley, Folkerts-Landau, and Garber (2004) are in favour of the mercantilist motive; and other studies, such as Aizenman and Lee (2005)

[2] Pontines and Rajan (2011) argue that, prior to the global financial crisis of 2008-2009, many emerging economies designated some portion of their foreign reserves to invest in less liquid, potentially high yield, high risk assets. Subsequently, the major argument is that exchange rates in these economies were heavily managed and effectively undervalued to sustain export-led growth.

[3] Bergsten (2015), refers to currency manipulation as the world's most protectionist international economic policy of this century.

[4] Furthermore, predictions for the 1997-2002 period revealed that reserve accumulation in Latin America was not excessive, but emerging Asia, on the other hand, reached a point where some slowdown in the rate of accumulation was necessary.

express limited support for it. Their results find strong support for foreign reserve accumulation as a result of the precautionary motive, even for China. Other studies evaluate how international reserves hoarding affects the real exchange rate. For example, Aizenman and Riera-Crichton (2008) observe that international reserves cushion the impact of terms of trade shocks on the real exchange rate, especially in Asian countries and countries that export natural resources.

In other studies, reserves are analysed as determinants for other macroeconomic variables. For example, Fukuda and Kon (2010) deal with the cost of foreign reserve accumulation[5]. Gonçalves (2008) investigates the interaction between monetary policy and foreign reserves. He concludes that there is a trade-off between reserve accumulation and macroeconomic stability, and that intervention decisions have an impact on the public's expectations for the monetary authority's inflation goal. Larger interventions lead to an increase in both the expected inflation target and the current inflation rate. Therefore, fast reserve accumulation may harm anti-inflationary credibility of the monetary authority.

The aim of this paper is to examine the behaviour of central banks' foreign reserve management since the recent financial crisis and analyse the complex relationship between movements of the foreign reserve and the fluctuations in exchange rates. The complexity of the analysis arises from the two-way causality between foreign reserves and exchange rates. It is important to observe how central banks react to exchange rate movements and equally important to identify how exchange rates, alongside other fundamentals, react to changes in foreign reserves. The three-step analysis conducted in this study starts with measuring the reaction of central banks to exchange rate appreciations/depreciations. The second step is the study of the fundamentals of exchange rates and the final step is the analysis of the effects of these fundamentals on central bank intervention policy changes. Additionally, the study uses matching techniques to ascertain the causality effect of intervention on exchange rates.

The analysis cover 31 emerging economies and 21 advanced economies spanning ten years including the recent financial crisis and post-crisis period. The value of foreign exchange reserves for countries selected in this study constitute approximately 80 percent of total foreign reserves. China has the highest amount of foreign exchange reserves by far, compared to other countries. In Europe, there has been a significant increase in the speed of reserve accumulation since the 2008 Financial crisis. Nearly all countries have increased their foreign reserves

[5] They conclude that increases in foreign exchange reserves raise external debt outstanding and shorten debt maturity. The results also imply that increased foreign exchange reserves may lead to a decline in consumption but can also enhance investment and economic growth.

significantly; Japan comes second to China in terms of high foreign reserve accumulation. Countries with a large accumulation of reserves during the pre-crisis period witnessed large reductions during the crisis. Since then, there have been huge jumps in total amount of foreign reserves in many countries such as China, Japan, Saudi Arabia, Switzerland, Brazil, Korea, Hong Kong, India, Singapore, Mexico, Thailand and Malaysia. All countries, excluding the euro zone (namely Slovakia and Lithuania) and Indonesia, have increased their foreign reserves between 2005 and 2015. The ten countries with the highest percentage increases (from 2005 to 2015) are Saudi Arabia, Libya, Switzerland, Singapore, Thailand, Malaysia, Japan, India, Korea and Israel. Incremental increases were also identified in Asia, oil exporting countries and most of the countries in Latin America. In Europe, the figure is slightly different so that the foreign reserves increase outside of the euro zone but significantly decrease within. This evidently shows the use of foreign reserves during crisis and post crisis periods.

This paper is different from earlier studies in several ways. Most studies to date have focused on the adequacy and/or the determinants of foreign reserves in a conventional way or they have studied interventions for a limited number of central banks with actual official released interventions. The central banks' foreign reserve management and intervention policy affects many economies, yet it is extremely difficult to measure this intervention due to the lack of actual intervention data[6]. Central banks have traditionally been reluctant to release intervention data to researchers, considering it to be too sensitive (Neely, 2000; Vitale, 2003). Then, the researchers are left to construct proxy variables for detecting central bank intervention. Sometimes daily intervention operations are reported from unofficial sources such as news or financial press. For example, Chang et al. (2017) followed Reuters' news to determine intervention. Others used central banks' holdings on international reserves (see Taylor, 1982; Kearney and Mac Doland, 1986 and Gartner, 1987). Lack of actual intervention data is the major difficulty in measuring the effectiveness of intervention policy. Furthermore, foreign exchange reserves may be an imperfect proxy for intervention, since reserves may be changed not only when central banks conduct foreign exchange intervention but also for other reasons such as government payment of debt denominated in a foreign currency[7]. Furthermore, Dominguez et al. (2012) criticised the misleading use of changes in foreign currency reserves

[6] Studies like Dominguez (1998), Ito (2002) and Neely (2000) used official intervention for limited number of advanced economies.

[7] Neely (2000), for example, found that changes in the reserves have positive but weak correlation with intervention activity for only 3 advanced countries; the US, Germany and Switzerland. Suardi and Chang (2012) found correlation asymmetry between changes in foreign reserves and official intervention in Germany and Japan but not in the US.

in models regarding its active and passive reserve accumulation. They argued that, especially during the period of a crisis, the value of some reserve assets would decline unless there is a reserve accumulation and the value of reserves would remain with reserve accumulation. Thus, it is necessary to discern the motives for the purchase and sale of foreign currencies when deciding what constitutes intervention by a central bank. This paper proposes an alternative approach that, under these constraints, represents the closest obtainable approximation to official intervention. Policy changes are detected in a binary analysis and interventions are determined either by examining the behaviour of foreign reserves in relation to exchange rates or by examining the magnitude of the change in foreign reserves. Filtering the reserves data to increase the correlation and the causal effect between intervention and exchange rate is an important part of the analysis. This includes many other macroeconomic variables to filter the foreign reserves data to obtain a better proxy for intervention. For example, the direction of the movement of foreign reserves in relation to the direction of the exchange rate and the percent changes in foreign reserves with the 2.5% and 5% threshold values are the main benchmarking in foreign exchange interventions. Furthermore, the behaviour of central banks for carrying out intervention operations are further analysed by including some benchmarks inspired by the criteria for the assessment of reserve adequacy (IMF, 2011). One benchmark is the possibility of intervention when increases in foreign assets are coincided with decreases in money stock, which is called as the sterilised intervention. Another benchmark for the possibility of intervention is when foreign assets are growing faster than the output. Final benchmark is set by including the possibility of intervention in countries where they experience trade surplus. Reserves to GDP ratio by and the reserves in relation to current account balance are the popular criteria for defining the reserve adequacy and determining excess reserves (Park and Estrada. 2009; Obstfeld et al., 2010; Gagnon, 2012). This paper is different from previous analyses since it does not only focus on the movement of foreign reserves alone, but also includes other important variables and detects the closest approximation to official intervention amongst many possible intervention alternatives. Rather than scaling the excess reserves, this paper compares the changes in the growth rate of reserves to changes in these variables to determine intervention. After interventions are detected, the focus of the analysis shifts to the determinants of intervention policy and finally to test whether these presumed interventions are meaningful and show a causal inference for the exchange rate movements by using the PSM technique.

Results show that central banks in both emerging and advanced economies behave more aggressively towards appreciation. There is a strong relationship between exchange rate fundamentals and intervention policy. Data from the official reserves is useful in detecting central bank intervention policy. Exchange rate fundamentals determine intervention policy and the model is more meaningful for countries with trade surplus and/or in which reserves are growing faster than the economy.

This study is structured as follows: Section 2 explains the theoretical analysis, Section 3 describes the central bank reaction function Section 4 presents the results of the central bank reaction function, Section 5 explains Propensity Score Matching, Section 6 presents the results of PSM estimations and finally Section 7 concludes the study.

2. Theoretical Analysis

Theoretical analysis of the relationship between international reserves and exchange rates begins with decomposing the money market equilibrium. The Money demand equation is represented as follows:

$$\frac{M_t^d}{P_t} = \alpha - \beta i_t$$

where M_t^d is money demand at time *t*, P_t is domestic price level at time *t*, and *i* is the domestic interest rate at time *t*. The Money supply equation is represented as follows:

$$M_t^s = NFA_t + NDA_t$$

where NFA is net foreign assets and NDA is net domestic assets at time *t*. Additionally, investors' behaviour is captured by the uncovered interest parity condition:

$$\frac{e_{t+1}^e - e_t}{e_t} = i_t - i_t^*$$

where e_t is the nominal exchange rate at time *t*, e^e_{t+1} is the expected exchange rate for period *t+1*, i_t is domestic interest rate and i^*_t is foreign interest rate.

There are basically three assumptions. First, the model assumes that the purchasing power parity holds and the foreign price level is normalised to 1. So, if $\frac{e_t P^*_t}{P_t} = 1$ with $P^*_t = 1$ then $e_t = P_t$. Second, with the assumption of perfect foresight, the model normalises the foreign interest rate to 0. If $e^e_{t+1} = e_{t+1}$ with $i^*_t = 0$, then $\frac{e_{t+1}-e_t}{e_t} = i_t$. Finally, there is a lower bound on the level of foreign reserves that the central bank owns. So NFA≥0. Under these assumptions the money market equilibrium is shown as follows:

$$M^s_t = M^d_t$$

$$\frac{NFA_t + NDA_t}{P_t} = \alpha - \beta i_t$$

$$\frac{NFA_t + NDA_t}{e_t} = \alpha - \beta\left(\frac{e_{t+1} - e_t}{e_t}\right)$$

Monetary policy implications will vary according to different exchange rate regimes. For fixed Exchange Rate Regime:

$$e_t = \bar{e} \quad \forall t$$

$$\frac{NFA_t + NDA_t}{\bar{e}} = \alpha$$

The above equation defines the condition for the fixed exchange rate system. It also determines the level of net foreign assets to defend fixed exchange rate parity.

$$NFA_t \geq \alpha\bar{e} - NDA_t$$

Floating Exchange Rate Regime

$$NFA_t + NDA_t = \alpha e_t - \beta(e_{t+1} - e_t)$$

According to Mussa (1981), official interventions in foreign exchange markets may signal a country's future intentions regarding monetary policy. For example, a purchase of foreign currency represents a capital loss in the case of a future monetary policy contradiction, whereas a sale of foreign currency represents a capital loss in the case of a future monetary policy expansion. Goncalves (2008) explains this phenomenon as such: when the intervention authority buys (sells) a certain amount of foreign currency, it also sells (buys) domestic currency in order to keep the level of liquidity in the economy constant.

$$\Delta MB = \Delta NFA + \Delta NDA$$

This can also be explained with the above equation, where MB is monetary base, NFA is net foreign assets and NDA is net domestic assets. Sterilisation aims to keep money supply unchanged as NFA increases, so NDA should be decreased. Direct cost of sterilisation occurs when interest earned on foreign exchange reserves are less then interest paid to domestic reserves.

Goncalves (2008) contributes to the model of Vitale (2003) and links monetary policy decisions and sterilised interventions. In his model, he considers a two-country world composed of domestic and foreign economies. There are two stages named 0 and 1. In stage 0, the amount intervened is x_0 (if it is positive then it means the central bank purchased foreign currency). In stage 1, the monetary authority sets monetary policy in order to achieve the desired rate of inflation, π_1. The objective function for the macroeconomic goals of output and inflation stabilisation is represented as follows:

$$L^{MA} = \theta(y_1 - \bar{y})^2 + \alpha(\pi_1 - \bar{\pi})^2$$

where L^{MA} is the liquidity of the monetary authority, y_1 is the output goal, $\bar{y}$ is the output level at the end of stage 1, π_1 .

Alternatively, Goncalves (2008) assumes that authorities want to accumulate reserves to achieve an exogenous level designed by $\bar{R}$. The objective function for the intervention authority to achieve the desired level of reserves becomes as follows:

$$L^R = (\bar{R} - x_0)^2$$

where superscript R represents reserves. The other important assumptions that Goncalves (2008) makes are: first, the initial level of reserves before any intervention is normalised to zero, $\bar{R}$ is positive, and the intervention authority can accumulate reserves by buying foreign currency on the foreign exchange market. Next, that intervention, x_0, is fully sterilised. The cost of intervention is represented as follows:

$$C = (e_0 - e_1)x_0$$

The equation above reflects the capital commitment or cost of intervention emphasised by Mussa (1981). Whenever the intervention authority buys (sells) reserves in stage 0, nominal appreciation (depreciation) occurs. So, the intervention authority incurs a capital loss (C>0). Alternatively, according to Goncalves (2008), *C* can be seen as a speculative motive to intervene. For example, the intervention authority buys (sells) foreign currency and this is followed by a nominal depreciation (appreciation). This time the intervention strategy yields profits. So, under the above assumptions, the intervention authority will minimise

$$L^{INT} = \gamma L^R + \beta C$$

where superscript *INT* is intervention authority, γ is the weight given to reserve targeting, and β is the weight given to the cost of intervention. According to Goncalves (2008), the objective function under centralisation, where monetary authority and the intervention authority are set by the same policymaker, is represented by c and it takes the following form:

$$L_c = L_c^{MA} + L_c^{INT}$$

$$L_c = \theta(y_1 - \bar{y})^2 + \alpha(\pi_1 - \bar{\pi})^2 + \gamma(\bar{R} - x_0)^2 + \beta(e_0 - e_1)x_0$$

$$Min_{\pi_1} = \theta(y_1 - \bar{y})^2 + \alpha(\pi_1 - \bar{\pi})^2 + \gamma(\bar{R} - x_0)^2 + \beta(e_0 - e_1)x_0$$

He assumes two additional relations. First the simple Lucas supply curve:

$$y_1 = b(\pi_1 - \pi_1^e).$$

where π_1 and π_1^e are inflation and expected inflation, respectively. The other is relative purchasing power parity.

$$e_1 - e_0 = \pi_1$$

where nominal exchange rates are identified with price changes. Assuming that the central banks has an objective of managing exchange rate movements as a policy target, then the nominal exchange rates are determined by price changes, which are affected by the target inflation rate, target output level and the amount of intervention to the foreign exchange market. Then the model becomes as follows:

$$\Delta e_t = (i_t - i_t^*) + (\pi_t - \pi_t^*) + \Delta R_t + (y_t - y_t^*) + (ex_t - im_t) + vix_t \quad (1)$$

where the changes in exchange rates, Δe, are determined by interest rate differential (the opportunity cost) derived from uncovered interest parity, domestic and foreign price differential derived from purchasing power parity, changes in foreign reserves, ΔRt that is equal to $(\bar{R} - x_0)$. Additionally, there are two control variables trade balance, $(ex_t - im_t)$, and market volatility index, vix, used as a proxy for risk aversion and uncertainty.

3. Central Bank Reaction Function

The central bank is assumed to have direct and complete control over a proxy measure of intervention by changing the size of their foreign exchange reserves. The monetary authorities are assumed to believe that if there is no intervention then, the exchange rate is a random walk (Ito and Yabu, 2004). The model of optimal intervention is a function to observe the behaviour of central bank when the exchange rate deviates from its fundamental value. It is assumed that the central bank intervenes in foreign exchange markets to minimise the following intertemporal loss function. The policy actions of a central bank are taken at the

period t conditional upon the information available at the end of the previous period. This is represented with the following intertemporal criterion:

$$\min_{\{INV_t\}} E_{t-1} \sum_{T=0}^{\infty} \delta^T L_{t+T}$$

(2)

where δ is the discount factor, INV is the volume of intervention defined as the purchases of foreign currency by the central bank and L_t is the period loss function. Following Surico (2008), Srinivasan et al. (2008), and Pontines and Rajan (2011), the equation for the loss function in linear-exponential form is as follows:

$$L_t = \frac{1}{2}(INV_t - INV^*)^2 + \frac{\lambda}{2}\left\{(\tilde{e}_t - e^*)^2 + \frac{\gamma}{3}(\tilde{e}_t - e^*)^3\right\}$$

(3)

where λ>0 is the relative weight and γ is the asymmetric preference parameter on exchange rate stabilisation. $\tilde{e}$ denotes the percentage change in exchange rate (Increases are associated with depreciations), INV^* is the optimal level of intervention and e^* is the central bank target rate (assumed to be zero).

If γ>0, it means that the deviations of the same size but opposite sign yield different losses where the weight of the rate of appreciation is greater than the rate of depreciation.

As it has been assumed, central bank interventions can reduce the rate of change in the exchange rate. Representation in the form of an equation is as follows:

$$\tilde{e}_t - e^* = a_0 + a_1 R_t + \varepsilon_t$$

(4)

Minimising equation (3) by choosing R_t subject to the constraint (4) leads to the following intervention reaction function:

$$R_t = R^* - \lambda a_1 E_{t-1}\left\{\tilde{e}_t + \frac{\gamma}{2}(\tilde{e}_t)^2\right\}$$

(5)

When expected values are replaced with actual values, the intervention reaction function is simplified as follows:

$$R_t = c + \alpha\tilde{e}_t + \beta(\tilde{e}_t)^2 + v_t \quad (6)$$

where α=-λa_1 and β=-$\lambda a_1 \gamma 2$. The symbols α and β is used to identify γ, the parameter for the asymmetric preference on the exchange rate stabilisation and is calculated as γ=2 β/α.

4. Reaction Function Estimation Results

Equation 6 is the main equation of interest in this section of empirical test allowing to estimate the intervention reaction function and the asymmetric preference parameter. We follow Pontines and Rajan (2011) and employ the generalised method of moments (GMM) for equation 6. GMM is the appropriate estimation method for orthogonality conditions implied by the intertemporal optimisation-rational expectations paradigm. It is used to solve endogeneity, heteroscedasticity and serial correlation of the random error term. The J-test indicates that the hypothesis of valid over-identifying restrictions is never rejected.

Table 1. Central Bank Reaction Function

	c	α	β	γ=2β/α	J-test	Sargan
EMERGING ECONOMIES	15.62 ***	14.98 ***	-7.82 ***	-1.04 ***	16.98	0.26
	(2.11)	(7.39)	(3.72)	(0.13)		
ADVANCED ECONOMIES	-0.03	-16.14 ***	75.04 *	-9.30 ***	13.32	0.15
	(0.03)	(8.00)	(45.82)	(2.25)		

*, **, *** denote statistically significance at 10%, 5% and 1%, respectively.
Panel Unitroot test results show that exchange rates both in developed and emerging economies and foreign reserves in developed ecomies do not reject the null of unitroot at level, rejecting null in first difference.
Instruments: EMERGING ECONOMIES: constant, lagged values 1 to 3 of exchange rates in first difference, lagged values 1 to 6 of forex reserves in difference, lagged values of monetary aggregate (M2) 1 to 2 at level, and lagged values 1 yo 2 of exports both in first difference and level. DEVELOPED ECONOMIES: constant, lagged values 1 to 2 of forex reserves both in first difference and level, lagged values 1 to 2 of exchange rates in first difference and lagged value 1 in level, and lagged values of monetary aggregate (M2) 1 to 2 at level.
Standard errors are in paranthesis. The standard error ofy are obtained using the delta method.
J-test refers to the Hansen's test of overidentification restrictions, Ho= valid overidentifiying restrictions.

Table 1 shows estimates for the intervention reaction function and the asymmetric preference parameter. The variables in equation is R_t= (Δlog *Reserves*$_t$)*100, where Reserves are the official foreign reserves and $\tilde{e}$ = (Δlog e_t)*100, where e is the nominal exchange rate

domestic per foreign currency. Increases are associated with depreciation and decreases are with appreciation. The results show that parameters on $\tilde{e}_t$, and α, are statistically different from zero both in EE and AE. There is a negative relationship between exchange rates and foreign reserves in advanced economies; when currency appreciates (depreciates), central banks accumulate (deplete) their foreign exchange reserves. The positive relationship between exchange rates and foreign reserves, however, shows that emerging economies do not immediately respond to currency fluctuations and central banks wait to intervene up until a threshold level determined by central bank officials. Our concern is β coefficient of $\tilde{e}_t$ squared in which we test β=0, which will determine whether γ=0. Coefficients in both EE and AE are statistically significant. Testing the restriction where H_0: β=0 also leads to testing H_0: γ=0; if γ is significantly different than 0, then it can be concluded that the central banks have an asymmetric intervention preference. Thus, γ shows how central banks appear to react differently to appreciation than depreciation. If γ<0, the central banks have a "fear of floating", where the weight of the rate of appreciation is greater than the rate of depreciation. If γ>0, the central banks have "fear of depreciation", where the weight of the rate of depreciation is greater than the rate of appreciation. The sign γ shows that central banks in both EE and AE have a fear of appreciation. They react more aggressively to appreciation than depreciation. The larger the absolute value of γ in advanced countries, the stronger the asymmetric preference in central bank foreign exchange market intervention is.

5. Propensity Score Matching

One of the important contributions of this study is the see whether proposed interventions are cognitively meaningful for the behaviour of exchange rates. The Propensity Score Matching (PSM) technique (Rosenbaum and Rubin,1983) is a highly popular method for pre-processing data to improve causal inferences in observation data (Ho et al., 2007, Morgan and Winship, 2014). PSM is the most commonly used matching method for causal analysis in observational studies (Pearl, 2010). It applies to all situations where there is treatment, a group of treated individuals and a group of untreated individuals. The nature of treatment may take various forms. The emphasis is on highlighting the difference between the outcomes of participants with and without treatment. Nevertheless, the mean outcome of nonparticipants may not be appropriate since participants and nonparticipants usually differ in the absence of treatment. This problem is called 'selection bias' and the matching approach is one possible

solution to the selection problem. PSM is based on the idea that we try to find observations in a large group of nonparticipants that are similar to the participants in all relevant predetermined characteristics of X, identified as covariates. Rosenbaum and Rubin (1983) use so called balancing scores $b(X)$, which are functions of the relevant observed covariates X, such that the conditional distribution of X given $b(X)$ is independent of assignment into treatment. This is called propensity score, that is, the probability of participating in a policy given observed characteristics X. Matching procedures based on this balancing score is known as propensity score.

For this study, the interpretation of the above information means any change in foreign reserve policy is associated with an intervention, countries that experience this intervention are considered participants whereas those which do not are considered nonparticipants. The exchange rates are the outcomes. The PSM technique uses information from a pool of units that do not participate in the intervention to identify what would have happened to participating units in the absence of the intervention. When there is treatment (intervention) there are two potential outcomes, Y (exchange rates), as Y0 and Y1. Y1 is the exchange rate with the intervention and Y0 is the exchange rate without the intervention. If there is treatment, then the observed outcome, Y will be equal to potential outcome in case of treatment, Y1, so Y0 is the counterfactual. If there is no treatment, the potential outcome is Y0 and Y1 is the counterfactual. There are also other variables that affects the exchange rate Y, as explained above as the covariates, X. The method employs a random assignment that our concern is not including all exchange rates into our analysis. We select certain variables to analyse the effect of intervention on exchange rates due to different algorithms explained in section 5. The random assignment assures that the treatment is independent of Y0 and Y1 and the factors influencing them (X). This means that it is the central bank intervention that determines the exchange rates with and without the intervention. Furthermore, without random assignment, intervention may be correlated with the factors influencing Y0 and Y1. It means that exchange rates with intervention may differ from the exchange rates without intervention due to other factors rather than the intervention itself. In this case, the exchange rates will not necessarily identify the impact of the intervention. The outcome for the participants relative to observationally similar nonparticipants are compared and this information is used to estimate the effects of the intervention (Heinrich et al. 2010).

Table 2: Central bank foreign reserve management

NUMBER OF INTERVENTIONS

EMERGING ECONOMIES	LATW[1]	LAA[2]	2.5%*	5%**
ARGENTINA	50	24	20	11
BRAZIL	74	33	18	2
BULGARIA	61	38	30	8
CHILE	75	42	43	29
CHINA	48	27	12	2
COLOMBIA	102	55	40	18
CROTIA	42	19	31	21
CYPRUS	59	28	42	31
CZECH REP	43	27	43	18
ESTONIA	57	29	46	33
GREECE	59	34	57	52
HUNGARY	77	35	32	10
INDIA	37	28	15	2
INDONESIA	53	41	30	9
KAZAKHSTAN	41	26	41	25
KOREA	34	23	10	2
LATVIA	66	36	31	14
LITHUANIA	43	23	53	40
MALAYSIA	44	27	9	4
MALTA	67	33	43	35
MEXICO	45	30	14	2
PERU	55	32	119	5
PHILIPPINES	71	40	55	47
POLAND	43	23	29	12
ROMANIA	63	32	22	5
RUSSIA	56	32	16	2
SINGAPORE	63	41	3	0
SLOVAKIA	60	31	34	27
SLOVENIA	74	35	40	28
THAILAND	29	16	21	3
TURKEY	29	16	21	3
Total	1720	956	1020	500
Average	55.5	30.8	32.9	16.1

ADVANCED ECONOMIES	LATW[1]	LAA[2]	2.5%*	5%**
AUSTRALIA	53	31	46	35
AUSTRIA	78	41	26	10
BELGIUM	78	41	16	9
CANADA	63	33	29	10
DENMARK	63	30	21	14
FINLAND	78	39	28	19
FRANCE	49	30	56	45
GERMANY	54	34	54	28
HONGKONG	50	35	15	7
IRELAND	45	26	54	43
ISRAEL	40	31	25	7
ITALY	99	51	25	10
JAPAN	72	34	24	20
LUXEMBOURG	83	42	41	28
NETHERLANDS	82	40	31	15
NORWAY	76	44	30	13
PORTUGAL	63	36	54	44
SPAIN	97	52	37	17
SWITZERLAND	75	45	27	16
UK	54	27	36	27
US	86	41	16	5
Total	1438	783	691	422
Average	68.5	37.3	32.9	20.1

Notes:
1 Leaning Against the Wind
2 Leaning Against Appreciation
* The number of interventions when percentage change in reserves are greater than 2.5. (Reinhart and Calvo, 2002. Fear of Floating, The Quarterly Journal of Economics 117 (2), pp. 379-408)
** The number of interventions when percentage change in reserves are greater than 5.

Table 2 presents the number of interventions used in PSM depending on different incentives. It is important to remember that the central bank forex interventions are strictly confidential in most central banks, so the analysis examines foreign reserve behaviours of central banks. The four incentives selected for analysis are also proxies for possible interventions. The first two intervention possibilities are identified by examining the behaviour of the direction of foreign reserves in relation to the exchange rates; the remaining two are determined by concentrating solely on the size of foreign exchange interventions relative to the monthly trading volume[8]. Leaning Against the Wind (LATW) intervention is an intervention operation that attempts to move the exchange rate in the opposite direction from its current trend. A central bank is selling currency when it is appreciating and buying when it is depreciating. When this occurs, the central bank becomes a speculator aiming to stabilise exchange rates. In the binary regression, LATW takes the value of 1 if changes in reserves and exchange rates increase and changes in reserves and exchange rates decrease, and zero in all other cases. Leaning Against Appreciation (LAA) is in effect if the binary regression takes the value of 1 if changes in reserves and exchange rates increase and zero in all other cases. The last two column examines the foreign exchange interventions by the size of intervention[9]. The third column in Table 2 shows that the value takes 1 if percentage changes in reserves are greater than 2.5% and zero in all other cases. In the last column, the value takes 1 if percentage changes in reserves are greater than 5% and zero in all other cases. Table 2 shows the number of interventions depending on different incentives. Central banks, in EE and AE regularly make interventions in foreign exchange markets and on average, central banks in AE intervened more than central banks in EE. Furthermore, Fratzscher et al. (2019) argues that in GDP-terms the average size of the interventions in AE are higher than EE. Further discussion of policy interventions will be presented out in section 6.

The basic steps for implementing PSM are defined by Sianesi (2001) to be as follows:

[8] Vitale (2003) argues the validity of the official interventions. For example, reports of the central bank intervention may appear in the press, but they are usually imprecise. Sometimes central bank may intervene without releasing a report and sometimes reports may appear in the press, but no intervention operation may have occurred. Furthermore, quantities are rarely indicated, and actual figures are greater than the figures in the reports that are released to the public.

[9] Fratzscher et al. (2019) identified intervention according to six dimensions, i.e. incidence of interventions, their direction (purchase or sale), size of interventions, their sequence, dependence on exchange rate regimes and intervention in turbulent vs tranquil times.

1. Estimate propensity scores on the covariates using probit or logit and retrieve their predicted values[10].
2. Pair each participant with a group of comparable nonparticipants (on the basis of the propensity score) by using different algorithms.
3. Estimate the counterfactual outcome of the participant as weighted outcomes of her neighbours in the comparison group.

After estimating propensity scores on the covariates, the next step is to match participants with the same propensity scores. There are various types of matching algorithms used to pair nonparticipants with participants. The algorithm used in this study is the nearest neighbour (NN) matching method used in this study. The individual from the comparison group is chosen as a matching partner for a treated individual that is closest in terms of propensity score. There are two possible ways to conduct NN matching: one way is `with replacement' and another is `without replacement'. In the former, an untreated individual can be used more than once as a match, whereas in the latter it is considered for use only once.

Another algorithm used in this study is the five nearest neighbour matching (5NN). With this method, the individuals from the comparison group are chosen as a matching partner for a treated individual that is five closest in terms of propensity score. The last algorithm is Kernel matching (KM), a non-parametric matching estimator using the weighted averages of all individuals in the control group to construct the counterfactual outcome. Common support condition is an important factor that determines the quality of matching and is more important in the implementation of KM than in the implementation of NN-matching. This study used two Kernel matching methods, which are Gaussian Kernel and Epanechnikov (Epan) Kernel (truncated quadratic) for matching. In KM matching, all untreated observations are used to estimate the missing counterfactual outcome whereas in NN-matching, only the closest neighbour (in 5NN-matching the five closest neighbours) is used (Caliendo and Kopeinig, 2005). One major advantage of this approach is the lower variance achieved due to more information used. A drawback of these methods is possibly the use of observations which may be poor matches.

[10]This study followed Forbes et al. (2015) and used logit instead of probit model in order to "spread out" the density of scores at very low and high propensity scores. There are four covariates used for each outcome.

6. PSM Estimation Results

The objectives of this paper, as stated above, are to detect intervention policy by using monthly foreign reserve data; to measure the effects of macroeconomic fundamentals on foreign reserve policy changes; and to measure the impact of intervention policy on exchange rates by using the PSM technique. So, the particular attention on the exchange rates allows us to start the analysis by identifying the exchange rates fundamentals. One of the important problems is the endogeneity that is particularly important in policy setting. Foreign reserves are an obvious example of an endogeneity problem in many exchange rate models. Central banks use foreign reserves as an instrument to manage exchange rates. In certain cases, central banks may build foreign reserves in periods of current account surpluses to resist the appreciation. Then, the fluctuations in exchange rate also becomes at the centre of attention for determining the level of foreign reserves. In the presence of endogeneity, OLS can produce biased and inconsistent parameter estimates and hypotheses tests can be seriously misleading. GMM for panel data is an estimator that happens to be naturally well suited to deal with potential endogeneity issues. Lagged values of the dependent variables are used as instruments to control this endogenous relationship. Table 3 shows the GMM estimation results for measuring macroeconomic fundamentals in determining exchange rates in EE and AE.

Results show that all coefficients of the exchange rate determinants with the exclusion of output differential in EE and price differential in AE are statistically significant. This means that macroeconomic fundamentals are useful in determining exchange rates both during and post-crisis period for these different regions. Interest differential coefficients have negative signs in both EE and AE, which is consistent with the theory, meaning that when domestic interest rates increase (decrease), nominal exchange rates appreciate (depreciate) and when foreign interest rates increase (decrease) nominal exchange rates tend to depreciate (appreciate). The negative signs show that high inflation boosts interest rates, which in turn attracts foreign investment, causing nominal appreciation of the domestic currency. The relationship between exchange rates and prices is more complex than what theories suggest. When prices rise, domestic currency tends to depreciate in theories, but for emerging economies this further pushes interest rates, causing capital inflow and appreciation of the domestic currency. The inter-relationship between a nation's imports and exports with the exchange rate is another issue, its structure extremely complex due to the feedback loop between them. In AE, the dynamics are consistent with theories predicting effects. High

imports cause an outflow of funds that results in the depreciation of the domestic currency and high exports cause an inflow of funds that results in the appreciate the domestic currency. It is quite the opposite in EE, where high imports are usually associated with economic growth, which causes appreciation of the domestic currency and high exports. However, at the same time, boosts in imports cause higher current account deficits and depreciation of the domestic currency.

Table 3. GMM Estimation Results

GMM ESTIMATION RESULTS

DEPENDENT VARIABLE: Exchange Rates

	EMERGING ECONOMIES		ADVANCED ECONOMIES	
	Coefficients	S.E.	Coefficients	S.E.
constant	-0.007	0.015	-0.009 ***	0.004
i-i*	-0.107 ***	0.041	-0.025 *	0.018
P-P*	-0.478 *	0.310	-0.222	0.375
EXPORTS	0.031 *	0.020	-0.030 *	0.020
IMPORTS	-0.028 *	0.018	0.030 *	0.020
RESERVES	-0.655 ***	0.195	-0.099 *	0.051
Y-Y*	-0.021	0.019	-0.107 **	0.049
VIX	-0.001 **	0.000	0.001 ***	0.000
Instrument R	16		23	
SARGAN	0.15		0.37	

*, **, *** denote statistically significance at 10%, 5% and 1%, respectively.
Panel Unitroot test results show that exchange rates and interest rate differentials both in developed and emerging economies and foreign reserves in developed ecomies and do not reject the null of unitroot at level, rejecting null in first difference.
Instruments: EMERGING ECONOMIES: constant, lagged values 1 to 3 of exchange rates in first difference, lagged values 1 to 3 of differenced monetary aggregate (m2) in first difference, lagged values 1 to 3 of domestic interest rate in level, lagged value 1 of vix in level, lagged value 1 to 3 of exports in level, and , lagged value 1 to 3 of imports in level. DEVELOPED ECONOMIES: constant, , lagged values 1 to 2 of exchange rates in first difference, lagged value of domestic interest rates, lagged values 1 to 2 of foreign interest rate, lagged values 1 to 4 exports in level, lagged vaues 1 to 2 of output differential, lagged values 1 to of price differential and lagged values 1 to 2 of monetary aggregate (m2) in first difference.
Sargan test refers to the p-values for the test of overidentifying restrictions with Ho= valid overidentifiying restrictions.

Another important fundamental is the level of foreign reserves, especially important for this study. When central banks sell (buy) foreign currency and reduce (increase) their reserves, they cause appreciation (depreciation) of their national currencies. There are three important issues to be discussed while explaining the role of reserves in determining the exchange rates.

First one is related to intervention with the varying consequences depending on whether the intervention is sterilised or unsterilised. The sterilised intervention has a relatively weaker effect on nominal interest rates than unsterilised intervention. For example, buying of foreign reserves in unsterilised intervention causes an expansionary policy that results in an initial jump in exchange rates with depreciation of the domestic currency. When the intervention is sterilised, the result of expansionary foreign exchange operation is offset by contractionary monetary policy reducing its effect on exchange rate movement. Chang (2018) questioned the effects of sterilised intervention and found evidence for sterilised intervention as an independent policy tool that also complements conventional monetary policy. The effects of sterilised/unsterilised intervention will be discussed further in the following binary regression model. The second important issue is the timescale of intervention. Pilbeam (1991) argues that sterilised intervention results in an initial real depreciation of the exchange rate, but this then reverses itself so that there is a long run real appreciation of the exchange rate (p. 107). Finally, the reserve accumulation may trigger other macroeconomic variables that can affect the exchange rate. Table 3 shows that foreign reserves are statistically significant for both groups of countries and is the largest coefficient in EE and the second largest in AE. The negative sign of the coefficients may be explained by the last two issues discussed above. One of the possible explanations for this negative relationship is that building up reserve has been coupled with excess net portfolio inflow by the accumulating countries. According to Smaghi (2010), there is a strong correlation between foreign reserve and net portfolio flows in such countries. Since the surge in net portfolio inflows to emerging economies put pressure on currency to appreciate, several countries seek to resist appreciation by engaging in expansionary foreign exchange operations may have even encouraged the upsurge in speculative net portfolio inflows to reserve accumulators.

The last two regressors of the GMM estimation are the output differentials and the volatility for determining the exchange rates. This study covers the period after the collapse in the US housing market and banking sector between 2007 and 2009. Since then, the Fed has systematically reduced interest rates in order to prevent the economy from entering a deep depression. Countries with greater incentive for precautionary motives are more likely to hoard foreign reserves. Another important variable for determining exchange rate is the economic growth differential. A negative sign means higher growth rates are associated with the possibility of the appreciation of domestic currency. The final determinant is the monthly variations in the Chicago Board Options Exchange volatility index (VIX) that only explains

the smallest share of nominal exchange rate variations. It is common in literature to assume that exchange rate variations are orthogonal to risk (Kohlscheen et al., 2016). This also gives rise to the complex relationship between exchange rate and risk in different economic structures. For example, the negative sign shows that in EE, which have higher interest rates than AE, domestic currencies tend to appreciate in periods of higher risk, defending so called carry trade motives of investors. On the other hand, high risk in advanced countries is associated with depreciation of the domestic currency.

Binary regression results in table 4 and 5 show the first stage panel logit regression results in calculating propensity scores. Since central bank interventions to control exchange rates are discreet in nearly all countries, this paper attempts to determine the change of foreign reserve policy for exchange rate intervention through examining four possible alternatives. The behaviour of the central banks for implementing their foreign reserve policies are assessed either through observing foreign reserve changes in line with nominal exchange rate movements or through changes in foreign reserves in relation to the previous period. Leaning against the wind (LATW) intervention is an intervention operation that attempts to move an exchange rate in the opposite direction from its current trend. Leaning against appreciation (LAA) intervention, however, is an attempt to only prevent national currency appreciation. There is a growing support in literature for the foreign exchange intervention in relation to the direction of the exchange rate movements[11]. The latter two possible intervention is detected by looking at the percentage changes of foreign reserves higher than the threshold rates of 2.5% and 5% respectively.

Table 4: Binary Regression Results Emerging Economies

[11] See Chang et al. (2017) found that LATW interventions strategies are effective in Asian countries.

FIRST STAGE LOGIT REGRESSION RESULTS TO CALCULATE PROPENSITY SCORES

EMERGING ECONOMIES

	constant	i-i*	P-P*	EXPORTS	IMPORTS	Y-Y*	VIX	Obs.[a]	Pseudo R^2
LATW	0.48 ***	-0.02	-0.07	-0.17 **	0.13 *	0.04	-0.01 ***	1733	0.01
LAA	-0.84 ***	0.00	0.01	-0.06	0.05	-0.01	0.00	968	0.00
Intervention (2.5%)	-0.40 ***	0.04	1.36 ***	-0.36 **	0.29 ***	-0.01	0.01 **	1024	0.02
Large Int. (5%)	-1.17 ***	0.02	1.90 ***	-1.05 **	0.97 ***	-0.10 **	0.00	502	0.05
STERILISED INTERVENTION									
LATW	-1.03 ***	-0.04	-0.49	-0.22 *	0.19 *	0.00	-0.01 *	689	0.01
LAA	-2.68 ***	-0.11	-1.33	-0.61 **	0.58 ***	-0.22 **	0.00	200	0.02
Intervention (2.5%)	-1.99 ***	-0.08	0.43	-0.85 **	0.79 ***	-0.11 *	0.00	290	0.03
Large Int. (5%)	-2.79 ***	-0.26	-1.31	-1.44 **	1.37 ***	-0.29 **	0.00	139	0.05
NON-STERILISED INTERVENTION									
LATW	-0.52 ***	0.00	0.09	-0.02	-0.01	0.04 *	-0.01 *	1040	0.00
LAA	-1.15 ***	0.02	-0.05	0.17 *	-0.18 *	0.02	0.00	764	0.00
Intervention (2.5%)	-0.89 ***	0.07	1.18 ***	-0.02	-0.04	0.02	0.01 *	733	0.02
Large Int. (5%)	-1.48 ***	0.06	2.02 ***	-0.72 **	0.64 ***	-0.04	0.00	362	0.03
INTERVENTION WITH TRADE SURPLUS									
LATW	-1.19 ***	0.03	-5.80 ***	4.66 **	-4.66 ***	0.01	-0.01 *	362	0.18
LAA	-2.19 ***	0.05	-4.02 ***	3.27 **	-3.25 ***	-0.07 *	-0.01	441	0.11
Intervention (2.5%)	-1.53 ***	0.06	-0.52	3.40 **	-3.46	0.00	0.01 *	435	0.13
Large Int. (5%)	-2.37 ***	-0.01	0.70 **	2.61 **	-2.68 ***	-0.06 *	0.00	151	0.10
RESERVES GROWING HIGHER THAN OUTPUT (RGHTO)									
LATW	-0.81 ***	0.05	-0.75 *	-0.03	-0.01	-0.19 **	0.00	875	0.01
LAA	-1.10 ***	0.06	-0.20	-0.09	0.04	-0.14 **	0.00	686	0.01
Intervention (2.5%)	-0.39 ***	0.01	0.77 ***	-0.39 **	0.30 ***	-0.20 **	0.01 *	862	0.04
Large Int. (5%)	-0.89 ***	0.02	1.20 ***	-1.02 **	0.90 ***	-0.25 **	0.00	469	0.06
STERILISED INTERVENTION AND TRADE SURPLUS									
LATW	-2.13 ***	-0.05	-5.88 ***	3.47 **	-3.47 ***	-0.02	-0.01 **	313	0.11
LAA	-3.42 ***	-0.36 *	-3.82 ***	2.56 **	-2.58 ***	-0.16 *	-0.01	81	0.06
Intervention (2.5%)	-2.18 ***	0.04	-0.77	3.11 **	-3.26 ***	-0.03	0.01	111	0.10
Large Int. (5%)	-4.00 ***	-0.37	-1.65	2.54 **	-2.63 ***	-0.18 *	0.01	34	0.08
TRADE SURPLUS AND RGHTO									
LATW	-1.96 ***	0.07	-4.26 **	3.41 **	-3.42 ***	-0.19 **	0.00	396	0.11
LAA	-2.33 ***	0.08	-3.19 ***	3.02 **	-3.03 ***	-0.16 **	0.00	295	0.09
Intervention (2.5%)	-1.60 ***	0.00	-0.97 **	3.28 **	-3.36 ***	-0.16 **	0.01	351	0.12
Large Int. (5%)	-0.89 ***	0.02	1.20 ***	-1.02 **	0.90 ***	-0.25 **	0.00	141	0.10

NOTES:

*, **, *** indicate statistical significance at 10%, 5% and 1% test levels, respectively.

[a] Number of bservations where dependent variable is equal to 1. Total number of observations is equal to 3688.

Table 5: Binary Regression Results Advanced Economies

FIRST STAGE LOGIT REGRESSION RESULTS TO CALCULATE PROPENSITY SCORES

ADVANCED ECONOMIES

	C	i-i*	P-P*	EX	IM	Y-Y*	VIX	Obs.[a]	Pseudo R^2
LATW	0.47 ***	0.19	-7.56 **	-0.51 ***	0.49 ***	-0.58	0.00	1431	0.00
LAA	-0.89 ***	-0.18	-6.72 **	-0.17	0.16	0.52	0.01 *	774	0.00
Intervention (2.5%)	-1.20 ***	0.14	5.03 *	0.13	-0.15	0.23	0.02 ***	689	0.01
Large Int. (5%)	-1.66 ***	-0.07	5.47	0.13	-0.17	0.19	0.02 ***	422	0.02
STERILISED INTERVENTION									
LATW	-0.78 ***	0.63 **	1.78	-0.46 **	0.44 **	-0.08	0.00	622	0.00
LAA	-1.38 ***	0.03	5.85	0.26	-0.34	-0.42	0.00	215	0.02
Intervention (2.5%)	-1.87 ***	0.12	8.23 *	0.10	-0.17	-0.76	0.02 ***	220	0.02
Large Int. (5%)	-2.19 ***	0.30	8.78	0.20	-0.28	-0.24	0.02 ***	146	0.03
NON-STERILISED INTERVENTION									
LATW	-0.79 ***	-0.13	-9.67 ***	-0.21	0.21	-0.73	0.01	817	0.00
LAA	0.17 ***	0.31	3.92 **	0.22	0.22	1.01	0.01 **	562	0.01
Intervention (2.5%)	-1.97 ***	0.26	2.40	0.07	-0.06	0.40	0.02 ***	471	0.01
Large Int. (5%)	-2.40 ***	-0.11	3.28	0.00	-0.01	-0.01	0.02 ***	280	0.01
INTERVENTION WITH TRADE SURPLUS									
LATW	-1.11 ***	0.46 *	-1.29	5.18 ***	-5.19 ***	-0.07	0.00	713	0.18
LAA	-2.06 ***	-0.14	-2.25	3.57 ***	-3.57 ***	1.14	0.01	393	0.10
Intervention (2.5%)	-3.21 ***	-0.25	7.20 *	4.36 ***	-4.34 ***	0.51	0.03 ***	321	0.16
Large Int. (5%)	-4.19 ***	-0.18	3.90	3.95 ***	-3.93 ***	0.70	0.05 ***	192	0.15
RESERVES GROWING HIGHER THAN OUTPUT (RGHTO)									
LATW	-0.96 ***	-0.17	-7.53 **	-0.24	0.23	-12.47 **	0.01 **	776	0.05
LAA	0.16 ***	0.29	3.85 *	0.21 **	0.21 **	1.01 **	0.00 ***	647	0.02
Intervention (2.5%)	-1.26 ***	0.16	3.03	0.06	-0.08	-2.06 **	0.02 ***	640	0.01
Large Int. (5%)	-1.67 ***	-0.06	5.05	0.09	-0.12	-0.72	0.02 ***	405	0.02
STERILISED INTERVENTION AND TRADE SURPLUS									
LATW	-1.83 ***	1.13 **	2.14	3.37 ***	-3.40 ***	0.34	0.00	296	0.10
LAA	-2.39 ***	0.41	1.81	3.27 ***	-3.34 ***	0.61	0.00	117	0.09
Intervention (2.5%)	-3.29 ***	0.37	8.53	3.80 ***	-3.87 ***	-0.46	0.03 ***	102	0.13
Large Int. (5%)	-4.10 ***	0.57	-3.89	3.86 ***	-3.92 ***	0.69	0.03 ***	66	0.13
TRADE SURPLUS AND RGHTO									
LATW	-2.12 ***	-0.16	-0.91	3.65 ***	-3.66 ***	-10.20 **	0.01	382	0.14
LAA	-2.58 ***	-0.27	-2.69	3.36 ***	-3.36 ***	-5.58 **	0.02 ***	302	0.11
Intervention (2.5%)	-3.33 ***	-0.27	3.23	4.30 ***	-4.29 ***	-2.23 **	0.03 ***	295	0.16
Large Int. (5%)	-4.28 ***	-0.21	3.06	3.98 ***	-3.96 ***	-1.02	0.05 ***	182	0.15

NOTES:

*, **, *** indicate statistical significance at 10%, 5% and 1% test levels, respectively.

[a] Number of observations where dependent variable is equal to 1. Total number of observations is equal to 2499

Additionally, the analysis covers other incentives of central banks in changing foreign reserve policy for intervening the foreign exchange markets. These are monetary sterilisation, trade balance and the growth of reserves in relation to the growth of aggregate output. In tables 4 and 5, the first four rows show the coefficients of macroeconomic variables for the four possible interventions explained above. The second four rows show coefficients for sterilised interventions for each four possibilities[12]. For example, the second row of the first group in the table for emerging economies shows the coefficients of macroeconomic determinants of the central bank LAA intervention. The model performed weakly and none of the macroeconomic coefficients are statistically significant. The second row of the second group, however, includes binary observations for LAA including only ones that are sterilised. The results show that exports, imports and output differentials coefficients are found to be statistically significant. By using a similar method, the analysis tries to measure whether macroeconomic fundamentals perform better if central bank incentives such as unsterilized intervention, intervention when there is trade surplus, or intervention when reserves are growing higher than output (RGHO) are included. The last four rows are macroeconomic variable coefficients that explain intervention for each of the four possibilities with further selecting the observations that have trade surplus and the ones where reserves are growing higher than output.

Results also show that not all macroeconomic fundamentals selected for explaining policy intervention are statistically meaningful. For example, interest rate differentials fail to explain foreign exchange intervention in both EE and AE. This explains the weak relationship between the central bank's monetary policy and foreign reserve policy. VIX, used as a proxy for uncertainty, is not significant in EE but meaningful in AE especially for interventions with threshold rates higher than 2% and 5%, yet the magnitude is very small. This result shows that the argument supporting foreign reserve hoarding as a precautionary motive is quite weak for this analysis. The price differential, in many of the estimations, fails to explain foreign exchange intervention in advanced economies. The magnitude of the coefficient of output differential is higher in advanced economies and exports and imports are the major determinants of intervention in both panel estimations.

Sterilised intervention seems to be more meaningful in the estimations in EE than estimations in AE. This is presented in the last group in table 4, the signs of the coefficients

[12] Sterilised interventions are calculated when increases in foreign assets are coincided with decreases in money stock (M2). Data on monetary aggregates is obtained from IMF, Eurostat and national central banks.

consistent with the theories and all coefficients have greater values when compared to the others. This provides enough evidence for the support of mercantilist motive for foreign exchange intervention where both export and import values are important in determining the central bank's intervention policy. Additionally, the model is best performed both in EE and AE when the central banks make interventions at the time of trade surplus and when reserves are growing faster than the economy.

The next step is the application of PSM with the use of different algorithms. Matching method is a common approach to address confounding. It estimates the effect of policy change by comparing treated variables to control variables with similarly observed characteristics. One possible disadvantage is that it does not directly measure the effects of matching variables on the outcome. Yet, matching ensures that any differences between the treatment and the control groups are not the result of differences in matching variables.

Table 6. Average Treatment Effect for Foreign Reserves Policy

EMERGING ECONOMIES OFFICIAL FOREIGN EXCHANGE RESERVE POLICY MEASURES ON EXCHANGE RATES:
MEANS FOR TREATED AND CONTROL GROUPS USING DIFFERENT MATCHING ALGORITHMS

					NEAREST NEIGHBOUR (No Replacement)		5-NEAREST NEIGHBOURS		GAUSSIAN KERNEL		EPAN KERNEL	
	Mean: Treated Group (μ_t)	Mean: Unmatched Control (μ_c)	*t*-statistics *(HO: $\mu_t = \mu_c$)*	Stand. Diff.	Mean: Matched Control	*t*-stat	Mean: Matched Control	*t*-stat	Mean: Matched Control	*t*-stat	Mean: Matched Control	*t*-stat
P-P*	0.01	0.02	0.02 ***	-9.35	-0.113	-1.40	0.032	0.40	0.041	0.52	0.041	0.53
EXPORTS	10.00	11.80	0.00 ***	-34.66	0.054	0.66	0.036	0.46	0.042	0.53	0.039	0.50
IMPORTS	10.21	11.88	0.00 ***	-32.29	-0.042	-0.53	0.053	0.65	0.041	0.52	0.040	0.48
Y-Y*	-0.18	0.06	0.00 ***	-19.56	0.010	0.13	0.046	0.57	0.052	0.68	0.042	0.54
Mean Predicted p-value	0.52	0.52			0.49		0.49		0.49		0.49	
Obs.	352	3337			352		352		352		352	

*, **, *** indicate statistical significance at 10%, 5% and 1% test levels, respectively (1000 repitions are used for the bootstrap)
Note: Equations include constant and lagged variables of the control variables.

ADVANCED ECONOMIES OFFICIAL FOREIGN EXCHANGE RESERVE POLICY MEASURES ON EXCHANGE RATES:
MEANS FOR TREATED AND CONTROL GROUPS USING DIFFERENT MATCHING ALGORITHMS

					NEAREST NEIGHBOUR (No Replacement)		5-NEAREST NEIGHBOURS		GAUSSIAN KERNEL		EPAN KERNEL	
	Mean: Treated Group (μ_t)	Mean: Unmatched Control (μ_c)	*t*-statistics *(HO: $\mu_t = \mu_c$)*	Stand. Diff.	Mean: Matched Control	*t*-stat	Mean: Matched Control	*t*-stat	Mean: Matched Control	*t*-stat	Mean: Matched Control	*t*-stat
EXPORTS	12.46	14.35	0.02 ***	-37.20	0.020	9.42 ***	0.035	16.05 ***	0.009	4.48 ***	0.010	4.98 ***
IMPORTS	12.21	14.34	0.00 ***	-41.87	0.020	9.53 ***	0.000	-0.17	0.009	4.53 ***	0.010	4.73 ***
Y-Y*	0.00	0.00	0.00 ***	-1.46	0.038	17.28 ***	0.023	10.69 ***	0.010	4.64 ***	0.010	4.58 ***
VIX	22.82	19.99	0.00 ***	27.77	0.018	8.29 ***	0.019	8.56 ***	0.011	4.95 ***	0.004	1.69 *
Mean Predicted p-value	0.52	0.51			0.51		0.51		0.51		0.51	
Obs.	295	2215			295		295		295		295	

*, **, *** indicate statistical significance at 10%, 5% and 1% test levels, respectively (1000 repitions are used for the bootstrap)
Note: Equations include constant and lagged variables of the control variables.

Binary regression results are used to calculate propensity scores. The choice of covariates is based on previous empirical findings shown in table 4 and 5. Logit regressions are used for estimating the propensity scores. The results of these estimations are reported in 4 and 5. Since the last two groups in the tables performed better results, the PSM technique has been employed for all four possible interventions for each group. These are the sterilised intervention with trade surplus and trade surplus with reserve growth higher than the output growth. The results of PSM shows that there is causal inference between intervention and exchange rate in emerging economies. The results are evident especially for the threshold values, both for 2.5% and 5% interventions, as shown in the last two paragraph of table 4. The analysis found no causality for the intervention in respect to exchange rates movements, represented as LAA and LATW. To avoid repetition, only one of the results, trade surplus with reserve growth higher than the output growth for intervention with 2.5% threshold is presented in table 6. The PSM results found no evidence that interventions causal inference for exchange rates in advanced economies. The model excludes interest rate differential and vix from the covariate list in EE and it excludes interest rate differential and price differential from the covariate list in AE, because they are found to be insignificant in tables 3 and 4. The results of the average treatment effects of foreign reserves policy are given in table 6. The first two columns are means of treated and control groups for each of the group prior to matching. The next two columns are the *p* values for the *t* statistics and standardised mean difference to test whether the mean of the treated group is equal to the mean of the unmatched control group. The matching technique is meaningful for covariates if means of treated and untreated control variables are statistically different. All variables both in advanced and emerging economies need matching when the outcome is the exchange rate.

The final step is to match treated outcome with similar untreated outcome to evaluate the impact of intervention policy on exchange rates. Matching pairs each participant to a comparison group member with the same values on observed characteristics so-called covariates. It means that we are matching the exchange rates with the intervention to exchange rate without the intervention, where they all behaved similarly to covariates. Then, we can easily see that the difference in exchange rate is completely the result of the intervention. The coefficients are estimated using different matching algorithms to ensure that these findings are not driven by the selection of a particular strategy. These are nearest neighbour matching, five nearest neighbour matching, Gaussian Kernel and Epan Kernel. After propensity scores are

estimated, standard errors are bootstrapped to ascertain the Average effect of Treatment on the Treated (ATT). ATT is used to test if there is a significant difference between the treated and control groups (see Lechner, 2002). The *t*-statistics for testing the hypothesis that the mean of all variables in the treated and control groups for emerging economies are equal for all four different matching algorithms This means that all the covariates are well balanced, and the matching was effective in building a good control group. It is important to mention here is that this method is not designed to measure the effect of intervention. It is rather used as a complementary to the previous section of the analysis where we proposed an alternative method for detecting official intervention. Those proposed interventions are now meaningful that they show causal inference for the behaviour of exchange rates with and without the intervention.

The results of the PSM technique used in expressing causal assumptions are found to be cognitively meaningful. The matching successfully eliminated the differences between treated and control groups only in EE. The observed exchange rate fundamentals, so-called covariates such as interest rate differentials, exports, imports and economic growth differentials are used in expressing a causal inference. The impact of foreign exchange intervention on exchange rates are meaningful for central banks in EE in all four matching techniques. In AE, on the other hand, the covariates fail to eliminate differences between treated and control groups, which makes the impact of intervention on exchange rates not meaningful. Therefore, the PSM technique is not appropriate for central banks in AE.

7. Conclusion

There has been a growing academic interest in the analysis of foreign exchange intervention by central banks with the purpose of controlling exchange rates. Since interventions are discreet, it is difficult to measure the effects on financial markets. The aim of this paper was to determine the factors that affect foreign reserve policy intervention in EE and AE. Despite criticism about the use for official reserve data, this study provides evidence showing we can analyse central banks' foreign reserve management and predict interventions by using official foreign reserve data and other major macroeconomic variables.

The intervention of central banks in foreign exchange markets has been an important area of research and will continue to be attractive for research into the behaviour of central

banks in the future. Central bank foreign reserve management in countries with floating exchange rate regimes and the hoarding of foreign reserves not only in emerging economies but also in most advanced countries have been important elements of the conduct of monetary policy. Having excessive reserves and carrying out interventions and/or manipulations is difficult to determine. Fear of floating and asymmetric preferences are still important. Since the financial crisis of 2008, central banks in both EE and AE react similarly and more aggressively to appreciation. The PSM technique for reserve intervention for the control of exchange rates fails to remove selection bias for treated and untreated control groups in AE but successfully removes selection bias in EE.

8. Appendix

8.1. Data

Changes in reserves are used as a proxy for intervention flows. Reserve assets include gold, SDRs and foreign exchange. The foreign exchange component of official reserves reflects foreign reserve policy actions, including interventions and reserve portfolio management. Exchange rates are the national currency per US dollars (for the US it is USD per Euro and ECU values are used before 1999Q1). Increases are represented as depreciation of national currency against US dollars. Both variables are obtained from the IMF (except ECU, which is obtained from EUROSTAT).

Data obtained from the national central banks, national statistical departments and OECD.

- The panel analysis includes 31 emerging and frontier economies and 21 advanced economies.
- Data range: 2008M1-2017M12
- Official foreign exchange reserves: foreign currency reserves of the central banks. (financial assets including securities and currencies and deposits)
- Exchange rates are the national currency per US dollar.
- CPI is used for prices and M2 is used for monetary aggregates
- Central bank target interest rate

- Exports and imports
- Industrial production index used as a proxy for volatility in the real sector.
- VIX used to measure financial markets' sensitivity to uncertainty.

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