The Dynamics of Indonesian's Currency Crisis in 1997

Gunawan Wicaksono[1]
Cornell University

The exchange rate behavior in Indonesian's recent crisis 1997 caused an interesting phenomenon of exchange rate disequilibrium. The exchange rate rose and fluctuated around its new quasi-equilibrium in damped oscillation behavior. Subsequent speculative attacks by some speculators which created new desired equilibrium generated such behaviors under two consecutive first order delays. Comparing the result with uncovered interest parity framework under a constant and oscillating risk premium revealed that exchange rate behaviors during the crisis was best explained by speculators attacks followed by uncovered interest parity under oscillating risk premium. Under some advisable range of parameters, exchange rate model with speculative attacks can explain the general behavior of the exchange rate during the crisis.

I. Introduction

About a dozen years ago, in 1997, a currency crisis took place in some Asian countries, including Indonesia. At that time, Indonesian's currency, rupiah, depreciated against dollar very sharply (Figure 1). This devaluation accounted for almost 400% of the pre-crisis value of domestic currency/dollar. By the end of 1999, the value of the rupiah achieved its new long-term quasi-equilibrium level. Most of the people in the world still recall of the amazing growth of Asian countries (including Indonesia) prior to 1997. Indonesia itself had high pre-crisis economic growth of around 7 to 9%. Only very few expected that currency crisis – also referred to as a 'financial crisis' – would occur in Indonesia.

[1] The author is a Graduate Student at Cornell University and can be contacted at gw89@cornell.edu

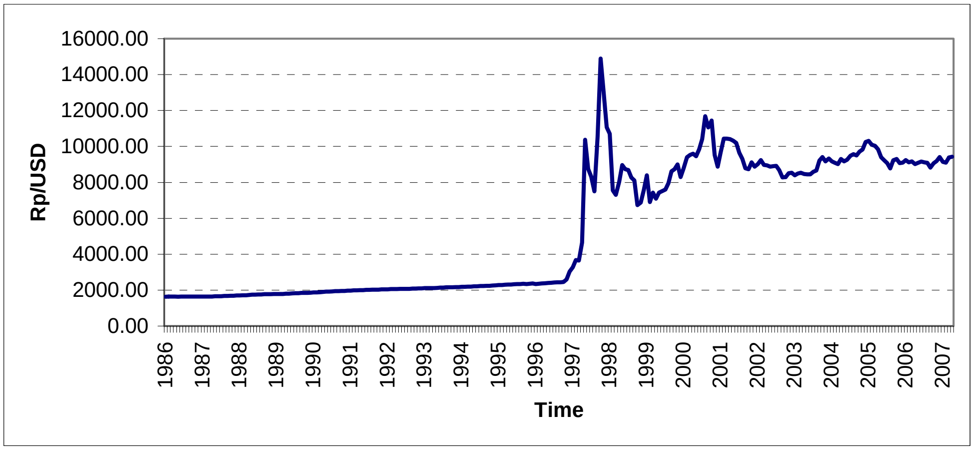
This paper will analyze the exchange rate behavior caused by speculators actions which create a new desired equilibrium different from the actual exchange rate level at that time. Exchange rate behavior during the crisis indicated that sudden movement of exchange rate toward its new quasi-equilibrium would not happen instantly but through a process of goal seeking behavior with overshoots and undershoots damped continuously toward a steady new quasi-equilibrium.

Basic fundamental behaviors in system dynamics provide an insightful possibility of the underlying common archetypal structure of the sudden movement of exchange rate during the crisis through the mechanism of continuously goal changes and two .rst order delays (Sterman, Chapter 4 p.121).

Problem Articulation

With respect to the currency crisis, it is interesting to understand the causes of the exchange rate behavior in Indonesia during the period of the crisis and why it exhibited S-shaped exponential growth behavior with overshoots and oscillation around its new long term level, and what kind of policy, if any, would have reduced the depreciation of exchange rate in terms of domestic currency against dollar during that period of time to prevent such “extreme” decline of the value of rupiah against dollar in the future. The wild movement of the exechange rate in terms of rupiah per dollar can be seen during the period of 1997 to 2007 (Figure 1)

Figure 1: The Market Rate of Rupiah/USD Exchange Rate during 1986 to 2007



Source: IFS Statistics

During the period of 1987 until the mid-1997, the government had intentionally depreciated rupiah as much as 5% annually. The policy was intended to promote continuous growth of exports. The risks of exchange rate appreciation caused by massive capital inflow were mitigated through sterilization interventions by the central bank. As the current account continued to deteriorate, and rupiah was maintained in its safe band, credit was expanding dramatically, overseas loans by private companies were mounting which was not reflected by the official capital account. Most of the private loans were not hedged properly. As a result, few speculators began to see the vulnerability of the currency crisis in Indonesia.

The attacks actually began in a neighboring country, Thailand. In a short period of time, Thailand's currency depreciated rapidly, thus plunging Thailand into a financial crisis. The downfall of Baht, the Thailand's currency, triggered another speculative attack on its neighbor country, Indonesia. In just two months after Thailand was hit by huge speculative attacks, Indonesia was hit. What happened in Thailand had driven up the perception of the rupiah's real exchange rate. Some speculative attacks hit rupiah and thus bringing the deterioration of rupiah. Indonesia then also fell into the crisis.

Background

Prior to the financial crisis, there were large capital inflows into the country. This capital increased investment, which then contributed to rapid economic growth. However, this capital inflow would also strengthen the domestic currency, and could reduce a country's ability to export. As what many countries did, Indonesia exercised "sterilization interventions" through its monetary policy conducted by the central bank.

Sterilization intervention is an action by a central bank to buy the foreign currency with domestic currency such that the supply of domestic currency will increase in comparison with its foreign currency counterpart in order to prevent the appreciation of domestic currency by market supply-demand mechanism. This action will essentially increase the money supply in the economy and thus reduce the interest rate. In the medium term, prices will increase, creating higher inflation which is "undesirable" in term of policy result. To preclude this, central bank or government usually will sell bonds to reduce the amount of money supply in the society. This action together with buying the foreign currency is called a sterilization intervention. In Indonesian's case, this was what the central bank had imposed during the high capital inflow. This explains the pre-crisis period behavior of steady depreciation around 5% annually.

The crisis began in mid-1997, due to anxiety about the future expected gain of holding rupiah. This resulted in a sudden reduction in capital inflows which then led to capital outflows. This is called a 'capital reversal'. While some Asian countries only experienced mild exchange rate depreciation pressure, there were some other countries that experienced considerable pressure of currency depreciation. Indonesia was one of them.

The huge capital outflow accompanied by speculative attacks[2] followed by massive currency substitutions[3] driven by changing of currency expectation was argued as the main reason that currency declined sharply. It took a range of time of two to four years that many believed the rupiah exchange rate had returned to its long run quasi-equilibrium. In this light, the standard approach of the "Uncovered Interest Parity"[4] does not hold due to the skyrocketing of risk associated with currency depreciation during the peak of the crisis.

Dynamic Hypothesis

Exchange rate behavior in the period of crisis would mainly be driven by extreme changes of exchange rate expectation and associated changes of the interest risk premium. One of the motives that could trigger the currency crisis would be a speculative attack which is driven by self-fulfilling forces (Eichengreen, Wyploz (1993)). The more expectation formed in favor of depreciation, the more people would act accordingly and by doing that, depreciation expectation is fulfilled. Unless the currency

---

[2] Speculative attacks are predicated on a belief by currency holders that the equilibrium value of a currency should be much than the current market rate.

[3] Currency substitutions are the activity of people to change their portfolio of currency compositions. Exchanging currency to foreign currency done by residents in a country is typical example of this activity.

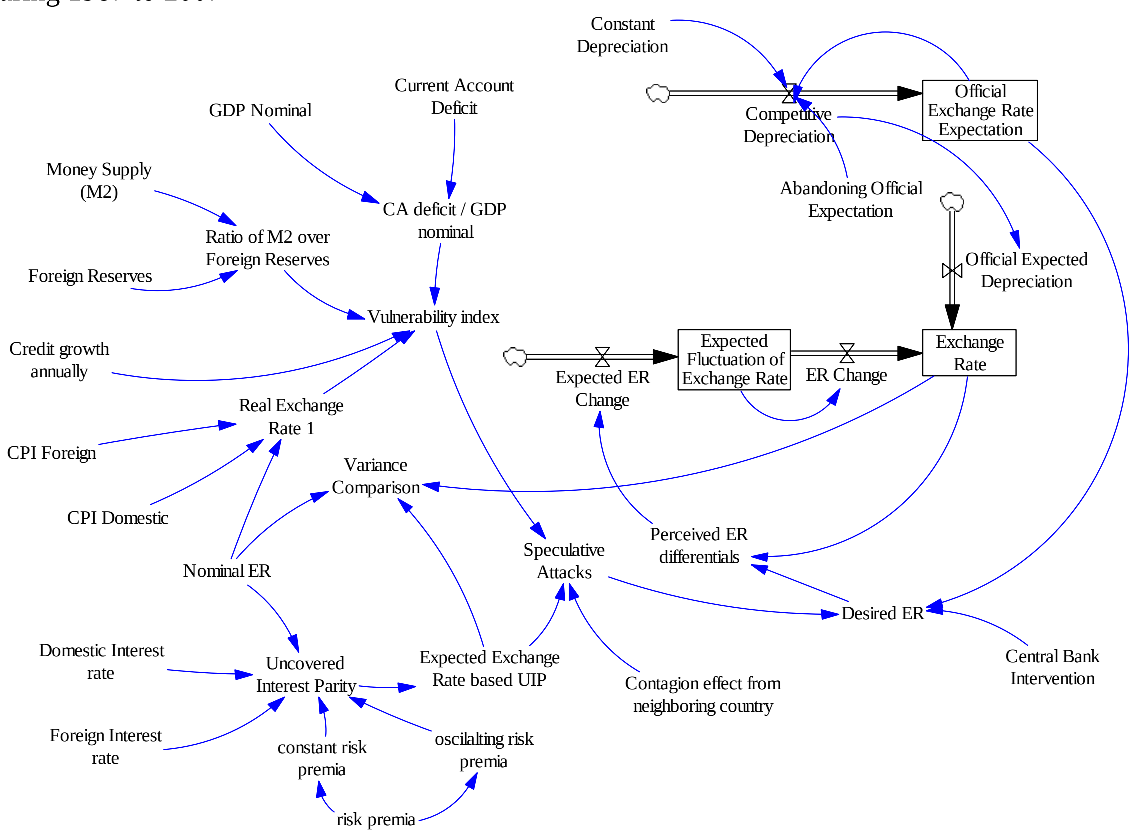
[4] Uncovered Interest Parity is also called the interest parity condition. The word "uncovered" is used to distinguish the relation from another relation called the covered interest parity which basically covering the risk of converting back the currency to foreign currency at a predetermined price (Blanchard, p.388). The assumption of uncovered interest parity has been discussed by Isard (2006). This assumption is an important building block in multi period models of open economy.

moves freely in free floating exchange rates, a Central Bank's effort to maintain its currency can be undermined. Depletion of a country's foreign reserves is a good sign for speculators that a country has trouble defending their currency's exchange rate. Krugman (1979) argues that speculators who anticipate depleted foreign reserves for a country can attack its currency before all the country's reserves are fully depleted.

The important variables to examine these dynamics are the foreign exchange rate, expected foreign exchange rate, and perceived risks. A dynamic hypothesis can be developed with speculative attacks, foreign and domestic interest rates, perceived maximum expected exchange rate, and adjustment times as exogenous variables. My simple model of exchange rate determination during the crisis is depicted in figure 2.

New equilibrium levels desired by speculators are one of the main causes that cause rupiah exchange rates to fluctuate in the pattern of S-shaped growth with oscillation before reaching their new quasi-equilibrium level. The time of speculative attacks that generate a currency crisis is thought of as determined by certain economic indicators. These indicators include the ratio of money supply to foreign reserves, annual growth of credit, real exchange rate depreciation and current account deficit over the gross domestic product (GDP). Speculators have in their mind of interpretations of current economic condition and justify their acts accordingly. However, one or two years in which the values of the indicator make the country look vulnerable category does not necessarily cause a country appear 'vulnerable' to currency speculators. Typically, the signals of vulnerability build up and are perceive gradually over a number of years. Decisions to attack are determined by the possibility of success of those attacks. Once a neighboring country falls into a crisis, there will be bigger likelihood that a vulnerable country can possibly fall into a crisis given such attacks happen. Such an event is called the contagion effect. The fell of Thailand's Baht is used by speculators to determine the time for their speculative attacks on rupiah. Once the attack begins, there will be gap between what speculators' new desired equilibrium and the exchange rate. This new desired equilibrium is translated into expected fluctuation of exchange rate by a first order delay in a very short time adjustment period. Then the expected fluctuation of exchange rate is translated further into the exchange rate by another first order delay which has relatively much higher time adjustment. A combination of the right two first order delays created an S-shaped growth with oscillation like what the actual exchange rate data.

Figure 2: The Simple Stock-Flow Diagram of Exchange Rate Rupiah/Dollar determination during 1987 to 2007



Model Structure

In this model, I deliberately set the current account deficit, money supply, Gross Domestic Product (GDP) nominal, foreign reserves, domestic and foreign interest rates, risk premium, growth of domestic credit, and contagion effect of neighboring countries as exogenous variables. Two main factors are speculative attacks and central bank interventions. The described structure is intended to just capture the essential forces that caused the exchange rate behavior during the currency crisis.

There are five main modules in this model. They are the module of:

1. exchange rate determination by new speculators' desired equilibrium;
2. exchange rate determination from uncovered interest parity under two approaches: constant risk premium and oscillating risk premium.

3. variance computation resulted from speculative attacks and uncovered interest parity.
4. vulnerability index construction.
5. simple decision making process by speculators.
6. additional structure to reduce the negative overshoot shock of exchange rate.

In the first module (Figure 3), the perception of markets is translated into the expectation of exchange rate by first order delay. This exchange rate expectation subsequently results in exchange rate changes through another first order delay. The perceived exchange rate differential which is constructed as differences between the actual exchange rate determined by the model and the desired exchange rate expected by the market. The perceived exchange rate differential serves as a floating goal in the model. The difference of the perceived exchange rate and the actual exchange rate moves the exchange rate into its new quasi-equilibrium. Perceived exchange rate serves as a carrying capacity concept (from population growth models) that limits the growth of the exchange rate and hence creates S-shaped growth. Oscillation comes from two simple first order delays mechanism. To imitate the actual exchange rate data, the first order delay of expected fluctuation of exchange rate must be much shorter (about one sixth to one eighth) than the first order delay of exchange rate. As a result, exchange rate fluctuates drastically before arriving at its next quasi-equilibrium. In reality, the exchange rate fluctuates a lot in time of seconds as a result of interaction between buyers and sellers in the market. These interactions will create another level of exchange rate by the end of the day. It follows that in monthly period data, the exchange rate relatively has a new level of equilibrium in each month. Two process adjustment used in this model is simplification of the real world change in exchange rate of Rupiah /USD on monthly bases.

A sequence of speculative attacks at appropriate times, combined with several counter attacks conducted by the central bank mimics the behavior of the actual exchange rate data. In preliminary phase of the model, the timing and extent of speculative attacks are determined exogenously. In a later phase, I refined it by imposing decision making process into speculators’ consideration such that the attacks are not entirely independent but on perception of vulnerability based on some economic indicators and a contagion effect from Thailand, a neighboring country.

In the second module, I tried to use a very famous and simple approach to explain the behavior of the exchange rate. I developed another theoretical structure based on UIP theory. The equation of Uncovered Interest Parity is

$$i_t^{domestic} = i_t^{foreign} + \left(\varepsilon_{t+1}^{e} - \varepsilon_t\right) / \varepsilon_t + RISK$$

where i stands for real interest rate and superscript domestic and foreign indicates whether it is domestic interest rate or foreign interest rate. Likewise, a symbol ε stands for the exchange rate in terms of domestic currency (rupiah) over the dollar and superscript e indicates whether it is expected exchange rate or just nominal exchange rate. Using this simple formulation, I tried to capture the formulation of expected exchange rate by imposing two conditions for the risk premium i.e. a constant risk premium and an oscillation risk premium.

In the third module, I compare the computed variances established by these two approaches and take the smallest variance as the basis for the imposed risk premium. The structure of the expected exchange rate with risk premium computation and variance comparisons are depicted in figure 4 and figure 5.

In addition to that, in the fourth module, I imposed a new structure for computation of the vulnerability index. This vulnerability index is constructed by implementing the idea of indicator index raised by Cerra and Saxena.[5] If the indicators are above their thresholds, they will be given a value of one, otherwise they equal zero. There are four indicators I use in this model. They are ratio of money supply to the country's foreign reserves, ratio of current account deficit to the GDP, annual growths of domestic credit, and real exchange rates.[6] Combining these four indicators into one vulnerability index

[5] Different from their approach which only use three indicators, annual credit growth, ratio of money supply to foreign reserves and real exchange rate depreciation, I add one more indicator of current account deficit to nominal GDP. In the original, they normalized the indicators by summation of all index components divided by their variances.

[6] The Real exchange rate is defined as the country's nominal exchange rate weighted by the ratio of foreign price index and domestic price index. The formula is $RER = \varepsilon . P^{f} \big/ P^{d}$ where RER is the real

will serve as the input for speculators to judge the vulnerability of a country. One year of bad indicators doesn't imply necessarily vulnerability of a country. It needs several years for speculators to be able to conclude that. Because of that, I imposed the implicit structure of stock and flows to capture summation of index during the years. In Vensim, this implicit structure is described by the usage of "Smooth" function which has a characteristic of the first order delay. The structure of vulnerability index construction is depicted in figure 6.

I admit that incorporating vulnerability index into speculators' decision making process is the hardest way. It can easily be expanded into a very complicated decision making process. Avoiding this complicated matter, in the fifth module (Figure 7), I deliberately just use a very simple rule of decision making process. Speculators will attack under condition that normalized vulnerability index is more than 0.7 in addition to a contagion effect from neighboring country which I put as constant effect of 0.2. If the decision to attack variable reaches value of more than one, speculators will attack with high confidence of success.

After restricting the speculative attacks under attacking process variable, I got a problem of the possibility of zero or negative exchange rates. In order to reduce this, I impose a non symmetric effect of exchange rates toward the shocks from speculators. A simple structure of lookup function is imposed that essentially stretches the time adjustment for expected exchange rates change once the exchange rates decline (Figure 8).

exchange rate, ε is the nominal exchange rate, P^f and P^d are the price index with respect to a foreign country and domestic country.

Figure 3: The Simple Model of Exchange Rate Determination During the Crisis

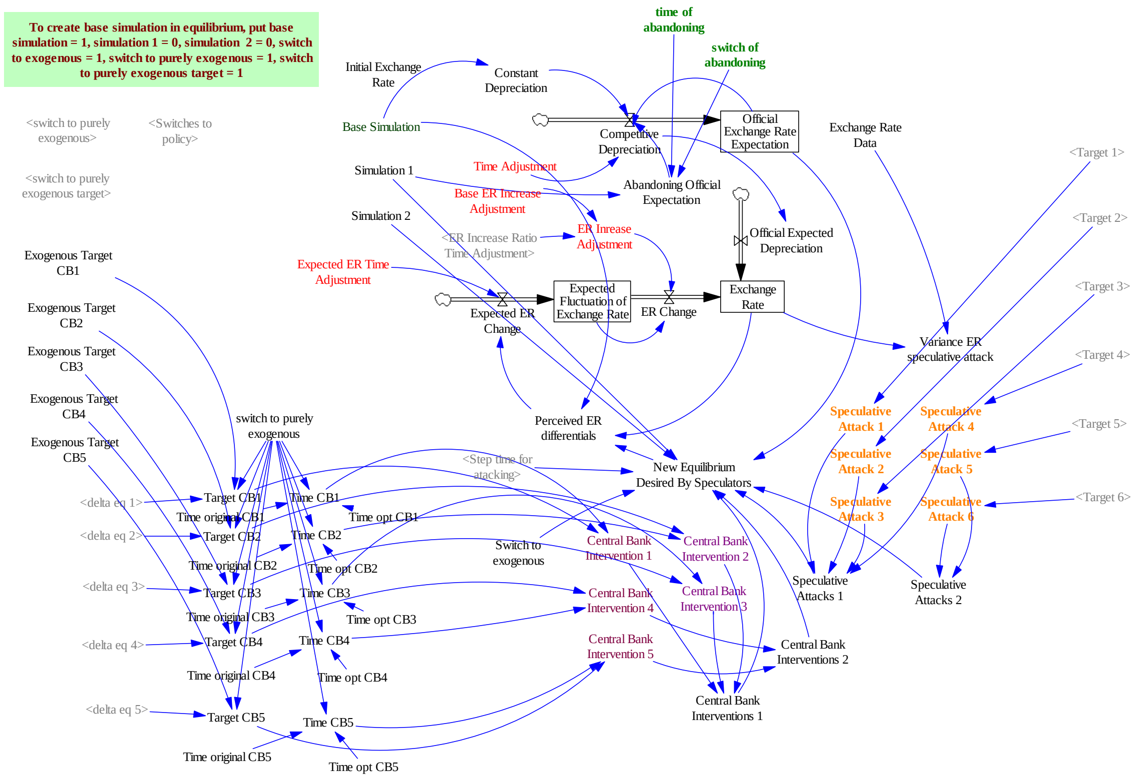


Figure 4: The Structure of computation of expected exchange rate by UIP with risk premium

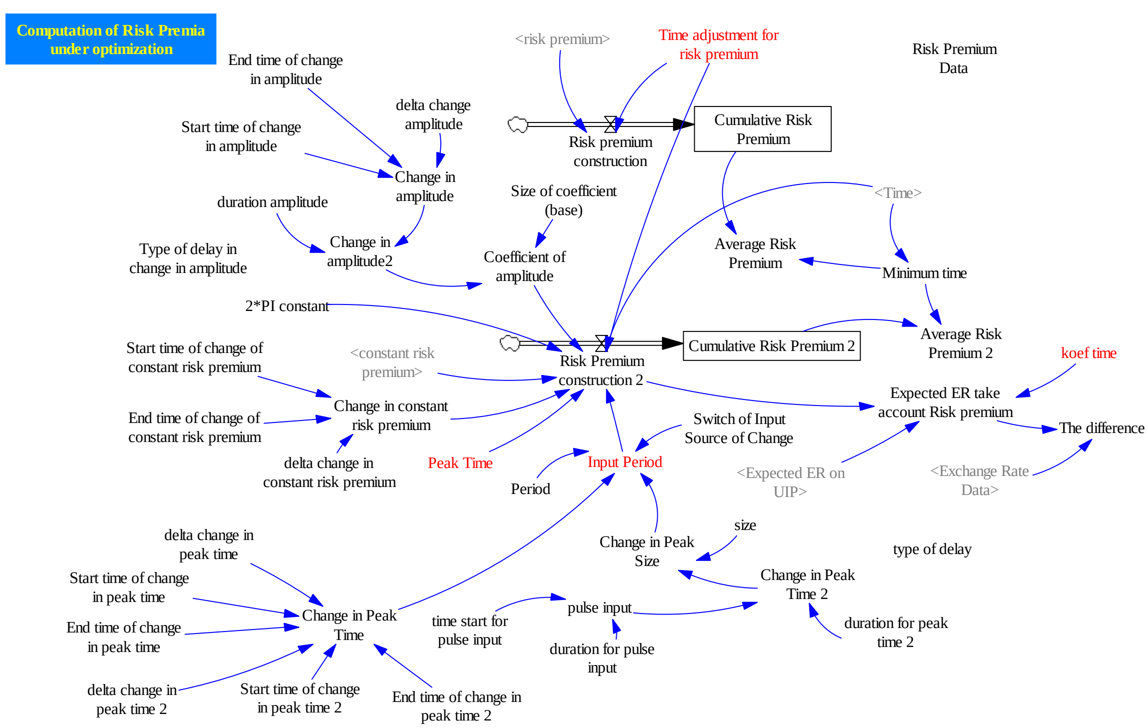


Figure 5: The Structure of Variance computations of UIP approach and speculative attacks approach

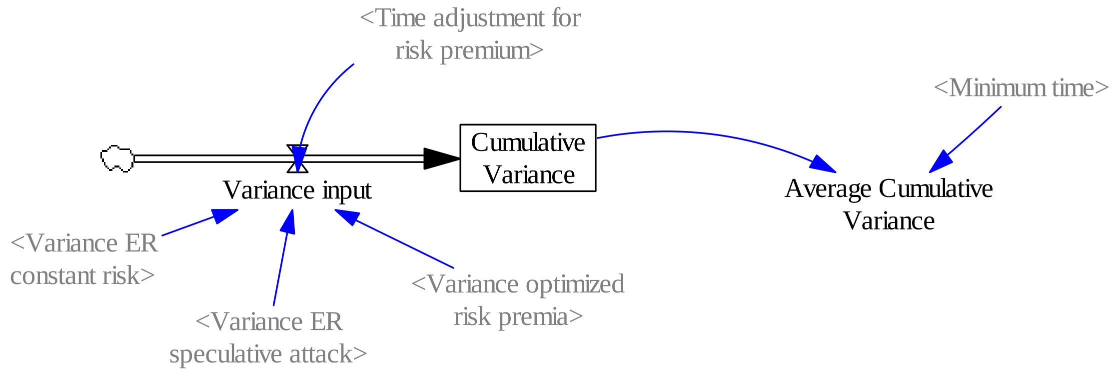


Figure 6: The Structure of Vulnerability Index Construction

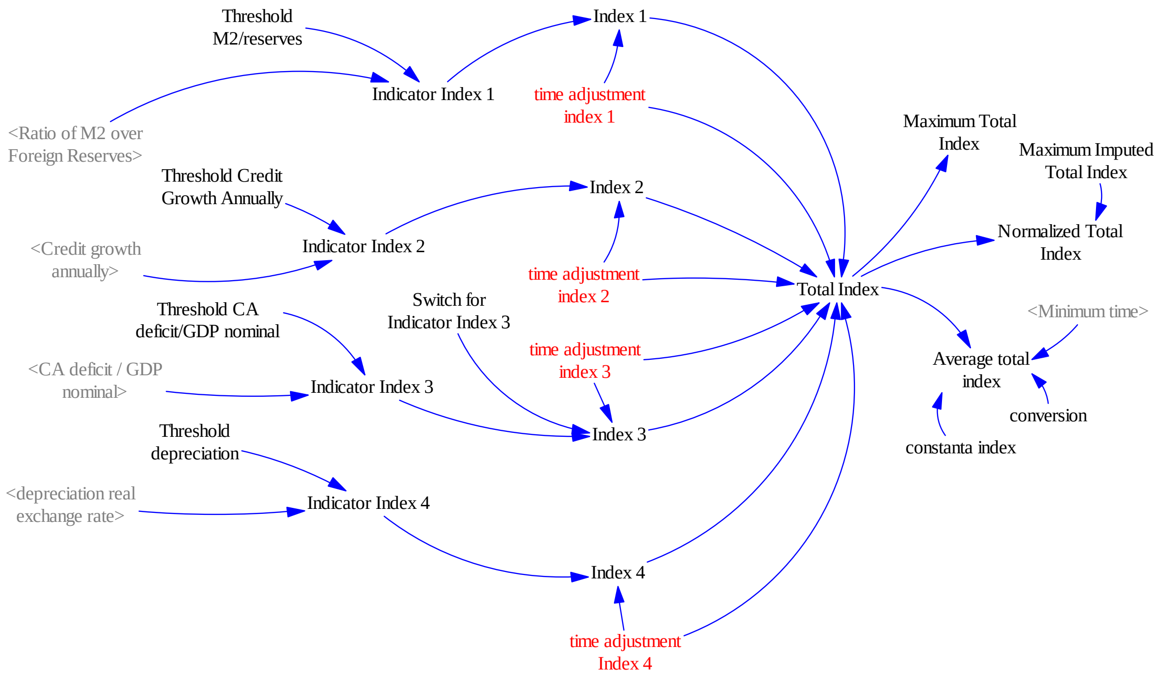


Figure 7: A Very Simple Decision Making Process

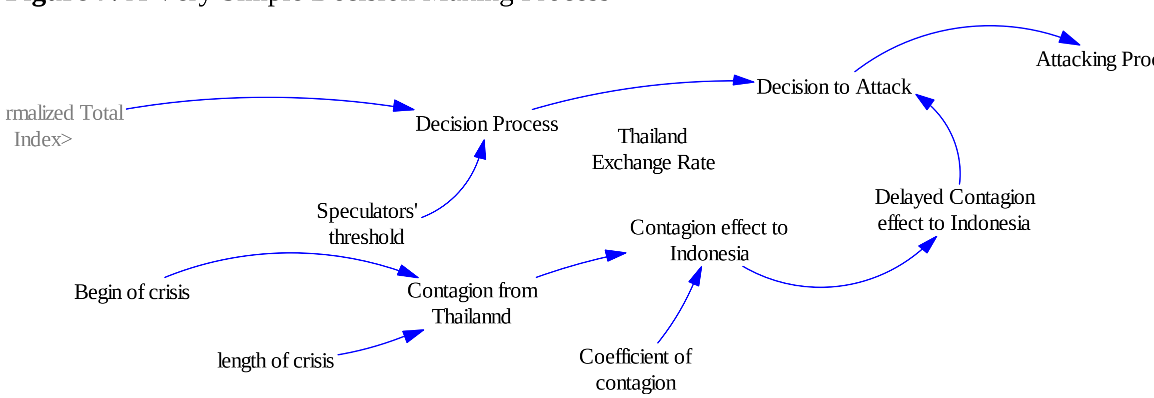
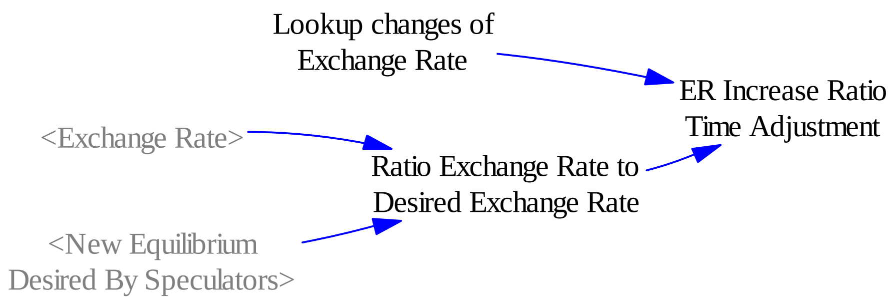


Figure 8: Additional structure to reduce the negative overshoot shocks which can cause negative exchange rates

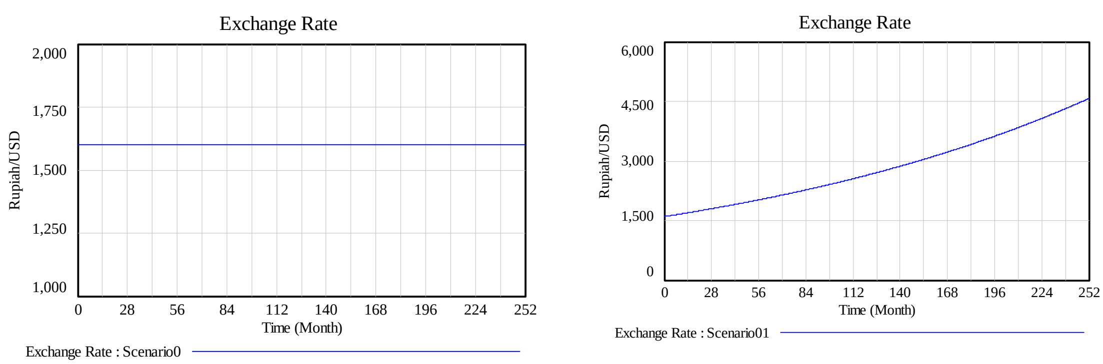


Model Simulation

The model when run without competitive depreciation and with competitive depreciation shows how without the existence of speculative attacks, exchange rate will be constant or depreciated deliberately of 5% annually. These two simulations are captured in figure 9.

Figure 9: The Base Run Simulation 1987 to 2007 without and with competitive depreciation (scenario0) and no speculative attacks (scenario01)

a. without competitive depreciation b. with competitive depreciation



Exogenous shocks to the model in forms of speculative attacks of a certain extent at certain times produced behavior that approximates of the observed exchange rate data (Figure 10). The left one is the figure with just one speculative attacks and the right one is with several speculative attacks together with central bank interventions.

Examination of the vulnerability index as one of input for speculators to judge the likelihood of a country falling into a crisis using some macroeconomic indicators (Figure 11), the index increased during the pre-crisis period. In fact, the average vulnerability index was high for some time before the crisis. This information could be processed by the speculators, who then look for the right time to attack. The sign of right time of attack is come from neighbor country, Thailand in the form of contagion effect.

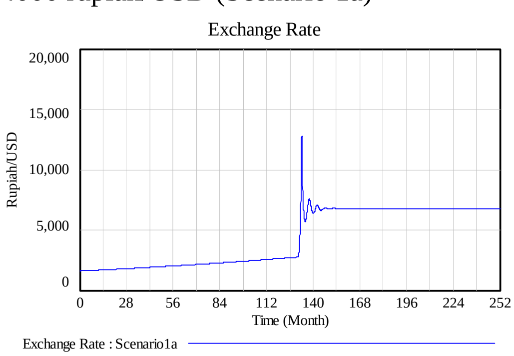
On the other side, UIP theory suggests that constant risk premium cannot serve well in time of crisis. As we can see from the risk premium calculated directly from the real data, there seems to be fluctuations along the time around some mean. The ratio of risk premium is 0.6 after some calculation. Applying a non-constant risk premium results is better approximation of risk premium and thus better approximation of the exchange rate expectation. Figure 12 depicts this computation.

As the result, computation of the exchange rate by applying the non constant risk premium resulted in much better approximation of the exchange rate. Comparison of those three approaches: speculative approach, constant risk premium and oscillating risk premium is depicted in figure 13.

The result supports that exchange rate based on speculative attacks produced a better estimation in time of crisis compared to two other approaches under UIP method. This suggests that wild swings of the exchange rate in time of crisis are the results of interactions between the “speculative attacks” and the central bank interventions.

Figure 10: The result of just one speculative attack (left) in comparison with several speculative attacks and central bank interventions

a. Non optimized one speculative attack of 4000 rupiah/USD (Scenario 1a)



b. Non optimized speculative attacks and central bank interventions (Scenario 1)

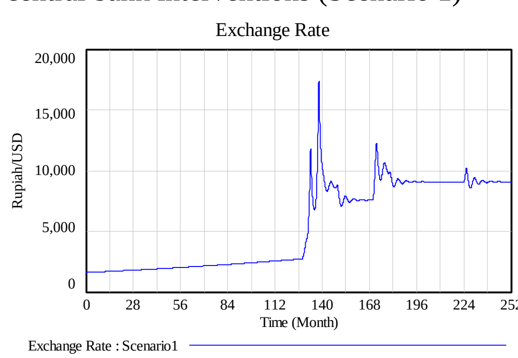
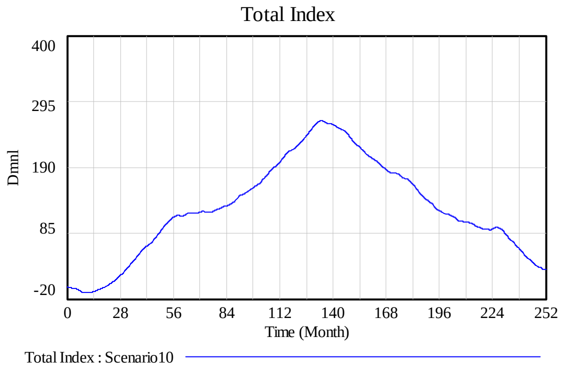


Figure 11: The vulnerability index of the crisis (Total and average)

a. Total vulnerability index



b. Average vulnerability index

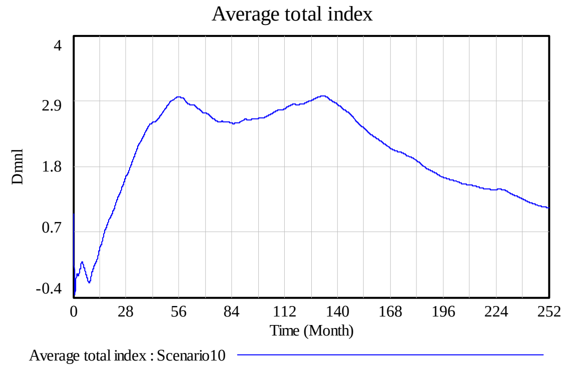
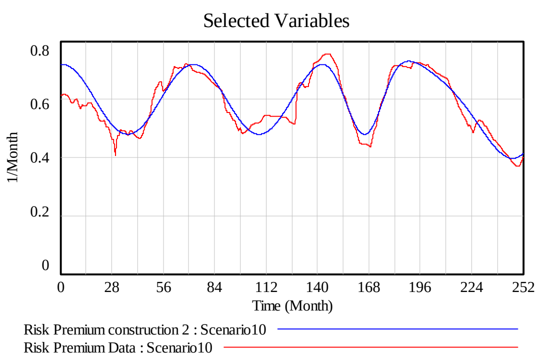


Figure 12: The risk premium computation and its approximation.

a. Risk premium approximation compare to the risk premium computation based on difference of exchange rate data.



b. Exchange rate using risk premium approximation compares to exchange rate data.

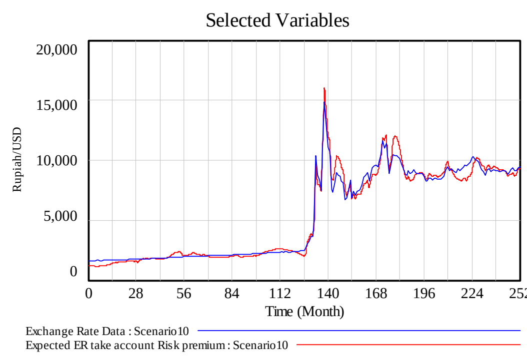
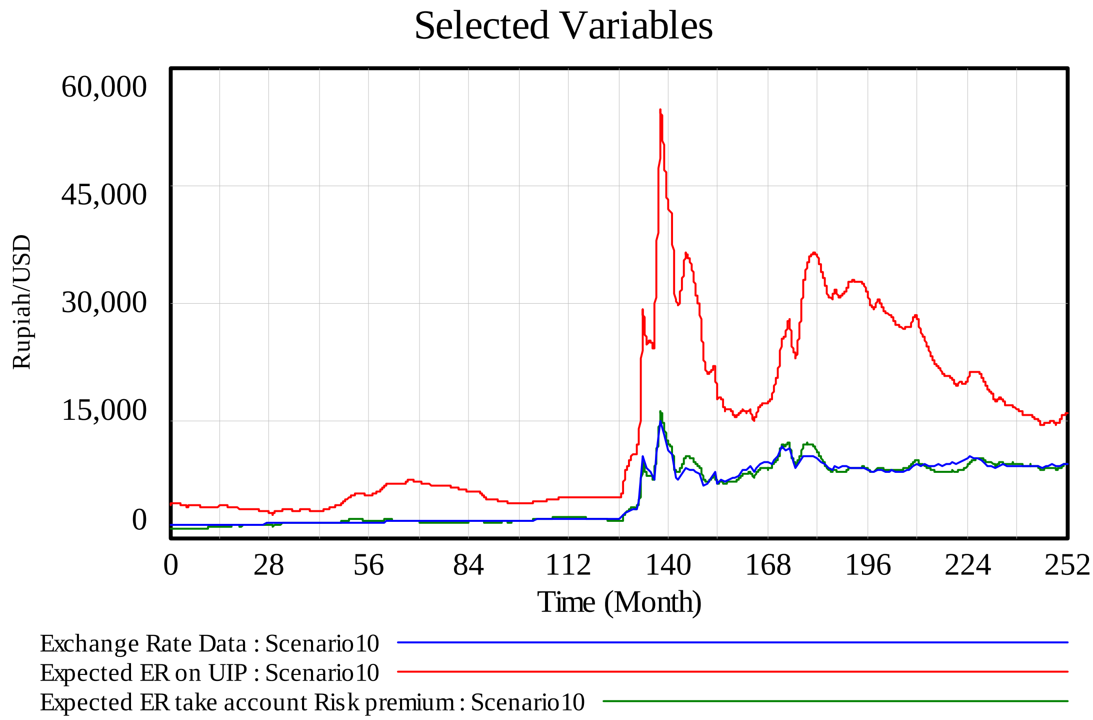


Figure 13: Comparison of Exchange rate approaches.



Model Evaluation

The basic assumptions used in this model include:

1. The exchange rates are assumed to just only follow the speculators' desired equilibrium and all the process that moves the changes of the exchange rates are derived from the existence of two first order delays. In reality, exchange rates are determined simultaneously not only from speculators' equilibrium but also from the fundamental economics derived from supply and demand of currency in the foreign exchange markets. This supply and demand are derived from fundamental economics such as exports, imports and capital flows of a country. A more fundamental approach that combines markets (supply and demand for non-speculative use) with speculative use could also be developed to help explain this phenomenon

2. Decision making process is just simply based on threshold value arbitrarily chosen and possible contagion effect from Thailand, a neighboring country. The actual

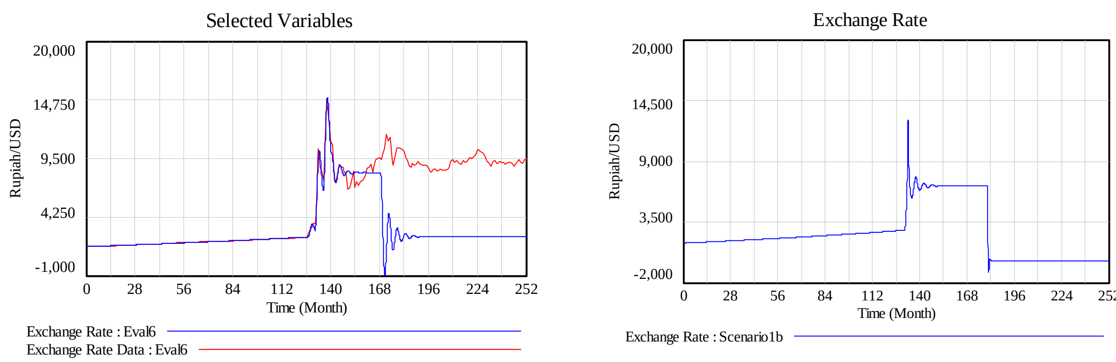
decision making process is complicated as it involves the preference of speculators over the possible gain they got from their attacks.

The evaluation on the model reveals that:

1. Time horizon of the model is enough to include the behavior of interest during the crisis which happened between 1997 until about 2001. The model simulates the period from 1987 to 2007.

2. Even though some simple structure has been applied to avoid the possibility of negative value of exchange rate stock, still under a very extreme condition, some stocks can take on negative values, including the value of exchange rate stock. This slightly negative scenario might exist if speculators' desired exchange rates are dropped drastically from 9000 to slightly above 0. Under this extreme condition exchange rate might have slightly negative values which are unreasonable (scenario 10, Figure 14: right). Before imposing different time adjustment in exchange rate change, this exchange rate fluctuates a lot below zero (eval6, Figure 14: left).

Figure 14: Exchange rates might become slightly below zero when the desired exchange rate is slightly above zero.



3. The model basically reveals the structure of the process of two first-order delay in the formation of expected exchange rates might produce the S-shaped behavior with oscillation. It also covers an application of theory of uncovered interest parity which generally fails to predict during the crisis. Usage of implicit stocks and flows for the computation of a vulnerability index to capture the accumulation of speculators perception is done by incorporating smooth function in Vensim.

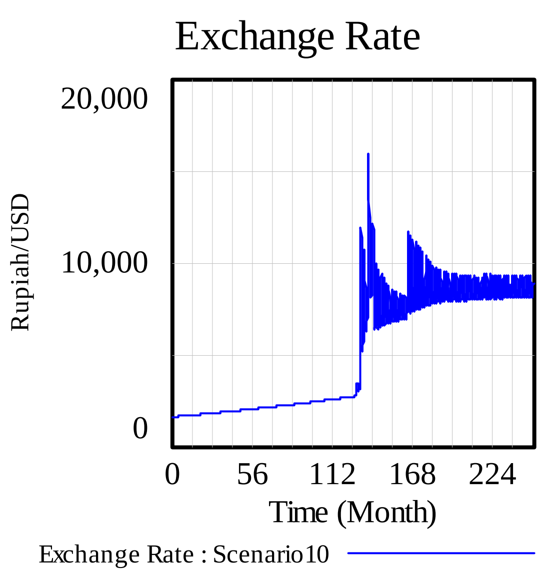
4. The model is dimensionally consistent. Conceptually, the exchange rate changes over time and the actual exchange rate are in line to each other. All the vulnerability indexes use dimensionless unit.

5. The parameters used in time adjustment for expected exchange rates as well as exchange rates are deliberately chosen. There is no clear reference of how much time needed for expectation to be made. Furthermore, time parameter in monthly bases data will be different from time parameters in daily bases data. The parameters are chosen for the purpose of monthly approximation of the actual exchange rate data.

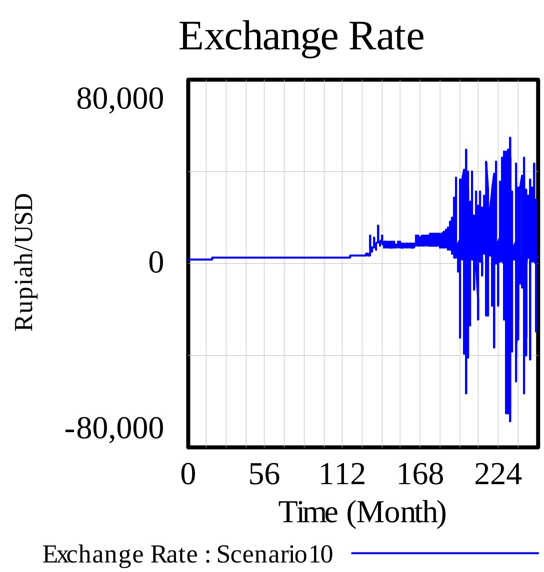
6. The model does not perform very well under some extreme values of variables. They cannot replicate the intended behavior of the actual exchange rates at expected exchange rate time adjustment less than 0.14. Beginning at Expected Exchange Rate time adjustment (EERTA) 0.14 exchange rates oscillates wildly but still goes to steady oscillation values while at EERTA 0.13 exchange rates are exploded. This is because the shortest time adjustment in the model is 0.3. As Sterman noted, since the time step used in this model is 0.0625, then the shortest time adjustment is 4 x 0.0625 = 0.25.

Figure 15: Changing in Expected Exchange Rate Time Adjustment

At EERTA = 0.14



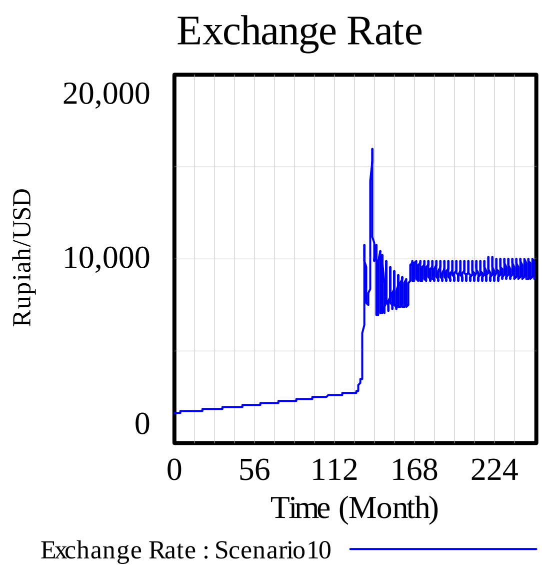
At EERTA = 0.13



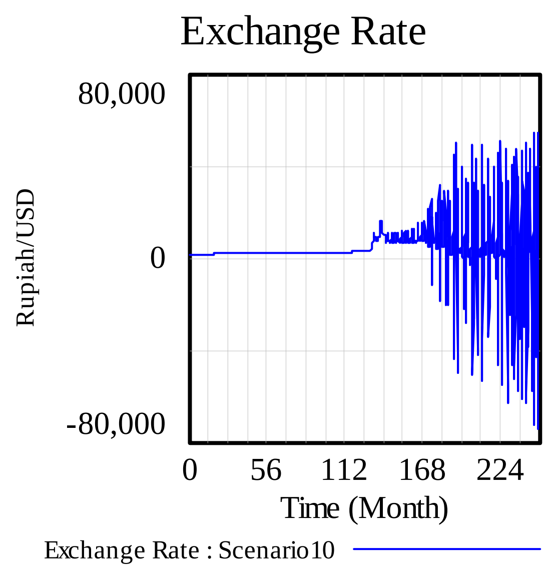
7. The choice of time step can still represent the oscillation and S-shaped behavior only until time step = 0.13. At time step = 0.13 oscillation is steady and continue and at time step equal or bigger than 0.14, exchange rates become explodes in oscillation. As Sterman stated that since shortest time adjustment in this model is 0.3 then, the largest time step that could be taken is 0.25 x 0.3 = 0.075.

Figure 16: Beginning at time step 0.13 and larger, exchange rates behavior are exploded.

At time step = 0.13

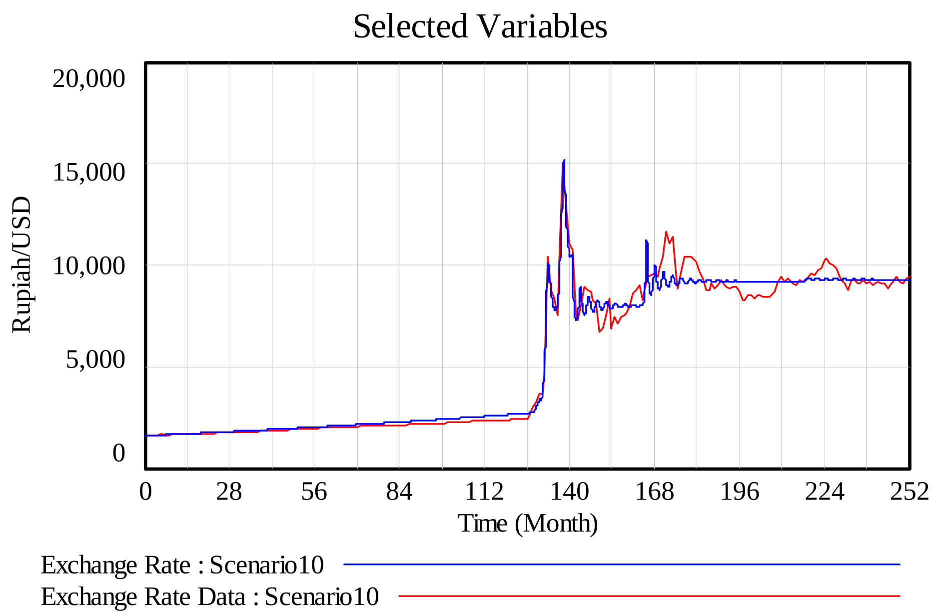


At time step = 0.31



8. The model can replicate behavior of the actual exchange rates under some reasonable range of value in parameters. In this model, there are two ways to replicate actual exchange rates data. One is by using the speculative attacks process and the other by using theory of uncovered interest parity. Both can perform well enough under some reasonable range of parameters.

Figure 17: Under some parameters, it can mimic generally the actual exchange rate.

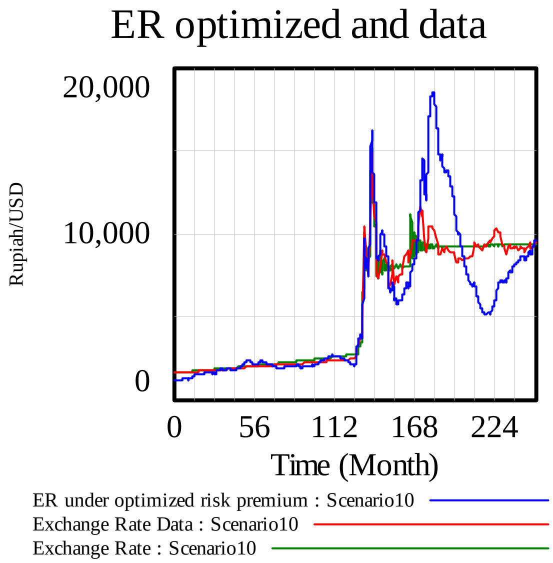


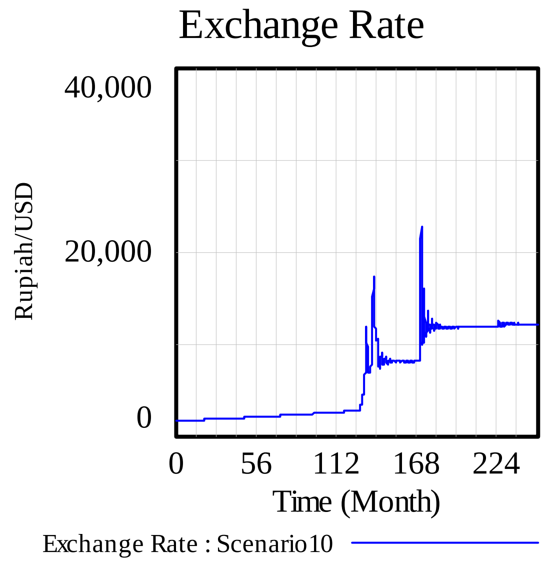
9. The model is sensitive to values of some parameters, such as Speculators' threshold, expected exchange rate time adjustment, size of oscillation, duration for peak time and some other parameters (exchange rate increase, amplitude of oscillation and vulnerability index). Model behaviors still have oscillation but surely it will not replicate the actual data once the parameters depart a lot from their current optimized values.

Figure 18: Effect of changing some parameters in Optimized Exchange Rate under Risk Premium and Exchange Rate under speculative attacks

Changes in size of oscillation = - 2.7

Changes in exogenous target 4 = 10000 Rupiah/USD.





Model Sensitivity

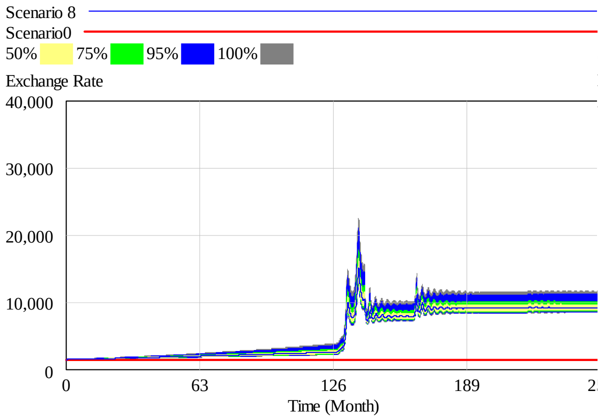
Sensitivity is conducted to the speculative attacks module and the optimized exchange rate under uncovered interest parity approach. Variables which are interested to inspect are Exchange Rate and Desired Exchange Rate. All time adjustment variables are defined as constants and exogenous with the following arrangement under normal distribution *(*Simulation run *Scenario 8,Scenario 8.vsc, Scenario 8.lst)*:

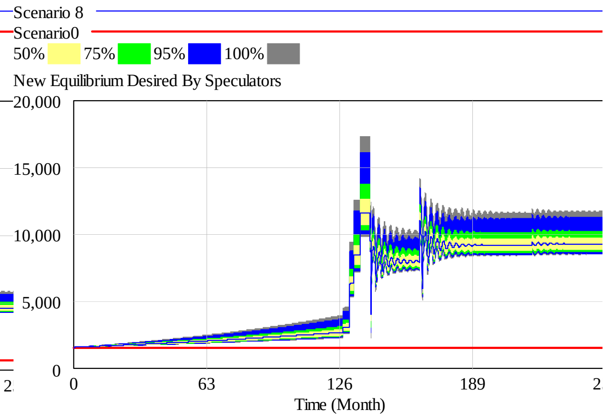
Parameters to check	Mean	Std.Dev	minimum	maximum
Expected ER Time Adjustment (Random Normal)	0.3	0.025	0.25	0.35
Time Adjustment (Random Normal)	12	3	6	18

The highest value achieved at 100% range is around 23000 rupiah/USD while the lowest possible value is around 6000 rupiah/USD (Figure 19) while the highest value of exchange rate level desired by speculators is around 17500 rupiah/USD and the lowest value is around 2500 rupiah/USD (Figure 19).

Figure 19: Sensitivity of Exchange Rate and New Equilibrium Desired by Speculators

Exchange Rate New Equilibrium Desired by Speculators



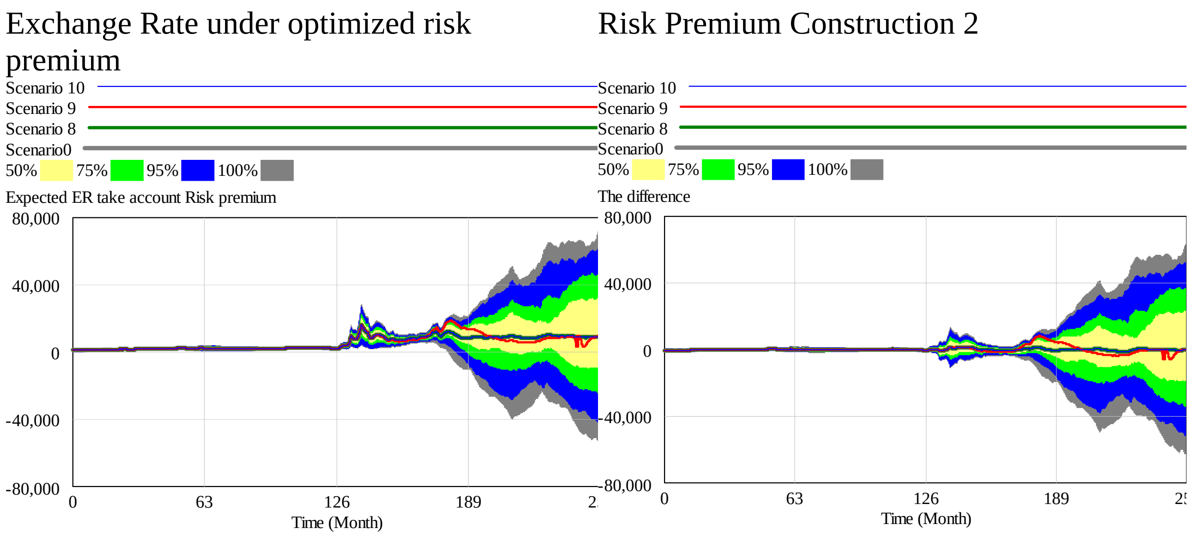


The second sensitivity is run toward the expected exchange rate under optimized risk premium. Variables of interest are Risk premium construction 2, which computes the risk premium under assumption that risk premium oscillates following the cosines cycles and some discontinuities. The difference, measures the difference between risk premium assumption and risk premium constructed as the residual of UIP computation. Four parameters are changed according to uniform distributions and one parameter which is constant risk premium is changed according to normal distribution in the following manners (Simulation: *Scenario 10, Scenario 10.vsc*, *Scenario 10.lst*, *switch input source = 1*):

Parameters to check	Mean	Std.Dev	minimum	maximum
Delta change amplitude (Random Uniform)	NA	NA	-0.1	0.1
Delta change in constant risk premium (Random Uniform)	NA	NA	-0.02	0
Duration for pulse input (Random Uniform)	NA	NA	23	63
Duration for peak time 2 (Random Uniform)	NA	NA	30	60
Constant risk premium (Random Normal)	0.6	0.1	0.4	0.8

The sensitivity graph shows the unrealistic range of movement of the exchange rate as it reaches negative points for some periods of time. The same phenomenon also happens to the risk premium construction 2 which shows unrealistic negative risk premium (Figure 20). Possible drastic change caused by oscillation parameters might be suspected for this kind of result.

Figure 20: Sensitivity of Exchange Rate under optimized risk premium



The result tells us that risk premium construction fluctuate wildly when there are shocks to some of inputs. This strengthens that constant risk premium can't serve well the exchange rate expectation in time of crisis.

Model Optimization

A calibration optimization was undertaken for speculative attacks with respect to the desired level of speculative attacks as well as time for those actions. The system has been set to determine the possible size of speculation. What I optimize is just the fraction of those sizes with respect to speculators and central bank and the appropriate time for speculative attacks. The exchange rate computed by the system is compared to the actual monthly exchange rate data be optimized in its parameters to be as close as possible to the actual data. Optimization is done by setting all data at scenario 1 with switch to purely exogenous = 0 and switch to purely exogenous target = 0 and put the result as Scenario 2 in optimized value resulted from optimization with The confidence bound of those target variables are listed in the last two columns.

Figure 21: Calibration Optimization under scenario 2 for desired levels of speculative attacks

Simulation run name: Scenario 2				
Optimization15c.vpd Optimization15c.voc				
Variable to optimized	Before optimized	Optimized	Lower Bound	Upper Bound
Fraction 1	0.5	0.136258	0.143049	0.143549
Fraction 2	0.5	0.22913	0.240526	0.240792
Fraction 3	0.5	0.948566	0.94701	0.947291
Fraction 4	0.5	0.394636	0.390106	0.390361
Fraction 5	0.5	0.387734	0.388662	0.388961
Fraction 6	0.5	0.0260121	0.0259527	0.0262807
Fraction CB1	0.5	1	0.999997	1
Fraction CB2	0.5	0.588954	0.592162	0.592435
Fraction CB3	0.5	0.000192227	0	0.000194519
Fraction CB4	0.5	0.5	0	1
Fraction CB5	0.5	0.5	0	1
Time opt CB1	140	141.083	141.031	141.094
Time opt CB2	141	140.604	140.656	140.719
Time opt CB3	148	147.935	139.406	8676.69
Time opt CB4	183	183.067	165.719	17531.3
Time opt CB5	228	228.508	138.844	89892.8
Time optimized 1	127	120	120	120
Time optimized 2	133	132.75	132.75	132.75
Time optimized 3	131	130.684	130.625	130.687
Time optimized 4	135	135.972	135.938	136
Time optimized 5	170	164.235	164.187	164.25
Time optimized 6	217	217.296	217.25	217.312
Simulation	1	4417		
Pass	0	3		
Payoff	-1.94E+09	-5.35E+07		

I also do calibration optimization for speculators' threshold with the result that speculators' threshold is optimized at 70 and coefficient of contagion is optimized at 0.22639 (Fig. 22). These values give the best match with actual exchange rate data.

Figure 22: Calibration Optimization of speculators' threshold under Scenario 3

Simulation run name: Scenario 3				
threshold.vpd threshold.voc				
Variable to optimized	Before optimized	Optimized	Lower Bound	Upper Bound
Speculator's threshold	70	70	0	93.7977
Coefficient of contagion	0.2	0.22639	0	0.4
Simulation	1	17		
Pass	0	3		
Payoff	-5.35E+07	-5.35E+07		

The third calibration optimization is optimization toward the parameters for uncovered interest parity (UIP) approach.

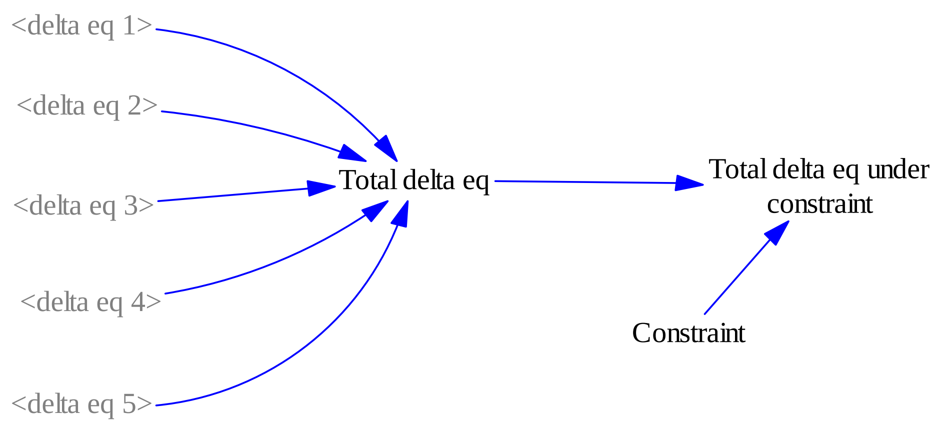
Figure 23: Calibration Optimization of UIP under Scenario 4

Simulation run name: Scenario 4				
UIP.vpd UIP.voc				
Variable to optimized	Before optimized	Optimized	Lower Bound	Upper Bound
Duration for peak time 2	45	45	20	60
Duration for pulse input	43.4277	43.4277	0	43471.1
Time start for pulse input	130	130	120	130130
Delta change in peak time	-0.102663	-0.102663	-0.2	0.2
Delta change in peak time 2	43.3696	43.3696	43.3696	43.3696
Time start for pulse input	130	130	0	43413
Delta change amplitude	0.00252188	0.00252188	0	2.5244
Duration amplitude	45.6073	45.6073	0	45652.9
Period	71.5592	76.2803	0	76356.6
Simulation	1	65		
Pass	0	3		
Payoff	-5.35E+07	-5.35E+07		

Model Policy Formulation

There is a simple policy formulation designed in this model. Bank Indonesia, the central bank, in this case has to decided level of equilibrium of exchange rate in order to minimize the loss due to central bank intervention. To simplify the model, three scenarios are developed. The first case is a case where the central bank has sufficient foreign reserve while the second case is a case where the central bank has only limited amount of foreign reserve. The last case or the third one is where the central bank has no foreign reserves at all to do the intervention. A very simple structure is added to the model as can be seen in Figure (24):

Figure 24: An added structure to compute policy optimization of central bank



In that structure, total delta eq under constraint is just the quadratic difference between the constraint and the total delta eq variable.

In addition to those scenarios, I also put an interesting comparison between calibration optimization and policy optimization done in Vensim which essentially will result a little bit different value. To examine that, I set up the variance variable which has to be minimized by policy optimization.

Optimization Results

In the first scenario, I assume that the maximum effort of central bank to reduce the exchange rate is 5000 Rupiah/USD. I have to minimize total delta eq under constraint executed by a central bank. It is minimized under the Policy of desired eq variable equals 7028.9 Rupiah/USD. The result can be seen in Figure (25).

Figure 25: Optimization of Policy-desired variable by the central bank

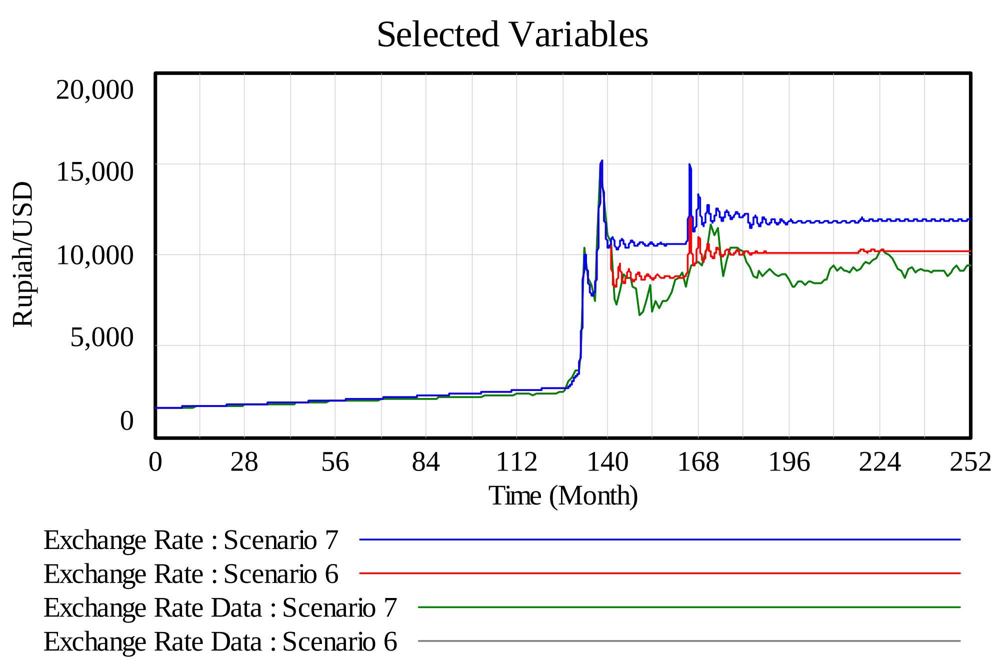
Simulation run name: Scenario 6 with the constraint -5000 Rp/USD				
policy2.vpd policy2.voc				
Variable to optimized	Before optimized	Optimized	Lower Bound	Upper Bound
Policy of Desired Eq	5000	7221.48	0	7221.48
Simulation	1	28		
Pass	0	3		
Payoff	-4.04E+09	-3.75E+09		

The second scenario is still the same as the first scenario but this time is with the constraint of 3000 Rupiah/USD. Under this constraint, it is minimized if the Policy of desired eq variable is 9948.31 Rupiah/USD.

Figure 26: Optimization of Policy-desired variable by the central bank

Simulation run name: Scenario 7 with the constraint -5000 Rp/USD				
policy3.vpd policy3.voc				
Variable to optimized	Before optimized	Optimized	Lower Bound	Upper Bound
Policy of Desired Eq	5000	9948.31	0	9948.31
Simulation	1	29		
Pass	0	3		
Payoff	-2.74E+09	-1.69E+09		

Figure 27: Comparison of policy optimization of central bank under the constraint of 5000 Rupiah/USD (scenario 6) and 3000 Rupiah/USD (scenario 7)



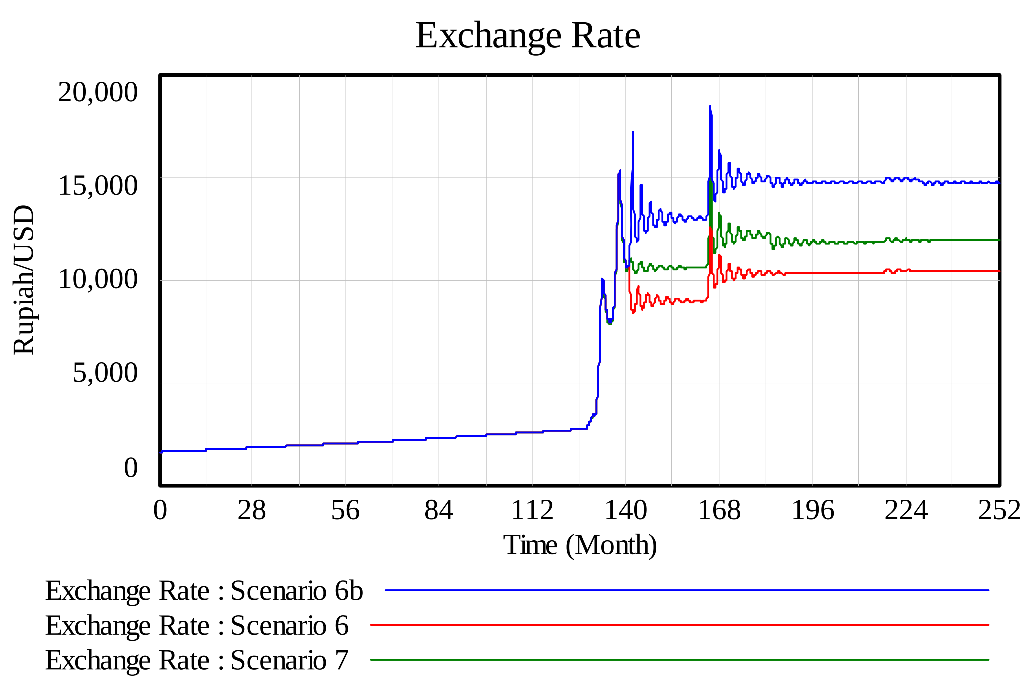
In this case it is clear whenever a central bank has only limited amount of foreign reserves, it will just intervene with limited amount of money and thus the result is that the level of exchange rate will be higher. On the other case, whenever, a central bank has enough foreign reserves, and willing to intervene to defend the currency at all out, then the level of exchange rate will be lower.

When a central bank has no foreign reserves at all, the result is undoubtedly the highest level of exchange rate that is 13,772.8 Rupiah/USD. This result tells that it is very important for a central bank to have sufficient amount of foreign reserves to defend the currency.

Figure 28: Optimization of the exchange rate by the central bank when there are no available reserves

Simulation run name: Scenario 6b with no ability to conduct the foreign exchange intervention				
policy4.vpd policy4.voc				
Variable to optimized	Before optimized	Optimized	Lower Bound	Upper Bound
Policy of Desired Eq	5000	13772.8	0	13773.9
Simulation	1	22		
Pass	0	3		
Payoff	-4.86E+09	-1.19E+09		

Figure 29: Comparison of policy optimization of central bank under constraints of 5000 Rupiah/USD (scenario 6) and 3000 Rupiah/USD (scenario 7) and no intervention (scenario 6b)



The additional thing is just to show that the result from calibration optimization in this model is a little bit difference from minimization of quadratic difference of exchange rate variable and actual exchange rate data.

Figure 30: Calibration Optimization (5a) and optimization of the exchange rate under minimizing the quadratic difference of the exchange rates.

Simulation run name: Scenario 5a and Scenario 5b				
policy1a.vpd policy1a.voc				
Variable to optimized	Before optimized	Optimized	Lower Bound	Upper Bound
Scenario 5a is a Calibration Optimization				
Policy of Desired Eq	5000	5720	5719.65	5720.27
Simulation	1	12		
Pass	0	3		
Payoff	-8.16E+07	-5.34E+07		
Scenario 5b is a Policy Optimization by minimizing quadratic difference of exchange rate				
Policy of Desired Eq	5000	5717.93	5717.17	5718.17
Simulation	1	12		
Pass	0	3		
Payoff	-8.16E+07	-5.25E+07		

Discussion and Conclusion

This model can explains S-shaped with overshoot of exchange rates during Indonesian crisis 1997/1998 under some reasonable range of parameter values. The-se reasonable values of parameters are justified using calibration optimization results.

UIP cannot serve well in the crisis period under constant risk premium. How-ever, oscillating risk premium might improve that behavior in the sense that intangible risk will increase given a crisis occur and will decline when a crisis subsided. In reality, an oscillating risk premium might not exist, and might be traced from the willingness of people to hedge their currency value in their international trade.

It is important for a central bank to maintain high foreign reserves such that it has sufficient ability to conduct interventions to maintain the currency level in its current quasi-equilibrium. If a central bank does not have sufficient amount of foreign reserves, speculators can attack the currency of a country with higher chance to have their desire of currency depreciation fulfilled.

As all models are essentially wrong, this model lacks of interrelationships of many macroeconomic indicators such as GDP, exchange rates, inflation, fiscal deficit and interest rates. In light of this, the feedbacks effects from exchange rates to all other variables are not exist in this model. Because of this reason, the ability of the model to estimate the medium and long run exchange rate levels is very low.

From my perspective, modeling is a systematic way of representing the essential part of a real system and how they interact to each other that will generate an outcome. With respect to that, modeling is continuous learning which always opens up new ways of improving a model. These lists of possible (but not necessarily easy) developments are made and can be achieved under some considerable time. In order to make the model more related to how the real worlds work, it is essential:

1. To make the size of attacks as endogen variables related to output, inflation and interest rate. The result of new quasi-equilibrium come from such an attack by speculators will be more likely to feed back to the system and influence other close related variables in macro model system such as money supply, interest rates, inflation and economic growth.
2. To link the exchange rate with interest rate, output, inflation in the sense that interest rate become endogenous variable related to inflation expectation and output. The idea of incorporating the effects of inflation expectation, interest rate directly to exchange rate will bring new questions of the exchange rate effects on those variables themselves or in general, questions about the feedback effects of exchange rate to all other macroeconomic variables. As exchange rates serve as prices in international trade mechanism, they surely bring their effect on supply and demand of goods and services which undoubtedly will influence a country's output. The effect on output will feed back to the exchange rate and the cycle continues to roll.
3. To begin a new structure framework of supply and demand of exchange rate to analyze the declining of foreign reserves under the crisis. In a more straight forward approach, the supply and demand of the local currency in the currency market will determine the level of the exchange rate that clears that market. It is not simple still,

since the supply and demand of the local currency will be determined from level of economic growth, size of international trade, inflation rate, domestic interest rate in comparison with foreign interest rate, and some other macro indicators. In addition to that, incorporating speculators' motive that triggers the currency attacks will require some speculators' foresight of what actually happen in the currency market, in day to day operation. Such variables, if tangible, could easily incorporated in the model, while if intangible, a more insight on how to insert it in the model is required.

4. To add benefit-loss function for speculators in order to justify their act in at-tacking the currencies. It is in 101 economic and management class that people who involve in one kind of investment have in their mind net benefits that they will get through those investments. However, benefits can mean everything from money value to intangible utilities such as security reasons or social activities. To restrain myself from these complicated things, I will just focus in monetary benefits of such specific action of exchange rate speculation in light of basic benefit-cost function related to interest rate differentials.

References

Cerra, Valerie and Saxena, Sweta Chaman. "Contagion, Monsoons and Domestic Turmoil in Indonesia: A Case Study in the Asian Currency Crisis". IMF Working Paper No.WP/00/60, March 2000.

Eichengreen, Barry, and Charles Wyplosz. "The Unstable EMS." Brookings Papers on Economic Activity 1:1993, 51-143

Ito, Takatoshi. "Capital Flows in Asia". NBER Working Paper No.7134. May 1999.

Isard, Peter. "Uncovered Interest Parity". IMF Working Paper No.WP/06/96. April 2006.

Krugman, Paul. "A Model of Balance-of-Payments Crises." Journal of Money, Credit and Banking 11 (August 1979), 311-25.

Obsfeld, Maurice. "The Logic of Currency Crisis". NBER Working Paper Series No.4640. February 1994.

Sachs, Jeffrey, Aaron Tornell, Andres Velasco. "Financial Crises in Emerging Markets: The Lesson From 1995". NBER Working Paper Series No.5576. May 1996.