This paper investigates the effect of central bank intervention using a heterogeneous expectations exchange rate model. We apply Markov switching approach on daily USD/IDR exchange rate, intervention data of Bank Indonesia, from 2006 to 2012. The results support both chartists and fundamentalist regimes, and confirm the two regimes to be persistent. Moreover, the intervention of Bank Indonesia on foreign-exchange is capable to drive the USD/IDR to its fundamentalist rule. However, on Bank Indonesia efforts to exert a stabilizing effect of foreign exchange interventions, the result is inconclusive.

Keywords: Exchange rates, foreign-exchange intervention, switching regression

JEL Classification: F31, E52, C24
I. INTRODUCTION

According to the postulate of impossible trinity, a free floating exchange rate regime will be adapted by a country with free capital mobility and independent monetary policy. Indonesia is one of country that adapts it. With the free floating exchange rate and a size of small open economy, the fluctuation of Rupiah’s rate depends strongly on the capital flows particularly the short run. In foreign exchange market, the capital flows is a reaction of the buy or sell activities from the market players, which is categorized in two groups. The first group is fundamentalists who buy or sell foreign exchange based on their exchange rate expectation following the fundamental economic condition. The second group is chartist who buys or sells foreign exchange based on their exchange rate expectation following the previous exchange-rate behavior. These two groups determine the market exchange-rate.

Sometimes the exchange rate moves beyond their fundamental value, and this requires the central bank to intervene to drive the exchange rate back to its long-run fundamental value. Many empirical literatures including Almekinders and Sylvester (1996), Frenkel (2004), Ito and Yabu (2007), and Neely and Weller (2001) suggested the foreign-exchange intervention policy was to reduce the exchange rate misalignment or undesired fluctuations.

We can distinguish two types of forex intervention; first is a non-sterilized foreign-exchange intervention where the decision of monetary authority to buy or to sell foreign exchange affects the monetary base, interest rates, market expectations and the exchange rate. Secondly, a sterilized-foreign-exchange intervention is policy by monetary authorities to “defend” the value of their currency or the domestic money supply despite external shocks or other changes, including the flow of capital out of the relevant area.

With central bank policy, we expect the exchange rates to stay in desired level and stable. Nevertheless, besides relying on central bank policy to stabilize the exchange rate, financial agents are sometimes actively hedging the exchange rate in order to avoid losses due to exchange rate fluctuations. Röthig, Semmler, and Flaschel (2005) argued that the negative effect of exchange rate on the balance sheet can be eliminated by risk management like hedging. Hedging generally conducts by forward transactions, swaps, NDF etc.

This paper analyzes the microstructure of foreign exchange market players (fundamentalists and chartists) in determining exchange rate. We expect this approach will be able to overcome failures of numerous empirical studies based on asset market approach on explaining the short term movements of exchange rate (Lewis, 1995 and Taylor, 1995. This paper adopts the exchange-rate microstructure approach called 'noise trading' channel pioneered by Hung (1997) and the coordination channel Reitz and Taylor (2008), and Taylor (2004), (2005). Ahrens and Reitz (2003) perform empirical study regarding to this issue and their result provide evidence that the heterogeneous expectations exchange rate model is able to explain daily German-US forward rates. Further research by Maatoug, Fatnassi, Omri (2010) finds that both regimes (fundamentalists and chartists) are persistent in Australia. However he finds that the
fundamentalist’s regime is riskier and when the RBA was not active in the foreign exchange, the fundamentalists were disappeared. Other study using Markov switching approach by Brunetti, Mariano, Scotti (2007) in Southeast Asia, finds that real effective exchange rates, money supply, stock index returns, are important variables to identify turbulence and ordinary periods.

To investigate different forecasting strategies by the players, the impact of central bank intervention is investigated by applying a heterogeneous expectations exchange rate model. The approach is also evaluated by including central bank intervention policy to drive exchange rate to its long-run fundamental value. Foreign-exchange interventions may influence the forecasting rules of chartists and fundamentalists, thereby altering the proportion of the two groups in the foreign exchange market. A central bank intervening in the foreign exchange market is considered effective if the exchange rate is driving closer to its fundamental value. Generally, foreign-exchange intervention may as well improve the performance of expectations based on fundamentals, especially when central banks try to correct current exchange rate misalignments. Following Frankel and Froot (1986) the excess demand/supply for foreign currency is assumed to be a function of the relative success of chartist and fundamentalist forecasting techniques. As is stated above the performance of chartist or fundamentalist predictions is expected to be temporarily improved by central bank intervention.

This research furthermore re-examines the effects of foreign-exchange intervention on exchange rate volatility within the heterogeneous groups in the foreign exchange market. These studies suggested new channels through which sterilized intervention may be transmitted: the noise trading channel (Hung, 1997), which assume that the noise traders will determine the exchange rate by flow of market equilibrium, and that the central bank should intervene in highly volatile market periods and keep its interventions secret (Reitz, 2002).

This empirical research is done by applying the Markov regime-switching approach originally proposed by Hamilton (1989) to daily Bank Indonesia data from 2006 to 2012. Considering the results of Neely and Weller (2001) intervention data is used only to construct a dummy variable distinguishing between intervention and no-intervention periods. Statistically significant estimates of dummy coefficients lead to the conclusion that an impact of central bank intervention on exchange rate expectation cannot be rejected.

The remainder of the paper is organized as follow. Section 2 describes the theory and literature study, followed by Research Methodology in section 3. Our main empirical results concerning intervention effectiveness are reported in Section 4, before the final section (5) concludes.
II. THEORY

2.1. The Microstructure of the Forex Market and Monetary Policies

In macro perspective, foreign exchange level should reflect the fundamental economy condition. As described so far, the determinants of the exchange rate like inflation, productivity, interest rate, etc. categorized as fundamental factors which significantly affect long-run exchange-rate. Furthermore, news related to the fundamental factors such as statistic announcements of money supplies, trade balances, or fiscal policies is received by the market, and the exchange rates will also change to reflect this news. However, there is also significant issue regarding foreign-exchange microstructure which also determines exchange rates. Understanding the “market microstructure” allows us to explain the evolution of the foreign exchange market, in which foreign exchange traders adjust their foreign-exchange purchase or sale. In addition to macroeconomic indicators news, there also exists private information from which some traders know more than others about the current state of the market.

As illustrated in Figure 1, exchange rate is determined by two groups according to different approaches of expectations; the fundamental analysis and the chartist analysis. The classification was proposed previously by Frankel and Froot (1986, 1990), and has been enhanced among others by Ahrens and Reitz (2003), Reitz (2002), Westerhoff (2003), Wieland and Westerhoff (2005). In this diagram, the market exchange-rate is built by combining fundamentalists and chartist’s exchange-rate expectation adjusted by their own proportion in the foreign-exchange market. In the period of misaligned exchange-rate from desired value, central bank will enter the market to re-adjust the exchange rate to its desired level or mitigate the short-term fluctuations.

![Figure 1. Fundamentalist-Chartist FX Expectation Mechanism](Source: Own Elaboration)
The global financial market has been pushing the financial market in emerging countries to integrate. As return of assets offered is often higher than ones in advanced financial market, the asset return including the exchange rate becomes more volatile. This condition is not accepted by most central banks as it will ignite greater uncertainty in their financial market. Some reasons include that a large movements in the real exchange rate away from medium-run equilibrium are costly, and secondly, there is imperfect capital mobility/asset substitutability. To overcome this phenomenon, most central banks in emerging market economies implement various monetary policies. The most popular ones are sterilized intervention and short-term policy rate. This opens up the fortuitous possibility that policymakers may be operating in a two-target, two-instrument world.

Lesson learned from previous financial crises, push central banks to maintain stable consumer prices if they are to achieve sustained and stable growth. Therefore, the central banks need more policies than just the policy interest rate such as foreign-exchange interventions. Lesson from crises taught that significant balance-sheet mismatches caused by exchange-rate misalignment, is not optimal. Thus, it is not wise to ignore possibly large deviations of the exchange rate from its medium-run equilibrium, even in an Inflation Target which requires floating exchange-rate system. The undesired exchange rate fluctuations might be response shortly by foreign-exchange intervention. On the contrary, reacting to such changes can deliver better economic outcomes under IT than benign neglect of the exchange rate (Stone, Roger, Shimizu, Nordstrom, Kisinbay, Restrepo, 2009). In this regard, beside two instruments (i.e. short-term policy interest rate and foreign-exchange intervention), there are potentially two policy targets: inflation and the exchange rate to be implemented in order to achieve sustainable economic growth.

Volatility in foreign exchange rates can disrupt domestic economy through deteriorating imports and exports performance, decreasing cross-border investment and funding, and threaten the stability of domestic prices through changes in prices for imported or exported goods (passed-through power of exchange rate to inflation). As a result, this could affect the domestic economy and even the economies of trading partners abroad. Therefore, the monetary authority even with ITF should manage the exchange rate to support the achievement of domestic price stability and domestic economy by applying monetary policies such as foreign exchange intervention. While many central banks objectives are to set the optimal level of foreign-exchange that support price stability achievement as well as to mitigate exchange-rate volatility, however, others prefer to limit exchange rate volatility rather than to meet a specific target for the level of the exchange rate. Beyond on that, most central banks admit that domestic interest is still the main reason why they enter the foreign-exchange market in a sustained basis. For example as summarized in BIS publication (2006), major emerging central banks in Asia perform selling intervention to halt the continuing their currency appreciation between the end of 2001 and the end of 2004. As a consequence, global foreign exchange reserves grew by over US$ 1600 billion, reflecting reserve accumulation by emerging market
economies. This phenomenon shows the emerging central banks was actively enter the foreign exchange market to avoid their undesired appreciation of their currencies as it would harm their export competitiveness/domestic economy.

On the other hand, some central banks have different views on exchange rate. They conversely prefer to stay behind from the foreign exchange intervention such as few developed countries have actively intervened within the last decade. There are some reasons behind that decision. One of them suggests foreign exchange intervention policy is not good for the economy where unbalances exist. Letting the exchange rate fluctuate freely is a sign of economic rebalancing is working. In this case, the dynamics of the exchange rate is a functioned as automatic stabilizer for the economy. This argument is elaborated in the studies by Calvo and Reinhart (2000) which concludes the foreign exchange intervention is a kind of fear of floating phenomenon. BIS (2006) summarize the reasons why developed countries no longer intervenes their foreign-exchange market actively. BIS suggest that the instrument is only effective if regarded as additional policy interest rate. Another reason implied that large-scale intervention can undermine the stance of monetary policy independence. The last reason is that private financial markets have enough capacity to absorb and manage shocks - so let the market determine the exchange rate.

Many economists are interested to see the effectiveness of the exchange rate intervention conducted by the central bank to stabilize the exchange rate. However, the existing views differ about the effectiveness of this intervention on stabilizing the exchange rate. Taylor (2004) examines the effectiveness of the exchange rate intervention by using Markov switching model on dollar-mark data during the period of 1985-98. In his conclusion, Taylor shows that the intervention increase the probability of stability when the rate is misaligned, and that its influence grows with the degree of misalignment. However, intervention within a small neighborhood of equilibrium will result in a greater probability of instability.

Beine, Grauwe, and Grimaldi (2009) investigated the effect of sterilized intervention in a noise trading channel with two states Markov switching model. Using biweekly data, they found that interventions increase the weight of fundamentalists in the foreign exchange market and therefore exert stabilizing influence on the exchange rate. The fundamentalist behavior tends to stabilize the market while the presence of chartists may cause destabilization. Other study by Dominguez (1998) explored the effect of foreign exchange intervention by the G-3 central banks (US, German, and Japanese) on the behavior of exchange rates over the 1977-1994 periods. The results indicate that intervention operations generally increase exchange rate volatility.

As discussed previously, the microstructure approach of exchange rate studies suggested two new channels through which sterilized intervention may be transmitted. In this regards, foreign-exchange intervention influence the expectations of foreign-exchange traders which are defined as fundamentalist and chartists. In this case, Frankel and Froot (1988) developed a model incorporate both players which is used to forecast the exchange rate expectations by
them. The fundamentalist approach forecasts exchange rate expectation by the fundamentalists based upon economic fundamentals, whereas the chartist approach forecasts exchange-rate expectation by chartists based upon the past behavior of the exchange rate. Furthermore, this model is developed by Vigfusson (1996) by implementing the Markov regime-switching model, in which explains the Chartist and Fundamentalists (C&F). He also suggests that using MA chartist model appears to do much better the AR chartist model. In this approach there are two rules in which two forecasting equations of both chartist and fundamentalist set up to estimate foreign exchange expectations. In each equation, C&F model placed the time-varying weight.

Further research from Reitz (2002) analyzed the exchange rate market player's behavior and also investigated the impact of central bank intervention to their exchange rate expectations. Reitz propose a generalization of the noise trader transmission mechanism to examine the impact of central bank intervention on exchange rates. Within heterogeneous exchange rate expectations model, the policy intervention suppose to support either the chartist or the fundamentalist forecasts, which drive the portfolio managers to adjust their foreign currency positions. He tests the model by applying daily US-dollar/DEM forward rates and intervention data of the Deutsche Bundesbank and the Federal Reserve from 1979 to 1992. He finds the performance of the simple chartist trading rules was strong whenever the central bank intervened on the foreign exchange market. Instead, the result of fundamentalist approach was worse.

In Australia, the RBA’s approach to foreign exchange market intervention has evolved since the floating of Australian dollar in 1983. This is particular because the foreign market in Australia has developed and on the other hand, the market participants are better equipped on managing their foreign exchange risk. Over time, the intervention on foreign exchange market becomes much less frequent and targets specific period when the market disfunction occur. Infact, during the 2008 crisis, the RBA has suspended the foreign exchange intervention.

2.2. A Basic Chartist-Fundamentalist Model for the Exchange Rate

In this paper, the foreign exchange equilibrium is determined by the interactions of two market players; the fundamentalist and the chartist, both with their own expectation on exchange rate. The chartists use technical analysis by exploring the historical data to forecast the exchange rate in the future. On the other hand, the fundamentalists base their forecasts on the assumption that the exchange rate will move around and will converge to its fundamental value.

We construct basic model following Maatoug, Fatnassi, Omri (2010: 30-34) and Reitz (2002: 3-7). Fundamentalists forecasting rules and Chartists forecasting rules can be expressed, respectively, as follow:

\[ r_{f,t} = \theta (f_{t-1} - e_{t-1}) + \epsilon_{f,t} \quad (1) \]
\[ r_{c,t} = \psi (r_{t-i}) + \epsilon_{c,t} \quad (2) \]
where:

- $r_{ft}$ = the forecasted value of the exchange rate return $r_t$ by fundamentalists
- $\theta$ = a speed of adjustment for fundamental rule
- $f_{t-1}$ = lagged fundamental exchange rate
- $r_{ct}$ = the forecasted value of the exchange rate return $r_t$ by chartists
- $\psi$ = speed of adjustment for the chartists forecasting rule
- $\epsilon_{ct}$ = the error term of chartists
- $\epsilon_{ft}$ = the error term of fundamentalists

To solve the model, one can apply the Markov regime-switching technique initially introduced by Hamilton (1989: 357-384) and later developed by, among others, Engel (1994: 151–165) and Dewachter (1996: 405-407). In Markov switching model, the dynamics of the exchange rate is governed by unobserved state variable or a latent variable $l_t$ ($l_t = c$ for chartist regime $l_t = f$ for fundamentalists). The indicator regime $l_t$ is parameterized as a first order Markov process and is driven by first-order transition probabilities. The transition probabilities across the two regimes could be expressed as:

\[
p = \text{prob}(l_t = f | l_{t-1} = f)
\]

\[
q = \text{prob}(l_t = c | l_{t-1} = c)
\]

These probabilities are constant over time. In this specification, $p$ is the probability to remain in the fundamentalist regime, and $q$ in the chartist regime.

\[
p = 1 - (1 - \exp(\pi_0))^{-1}
\]

\[
q = 1 - 1 - (1 - \exp(\kappa_0))^{-1}
\]

### III. METHODOLOGY

#### 3.1. Markov Switching Approach

As is stated in Clarida, Sarno, Taylor, Valente (2001: 61-83) the Markov regime-switching model is a natural candidate to characterize exchange rate behavior. In this model, the conditional mean of the exchange rate ($\mu_t$), the conditional variance ($h_t$), changes of exchange rate ($\Delta e_t$) are allowed to follow two different regimes—a chartist and a fundamentalist regime-represented by an unobservable state variable $S_t$. The regime indicator $S_t$ is parameterized as a first-order Markov process, where the transition probabilities ($P$ for fundamental regime and $Q$ for chartist regime), follow the typical Markov structure:
Thus, under conditional normality, an observed realization $\Delta e_t$ is presumed to be drawn from a $N(\mu_0, h_0)$ distribution if $S_t = 0$, whereas $\Delta e_t$ is distributed $N(\mu_1, h_1)$. The evolution of the log first differences of exchange rates can there for be written as

$$\Delta e_t = \mu_0 (1 - S_t) + \mu_1 S_t + \sqrt{h_0} (1 - S_t) + h_1 S_t \epsilon_t$$

(8)

Where $\epsilon_t$ is an i.i.d. standard normal variable. The parameter estimation of the mean ($\mu_t$) and variance ($h_t$) equations in the regime switching model are derived from maximization of the log-likelihood function

$$L = \log p_{1t} \frac{1}{\sqrt{2\pi h_{1t}}} \exp \frac{-\Delta e_t - \mu_{1t}}{2h_{1t}} + (1 - p_{1t}) \frac{1}{\sqrt{2\pi h_{2t}}} \exp \frac{-\Delta e_t - \mu_{2t}}{2h_{2t}}$$

(9)

$p_{1t} = Pr (S_t = 1 | \Phi_t)$ is the probability that the analyzed process is in regime 1 at time $t$ and is updated by means of Bayesian inference using information available at time $t-1$. Therefore, $p_{1t}$ and $(1-p_{1t})$ can be regarded as weights assigned to regime dependent forecasts resulting from a rational learning process as outlined in the theoretical exchange rate model. For comparison purposes, this research first specifies the mean equations without taking into account foreign exchange market activities of central banks. However, the important results of the study are derived from mean equations that include intervention dummies as it is done in the second specification.

### 3.2. The Chartist-Fundamentalist (C & F) Model Specification

This paper applies the Markov-switching approach on exchange rate expectation by fundamentalists and chartists in Indonesia as suggested by Reitz (2002). This paper will augment the basic model with some contemporaneous variables beside exchange-rate return and exchange-rate intervention with other variables such as NDF return and CDS. These augmented variables are used as they may have significant impact on exchange-rate behavior.

In the standard chartist and fundamentalist (C&F) model originally suggested by Frankel and Froot (1986: 24–38), the (log of the) exchange rate $S_t$ is driven by the decisions of portfolio
managers. In his model, foreign-exchange players buy and sell foreign currency in response to changes in their expected rate of changes and a set of contemporaneous variables included in a vector \( z_t \). Thus, the exchange rate is written as:

\[
S_t = a E_t[\Delta r_{t+1}] + \beta z_t
\]  

(10)

where the vector of elasticity of the contemporaneous variables (\( \beta \)) and the elasticity of exchange rate expectation (\( a \)) should be constant overtime. Regarding to Frankel and Froot (1986: 24–38), it is assumed that portfolio managers generate their exchange rate expectations using a mixture of chartist \( E^c_t[\Delta r_{t+1}] \) and fundamentalist \( E^f_t[\Delta r_{t+1}] \) forecasts:

\[
E_t[\Delta r_{t+1}] = \omega_t E^f_t[\Delta r_{t+1}] + (1-\omega_t)E^c_t[\Delta r_{t+1}]
\]  

(11)

The parameter \( \omega_t \), denoting the weight given to fundamentalist views at date \( t \), is dynamically updated by the portfolio managers in a rational Bayesian manner:

\[
\Delta \omega_t = \delta(\omega^*_t - \omega_{t-1})
\]  

(12)

With:

\[
\omega^*_{t-1} = \frac{\Delta e_t - E^c_t(\Delta e_t)}{E^f_{t-1}[\Delta e_t] - E^c_{t-1}[\Delta e_t]}
\]

Where \( \omega^*_t \) is the ex-post calculated weight that must have been assigned to fundamentalist forecast in order to predict the current exchange rate change accurately. The value of \( \delta \) reflects the extent to which portfolio managers enclose new information in this adaptive process and proves responsible for the exchange rate dynamics. Since portfolio managers always maintain a positive weight for both chartist and fundamentalist forecasts, \( \Delta \omega \) has to be restricted so that stays in the range between 0 and 1. To make sure that the empirical analysis remains tractable, another feedback rule is introduced. Similar to Lewis (1989: 79–100), portfolio managers are supposed to optimize the weight assigned to fundamentalist forecasts by means of a Bayesian learning process:

\[
\omega_t = \frac{\omega_{t-1} \cdot \varphi_f(\Delta e_t|E^f_{t-1}[\Delta e_t])}{\omega_{t-1} \cdot \varphi_f(\Delta e_t|E^f_{t-1}[\Delta e_t]) + \omega_{t-1} \cdot \varphi_c(\Delta e_t|E^c_{t-1}[\Delta e_t])}
\]  

(13)

Where \( \varphi_c(\Delta e_t|E^c_{t-1}[\Delta e_t]) \) and \( \varphi_f(\Delta e_t|E^f_{t-1}[\Delta e_t]) \) is density function of forex return, both for chartists and fundamentalists respectively. Concerning the
expectation formation fundamentalists have in mind some kind of long-run equilibrium $\bar{S}_t$, to which the exchange rate reverts with a given speed $\theta$ over time, i.e.:  

$$E_t^f [r_{t+1}] = \theta (\bar{S}_t - S_t)$$  \hspace{1cm} (14)  

According to fundamentalist, foreign-exchange expectation by the exchange-rate traders can be moved as distributed symmetrically around its fundamental value $\bar{S}_t$. Although several research uses PPP as proxy of exchange-rate fundamental value, this paper uses that the fundamental value $\bar{S}_t$ as described by uncovered interest parity (UIP). The model above explains that market exchange-rate will converge to its fundamental value $\bar{S}_t$ in the long run. A study using PPP by Takagi (1991) provides evidence there is a valid relationship between market exchange-rate and fundamental exchange rate only in the long run implying low values for $\theta$. This view is also supported by Taylor and Peel (2000) and Taylor (2001) showing that due to its nonlinear dynamics the exchange rate reverts to the PPP level, but only in the long run. Furthermore, PPP or UIP as a measure of the fundamental exchange rate seems to be suitable for the investigation of central bank intervention, because monetary authorities have used it as a target level (Domínguez and Frankel, 1993).

If market exchange rate does not converge to its fundamental value in the long run, central banks will enter the foreign exchange market. The efforts of the central banks on foreign exchange markets can be called effective, if the adjustment of the exchange rate ($\theta$) to its long run equilibrium is accelerated.

This implies that the observed reversion of the exchange rate to PPP or UIP – denoted by $\zeta_t$ - is driven by fundamentalist speculation, central bank intervention, NDF rate and CDS rate. Denoting the influence of foreign exchange intervention/monetary policy by $\delta_\theta$, NDF by $\alpha_\theta$ and CDS by $\omega_\theta$, this research can formulate $\zeta_t$ as a function of a 0,1- Exchange-rate Intervention dummy $l_t$, NDF$ _{t}$ and CDS$ _{t}$ as follows:

$$\zeta_t = \theta + \delta_\theta l_t + \alpha_\theta \text{NDF}_t + \omega_\theta \text{CDS}_t \quad \text{ where } \theta, \delta_\theta, \alpha_\theta, \omega > 0 \quad (15)$$

Adopted from Reitz (2002), chartists are defined as market participants who believe that market exchange rate will move to its long-run average value measured by technical trading rules ($ma_{200}$). Chartists are supposed to expect that a future exchange rate increases predicted by the proportion $\psi$ of the positive difference between the 3 day moving average ($ma_3$) and 200 day moving average ($ma_{200}$) and vice versa. Hence, their exchange rate expectation at $t$ is:

$$E_t^c [\Delta e_{t+1}] = \psi (ma_{200,t} - ma_{3,t})$$  \hspace{1cm} (16)  

As is stated in the noise trader hypothesis (Hung, 1997), central bank will implement a leaning against the wind-strategy to change the trader’s expectation back to chartist exchange
rate fundamental value $ma_{200,t}$. Subsequent changes in noise trader’s positions magnify the initial impact of intervention operations. This research assumes that this kind of trend establishing intervention can be formalized by means of a moving average specification very similar to speculation based on chartist analysis. This implies that a given trend in the exchange rate ($\eta_t$) is due to chartist speculation, central bank intervention and NDF rate. Denoting the influence of foreign exchange intervention/monetary policy by $\delta_{\psi}$, NDF by $\alpha_{\psi}$ and CDS by $\omega_{\psi}$, this research can formulate $\eta_t$ as a 0,1-intervention dummy $l_t$, NDF$_t$ and CDS$_t$, as follows:

$$\eta_t = \psi + \delta_{\psi}l_t + \alpha_{\psi}NDF_t + \omega_{\psi}CDS_t$$

where $\psi$, $\delta_{\psi}$, $\alpha_{\psi}$, $\omega_{\psi} > 0$ (17)

When applying the C&F model with exchange rate data, the econometric approach should be able to describe the conditional distribution of the exchange rate change by a mixture of (normal) distributions.

Clearly, if the foreign exchange intervention of the central bank had an impact on the forecasting performance of chartists and fundamentalists, a change of coefficients represented by significant estimates of the various $\delta_i$ should be observed. By introducing intervention dummies, NDF rate, and CDS rate in the specification of second moment, the conditional variance becomes:

$$h_{0t} = \sigma_F^2 + \delta_{\sigma_F^2}l_t + \delta_{\sigma_F^2}NDF_t + \delta_{\sigma_C^2}CDS_t$$

for the fundamental regime, and

$$h_{1t} = \sigma_C^2 + \delta_{\sigma_C^2}l_t + \delta_{\sigma_C^2}NDF_t + \delta_{\sigma_C^2}CDS_t$$

for the chartist regime. Thus, this paper is able to re-examine the relationship between central bank intervention, NDF, CDS and exchange rate volatility.

### 3.3. Data

The data are daily for the sample period 2006 – 2012. All variables are in logarithms except for the interest rate variables, which are in annual terms. The foreign variable is US Federal Funds Rate. The Indonesian variables are domestic o/n interbank interest rate, the underlying consumer price index, NDF USD/IDR Rate, and the USD/IDR spot exchange rate. The microstructure of foreign exchange in Indonesia is still limited as few traders exist in foreign exchange market. Even though there are 72 foreign exchange banks in Indonesia, only about 22 to 38 banks actively trade in the foreign exchange market. However, Bank Indonesia state that the microstructure of the domestic foreign exchange market also influences the effectiveness of intervention. The net supplier of foreign exchange is still dominated by domestic state-owned banks, while foreign
banks’ supply or demand depends on capital inflow/outflow. The volume of transactions tends to be larger during periods of heavy portfolio inflows. Most foreign-exchange transactions are spot accompanied by swap, although forward transactions are developing. There are counter-party transaction limits, especially for smaller banks. Foreign-exchange transactions must have underlying and are limited to domestic players only (Warjiyo, 2013).

VI. RESULT AND ANALYSIS

The models described above were estimated by maximum likelihood. Parameter estimates were obtained using the BFGS algorithm, and the reported t-statistics are based on heteroscedastic-consistent standard errors (White, 1982). The estimates are derived from the daily USD/IDR spot exchange rate series provided by the Bloomberg. The UIP was constructed using daily O/N Interbank rate of IDR and USD. The intervention dummy series is based on intervention data kindly provided from the Bank Indonesia. The foreign exchange intervention series only includes active foreign-exchange interventions made by Bank Indonesia to influence foreign exchange rates. Foreign exchange interventions by BI are reported whenever they changed their net foreign assets. The sample extends from January 2006 to June 2012. The series of the spot exchange rate, the UIP relation, the 200 day moving average, and Bank Indonesia purchases and sales of Dollars against IDR are provided below.

![Figure 2. USD/IDR spot rate, UIP, 200d MA and BI FX Intervention](image-url)
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>$\theta$</td>
<td>0.094 (11.47)***</td>
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<td>0.075 (10.06)***</td>
<td>0.079 (8.17)***</td>
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<td>0.034 (2.68)***</td>
<td>0.035 (2.89)***</td>
<td>-0.033 (2.79)***</td>
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<td>$\alpha_\theta$</td>
<td>0.051 (1.50)***</td>
<td>0.063 (1.83)***</td>
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<td>-1.43 x 10^{-3} (-0.95)***</td>
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<tr>
<td>$\psi$</td>
<td>0.045 (5.65)***</td>
<td>0.049 (12.60)***</td>
<td>0.031 (4.82)***</td>
<td>0.023 (2.90)***</td>
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<tr>
<td>$\delta_\psi$</td>
<td>-0.020 (-2.88)***</td>
<td>-0.012 (-1.60)***</td>
<td>-7.96 x 10^{-3} (-0.95)***</td>
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<td>$\alpha_\psi$</td>
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<td>0.119 (4.37)***</td>
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<tr>
<td>$\omega_\psi$</td>
<td>7.86 x 10^{-3} (4.35)***</td>
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<td>$\sigma^2_F$</td>
<td>3.85 x 10^{-5} (5.22)***</td>
<td>2.07 x 10^{-5} (4.99)***</td>
<td>2.12 x 10^{-5} (6.18)***</td>
<td>2.08 x 10^{-5} (4.51)***</td>
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<tr>
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<td>2.99 x 10^{-5} (2.09)***</td>
<td>2.97 x 10^{-6} (1.74)***</td>
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<tr>
<td>$\sigma^2_C$</td>
<td>2.36 x 10^{-6} (6.80)***</td>
<td>1.97 x 10^{-6} (6.77)***</td>
<td>1.60 x 10^{-6} (6.33)***</td>
<td>1.39 x 10^{-6} (4.74)***</td>
</tr>
<tr>
<td>$\delta^2_{\sigma^2_C}$</td>
<td>6.21 x 10^{-7} (1.17)***</td>
<td>8.00 x 10^{-7} (2.00)***</td>
<td>7.83 x 10^{-7} (0.88)***</td>
<td></td>
</tr>
<tr>
<td>$P$</td>
<td>0.888 (22.64)***</td>
<td>0.890 (18.67)***</td>
<td>0.814 (12.87)***</td>
<td>0.784 (11.18)***</td>
</tr>
<tr>
<td>$Q$</td>
<td>0.931 (58.87)***</td>
<td>0.926 (32.19)***</td>
<td>0.894 (23.71)***</td>
<td>0.853 (18.17)***</td>
</tr>
<tr>
<td>$\bar{P}$</td>
<td>0.380</td>
<td>0.400</td>
<td>0.365</td>
<td>0.360</td>
</tr>
<tr>
<td>$\bar{Q}$</td>
<td>0.620</td>
<td>0.600</td>
<td>0.635</td>
<td>0.640</td>
</tr>
<tr>
<td>$(1 - P)^{-1}$</td>
<td>8.90</td>
<td>9.06</td>
<td>5.39</td>
<td>3.82</td>
</tr>
<tr>
<td>$(1 - Q)^{-1}$</td>
<td>14.52</td>
<td>13.57</td>
<td>9.39</td>
<td>6.80</td>
</tr>
<tr>
<td>Log-Likelihood LRT</td>
<td>6279.31</td>
<td>6313.95</td>
<td>6362.74</td>
<td>6379.40</td>
</tr>
<tr>
<td></td>
<td>69.28***</td>
<td>166.86***</td>
<td>200.17***</td>
<td></td>
</tr>
</tbody>
</table>

Table 1 contains the estimates of the RS-CF, the RS-CF-INT, RS-CF-INT-NDF and RS-CF-INT-NDF-CDS models. As regards the smoothed transition probabilities, all models differ slightly. The $P$ and $Q$ range above 0.78 thereby indicating a high persistence of the regimes. The unconditional probability of the fundamentalist regimes $P$ is lower than the one assigned to chartist regime. This is also reflected in the expected duration of regimes.
In the RS-CF model (a), the (first) fundamentalist regimes are expected to last up \((1-P)^{-1}\) to 8.9 trading days whereas the (second) chartist regimes \((1-Q)^{-1}\) have a longer duration of at least 14.5 trading days. Meanwhile, the fundamentalist rule USD/IDR expectation share \((\tilde{P})\) is about 38\% smaller than the chartist rule USD/IDR expectation \((\tilde{Q})\) is 62\% in performing USD/IDR market rate. Significant estimates of variances, point to regime dependent heteroscedasticity, which capture the periods of high and low volatility. The variance in the second regimes \(\sigma_F^2\) in these conditional regimes is lower than the variance in the first regimes \(\sigma_C^2\). The estimates of chartist and fundamentalist coefficients \(\psi\) and \(\theta\), are statistically significant and of the correct sign.

![Smoothed Probabilities of USD/IDR, Reitz Model](image)

In the RS-CF-INT model (b), the (first) fundamentalist regimes are expected to last up \((1-P)^{-1}\) to 9 trading days whereas the (second) chartist regimes \((1-Q)^{-1}\) have a longer duration of at least 13.5 trading days. Even it is better that model (a) because of BI exchange rate intervention, the fundamentalist rule USD/IDR expectation share \(\tilde{P}\) is about 40\% still smaller than the chartist rule USD/IDR expectation \(\tilde{Q}\) (60\%) in performing USD/IDR market rate. Significant estimates of variances point to regime dependent heteroscedasticity capturing periods of high and low volatility: the variance in the second regimes \(\sigma_F^2\) in these conditional regimes is still lower than the variance in the first regimes \(\sigma_C^2\) even though for chartist it gets smaller variance. The estimates of chartist and fundamentalist coefficients \(\psi\) and \(\theta\), are also statistically significant and of the correct sign.
In the RS-CF-INT-NDF model (c), the (first) fundamentalist regimes are expected to last up to 5.4 trading days whereas the (second) chartist regimes have a longer duration of at least 9.4 trading days. Because of BI exchange rate intervention and NDF rate variable, the fundamentalist rule USD/IDR expectation share decreases to about 37% which is even smaller than the chartist rule USD/IDR expectation (63%) in performing USD/IDR market rate. Significant estimates of variances point to regime dependent heteroscedasticity capturing periods of high and low volatility: the variance in the second regimes in these conditional

![Figure 4. Smoothed Probabilities of USD/IDR, Model with augmented BI intervention](image1)

![Figure 5. Smoothed Probabilities of USD/IDR in the model with augmented BI intervention and NDF](image2)
regimes is still lower than the variance in the first regimes $\sigma^2_1$ even though for chartist it gets smaller variance. The estimates of chartist and fundamentalist coefficients $\psi$ and $\theta$, are also statistically significant and of the correct sign.

In the RS-CF-INT-NDF-CDS model (d), the regime switching is getting faster than those in previous models meaning of increasing exchange rate uncertainty, the (first) fundamentalist regimes are expected to last up $(1-P)^{-1}$ to 3.8 trading days where as the (second) chartist regimes $(1-Q)^{-1}$ have a longer duration of at least 6.8 trading days. Because of BI exchange rate intervention, augmented with NDF rate, and CDS 1mth, the fundamentalist rule USD/IDR expectation share $\tilde{P}$ decreases to about 36% which is even smaller than the chartist rule USD/IDR expectation $\tilde{Q}$ (64%) in performing USD/IDR market rate. Significant estimates of variances point to regime dependent heteroscedasticity capturing periods of high and low volatility: the variance in the second regimes $\sigma^2_2$ in these conditional regimes is still lower than the variance in the first regimes $\sigma^2_1$ even though for chartist it gets smaller variance. The estimates of chartist and fundamentalist coefficients $\psi$ and $\theta$, are also statistically significant and of the correct sign.

The most important results from these Markov switching procedures are the significant estimated parameter both for the chartist and the fundamentalist forecasting techniques within the heterogeneous expectations framework. As has been outlined in the theoretical section of the paper, central bank interventions are supposed to affect exchange rates by influencing chartist and fundamentalist forecasting success. Because the standard RS-CF model is nested in the more general RS-CF-INT-NDF-CDS model, the hypothesis can be examined by the values of the log-likelihood functions, the likelihood ratio test (LRT) statistic and the estimates of the various $\delta, \alpha, \omega$, in Table 1.
As the LRT statistic suggests, the consideration of intervention dummies, NDF, and CDS, explain a significant improvement in the log-likelihood function. Hence, the hypothesis that exchange rate expectations are not affected by central bank interventions, NDF, and CDS has to be rejected. Particularly, the results of parameter estimates give rise to the conclusion that foreign exchange activities of Bank Indonesia, NDF and CDS, could have supported fundamentalist and chartists rules. The dummy exchange-rate intervention coefficient $\delta_\theta$ of the central bank is significant and reports a significant increase of $\xi_t$ whenever $I_t = 1$. In the case of addition of new variable ‘NDF’ and ‘CDS’, respectively the coefficient $\alpha_\theta$ of the central bank is significant, while $\omega_\theta$ is not. However, in total there is a large increase of $\xi_t$, showing that the speed of adjustment for the exchange rate back to its long-run value is increasing when the fundamentalists dominated the market and the central banks intervene.

In model (b), the significant decrease of $\eta_t$ implies that the adjustment of the exchange rate back to its long run equilibrium decelerates when the chartists dominated the market and central banks intervene. Adding variable ‘NDF’ and ‘CDS’ to the chartist model shows that the coefficient of the central bank intervention ($\alpha_\psi$ and $\omega_\psi$) are significant, and there is also a large increase of $\eta_t$. Again, this implies that the speed of adjustment for the exchange rate back to its long-run value is increasing, but the intervention will be insignificant when the chartists dominate the market.

However, the results must be interpreted cautiously in another case when exchange-rate intervention is not effective. Before quickly concluding that the contributions of central banks to bring back exchange rates to the UIP level or long-term moving average are deniable, a particular property of the model has to be considered: Due to the construction of chartist and fundamentalist expectations, forecasts of equal sign are generated, when the exchange rate reverts to its equilibrium value. Obviously, central banks could also made use of the noise trader channel and provided support to chartist speculation when the exchange rate already moved into the ‘right’ direction. If this is the empirically relevant case, this research would expect only a small number of intervention operations within the chartist regime whenever the exchange rate deviates from long-term MA exchange-rate (MA$_{200}$).

Regarding to volatility in relation with central bank’s FX Intervention, this research finds that this is confirmed by the finding that the FX intervention dummy (especially in fundamentalist regime) in the model RS_CF_INT, identified periods in which the volatility is a bit increase except in chartist regime which is not significant, as shown in Figure 3. It has also same conclusion when using model (d) while model (c) reports contradiction. However, the result should be very careful before quickly concluding that exchange rate volatility increase in fundamental regime is due to intervention operations. Disorderly markets’, i.e. high volatility, may have challenged central bank activities. But as long as this reserve causality is not confirmed, central bank intervention remains an ambiguous policy tool in influencing exchange rates. This is confirmed in a study by Baillie and Osterberg (1997a) that find evidence that foreign-exchange interventions by US,
German, and Japanese central banks have tended to increase foreign-exchange volatility in the USD/JPY forward market when JPY/USD is under pressure.

V. CONCLUSION

In this paper, the effect of central bank’s intervention within a heterogeneous expectations exchange-rate model is investigated. The results are supporting both chartists and fundamentalist regimes. It is shown that the two regimes are persistent as the LRT statistic suggest, the consideration of intervention dummies explain a significant improvement in the log-likelihood function. Hence, the hypothesis that exchange rate expectations are not affected by central bank interventions has been to be rejected. Particularly, the result of parameter estimates give rise to the conclusion that foreign exchange activities of BI could have supported fundamentalist (UIP) & chartist (Moving Average) trading rules but in opposite direction. The dummy BI FX Interventions coefficient in the fundamentalist period $\delta_\theta$ is positive whereas in the chartist period $\delta_\psi$ is negative; but only the coefficient of fundamentalist is highly significant in the complete model (d).

When looking at the link between BI FX Intervention within both fundamentalist/ chartist exchange rate expectations, this study recognizes very significant change of $\zeta_t$ and $\eta_t$ but in opposite direction. This implies that the adjustment of the exchange rate to its long run (fundamental) equilibrium ‘UIP’ has been accelerated in the periods when fundamentalists dominated the market and central bank intervenes. Apart from providing the rationale for the application of trading rules, intervention may as well improve the performance of expectations based on fundamentals, especially when central banks try to correct current exchange rate misalignments. On the other hand, the adjustment of the exchange rate to its long run (fundamental) chartist’s equilibrium ‘MA200’ has been decelerated in the periods when chartists dominated the market and central bank intervenes.

In the case of Indonesia, it is shown that the predictive power of sophisticated fundamentalist forecasting techniques approximated by the deviation of the current exchange rate from the UIP level and simple chartist approach, were enhanced whenever the Bank Indonesia intervened on the foreign exchange market. There is evidence that within this framework, central bank operations on foreign exchange market is considered to be effective, as the adjustment of the exchange rate to its long run (fundamental) equilibrium is accelerated when fundamentalists dominated the market and central bank intervenes. In this regards, Bank Indonesia’s foreign-exchange intervention has been able to drive the USD/IDR to long-run/ fundamental ‘UIP’ (presumed in fundamentalist rule).

With regard to exchange-rate volatility, however, the effectiveness of Bank Indonesia to stabilize the rate is inconclusive. The possible limitations which lead to this conclusion are the under estimate of the effect of intervention, and may even be perverse. Practically, as the goal
of intervention has evolved toward addressing instances of disorderly market, it has become less clear that such specifications are still well-suited for assessing the effectiveness of foreign exchange intervention in Indonesia. Furthermore, excessive exchange rate volatility may have becoming an obstacle for Bank Indonesia in achieving price stability. As these objectives are not clear enough and causality is not confirmed, the central bank foreign exchange intervention policy remains an ambiguous policy tool in influencing exchange rates.

Those conclusions above imply the central bank should pay attention more to the foreign-exchange market player, especially the fundamentalist and chartist as they have a significant role in determining market exchange rate. The central bank should drive exchange rate expectation to the fundamentalist’s rule as it is relevant with monetary objective in achieving targeted inflation. Furthermore, foreign-exchange intervention is proven effective when exchange rate expectation is dominated by fundamentalist. As consequence, the central bank should implement optimal monetary policy with appropriate strategy especially in determining optimal interest rate and exchange rate intervention as well as implement governance aspects of monetary policy.

For a small open economy like Indonesia, exchange rate movement does not always reflect fundamental value. Increasing USD/IDR exchange rate volatility often occurs as a result of rising uncertainty of global economic condition which ignites sudden massive capital flows, irrational behavior of market players, the microstructure conditions of the market, and offshore market influence. Furthermore, relying solely on Bank Indonesia’s interest rate policy to achieve the inflation target and maintain stability is not always sufficient. The central bank’s strategy is to include exchange rate policy in the monetary and macro-prudential policy in order to achieve its goal more effectively.
REFERENCES


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