A Model of Speculative Attacks and Devaluations in Korea and Indonesia

Austin Yi Lin*

Kent Kimbrough, Faculty Advisor

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* The author will be working for Capital One as a Business Analyst following graduation and can be reached via email at austinlin87@gmail.com.

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Abstract

Since the beginning of the Bretton Woods era, currency crises and speculative attacks have affected the world economy. This paper presents a model, originally derived by Blanco and Garber, that predicts one-period ahead probabilities of a currency devaluation and the expected exchange rate conditional on a devaluation. The analysis is then applied to Korea and Indonesia during the periods of 1960-1980 and 1969-1989, respectively. Despite numerous devaluations during both periods, all of the calculated probabilities of devaluation in the next period are close to zero for both Korea and Indonesia. However, it is promising that rises in predicted probabilities of devaluation are observed before actual devaluations for Indonesia.

I. Introduction

Since the beginning of the Bretton Woods era, currency crises and speculative attacks have affected financial markets on an international scale, particularly within the last decade of the 20th century. Because these events often have wide-ranging implications not only for the countries in which they occur but for the world economy as well, it is crucial to gain a better understanding of what triggers a currency crisis in order to be able to predict and potentially avert speculative attacks in the future. More concretely, learning how currency crises can affect development during industrialization is important to placing currency crises in the context of today's emerging markets. As Gray and Irwin (2003) discussed, one of the main risks and concerns for foreign investment in the infrastructure of a developing country is devaluation of the local currency. From 1978-2003, the currency of developing countries fell on average by 72% relative to the U.S. dollar. Indeed, in Indonesia, one of the countries that received the most investment in private infrastructure projects, state-owned utilities defaulted on payments to independent power producers because payments were denominated in dollars (Gray & Irwin, 2003). As a result, development is often inherently tied to stability of currency and the markets, and the development of a country can be heavily influenced by the type of exchange regime it chooses (Chung & Yang, 2000).

This paper presents a model that will analyze the probability of a devaluation in a fixed exchange rate regime. Specifically, the model will predict the one-period-ahead probabilities of a devaluation and the expected exchange rate if a devaluation occurs.

In asset price-fixing regimes, including gold and fixed exchange rates, the government attempts to maintain the price level of the asset by stockpiling reserves. In this situation, rational agents will speculate against the reserves by buying the asset in large quantities. Once the reserves are depleted, the government is forced to devalue the asset by raising prices, which reduces demand. The rational agents subsequently realize a gain because the assets that were bought at a lower price can now be sold for a higher price (Salant & Henderson, 1978).

The model presented in this paper derives from the assumption that the speculative behavior of rational private agents can be observed and utilized to predict the timing of a devaluation and subsequently, the new expected exchange rate. The model will be based upon the domestic money market and a policy rule for devaluation, both of which depend on the surplus domestic money supply in the economy. The analysis will then be applied to Korea and Indonesia from 1960 to 1990 and from 1969 to 1989, respectively.

The research on currency crises can be broken down into three different types of models. The first type of model examines a situation where the government's domestic fiscal policy is not aligned with a fixed exchange rate policy. The second type of model explores a purported "temptation" by the government to pursue expansionary economic policies, which leads to a devaluation due to speculative attacks. The third type of model determines whether a currency crisis is a sign of underlying financial troubles (e.g. the East Asian Financial Crisis) (Sarno & Taylor, 2002, 245).

The literature on the first type of model is most relevant to this paper. In 1978, Salant and Henderson analyzed the effects of expected government sales policy on the real price of gold, the precursor to a model with currencies and exchange rates. They conclude that when the government controls the price of gold and hopes to keep the price constant by stockpiling reserves, eventually a speculative attack will occur in which speculators will buy out remaining gold reserves. Krugman(1979) introduced a model for balance-of-payment crises based on Salant and Henderson's previous research on the stockpiling of exhaustible resources by the government. Krugman's framework follows the one-good, two asset model developed by Kouri with the following two major properties: domestic currency demand is exchange rate dependent and the exchange rate is dynamic. The model was examined under a small open economy with perfect foresight and with a flexible and then a fixed exchange rate regime. From the model, Krugman was able to determine the qualitative features of the timing of a collapse. For example, under a fixed exchange rate regime, he concluded that as domestic credit grows relative to money demand in the economy, the price level begins to rise which is reflected in the expected rate of inflation. Once the expected rate of inflation increases, domestic money demand decreases and the exchange rate experiences a discrete jump. Moreover, Krugman's model also predicts that a balance-of-payments crisis follows "a period of gradually declining reserves, a sudden speculative attack, and a post-crisis period during which the currency gradually depreciates." However, ultimately, he was not able to explicitly predict the timing of the collapse and the magnitude of the subsequent devaluation due to the nonlinearity of his model. Flood and Garber (1984) were able to give an explicit solution for a stochastic, log-linear version of Krugman's model, although, in order to solve, they had to assume, as Krugman did, that the government institutes a flexible exchange rate system after the collapse of the fixed exchange rate regime.

While many theoretical studies of balance of payments crises and the collapse of fixed exchange rate systems exist, empirical studies are less common and generally center on lesser-developed countries (Sarno & Taylor, 2002, 249). Blanco and Garber (1986) created a model that predicts the timing and the magnitude of recurring speculative attacks which compel the government to devalue fixed exchange rates. Specifically, based on the expectations of rational agents, the model estimates a one-period-ahead probability of devaluation, predicts the expected value of the new exchange rate, and determines the confidence interval for the predicted exchange rate based on the expectations of rational agents. Blanco and Garber then applied their model to the Mexican exchange rate system from 1973-1982. Their model was accurate in predicting when major exchange rate devaluations occur (Aug. 1976 and Feb. 1982).

Cumby and van Wijnbergen (1989) built a balance-of-payments crisis model and applied it to the Argentine crawling peg (Dec. 1978 – Feb. 1981), estimating the probability of collapse of the crawling peg. Cumby and van Wijnbergen utilized a model where real money demand is a function of nominal interest rate, which serves as the opportunity cost to holding money. In the Cumby and van Wijnbergen model, when a lower threshold of reserves is reached, the peg will be abandoned for a floating exchange rate policy by the central government. The probability of collapse is then based on the credibility of the announced policy and expectations of rational agents and is solved numerically based on the probability of collapse conditional on the lower threshold of reserves. Their results indicated that domestic credit creation and exchange rate policy must be in sync in order for the government to maintain an exchange rate regime. Whereas Cumby and van Wijnbergen examined a shorter period and focused on the domestic credit/money supply process while abstracting the influence of income on money demand, the Blanco and Garber model assumes that money demand depends on income. Thus, Blanco and Garber modeled money supply and money demand through the excess supply of currency in the economy. Grilli (1990) added to this literature by considering how effective borrowing can hold off or prevent exchange rate crises. He examined the probability of collapse of an exchange rate regime in the context of the gold standard in the United States from 1894-1896. Through a model predicting the probability that a speculative attack on the fixed parity will occur in the next period, Grilli showed that a currency crisis may be avoided through lines of credit in foreign currency. However, the size of the loan must be optimized in order to avoid a drastic increase in debt obligation and thus an expansion of domestic money creation in the future.

The main goal of this analysis is to further explore exchange rate crises by examining whether or not the Blanco & Garber model can be generalized to other countries and time periods and to regimes that are not strictly fixed exchange rate regimes. Based on data considerations for implementing the Blanco & Garber model, Indonesia and South Korea were chosen for this study. Both countries have had repeated exchange rate crises over a long period of time and have relatively complete data sets covering these numerous episodes.

After declaring independence from the Netherlands in 1949, Indonesia began to experience modest economic growth. Unfortunately, due to expropriation of Dutch property and "regional insurrections" at the end of the 1950s, the country became politically volatile. In his Independence Day speech on August 17 1959, President

Sukarno spoke of a "Guided Economy" which set forth plans for a framework for economic policy. Stemming from his framework, an ambitious Eight Year Plan was drawn up, detailing Indonesia's goal to become self-sufficient in basic goods within three years and to have self-sustained growth within five years. However, from 1961-1964, the economy did not grow. Indeed, fiscal budget deficits that amounted to 10 to 30 % of receipts in the 1950s rose to more than 100% of receipts in the 1960s. Moreover, inflation skyrocketed due to the printing of money that was used to pay off the deficit which resulted in the increase in general prices by 500% in 1965. Other factors that contributed to the malaise in the economy included the switch from financial to real assets and the decline of the tax base. At the same time, Indonesia was fighting over the territory of Borneo with Malaysia. By itself, this military campaign consisted of 19% of the total government expenditures in 1965 (Hill, 1996, 2).

1966 marked a turning point in Indonesia's economic history. From 1966 to 1970, the Indonesian government worked to rein in runaway inflation through traditional monetary and fiscal policies and continued its positive relationship with the international donor community. During this period, the average annual rate of growth for the economy was 6.6% (Hill, 1996, 14-15).

From 1971 to 1981, the Indonesia economy experienced rapid growth and the Real GDP grew at an annual average rate of 7.7%. However, at the same time, the economy faced many unexpected exogenous forces. In 1972, a poor rice harvest caused rice prices to double, but in the latter half of 1973, international petroleum prices increased by four fold and Indonesia, a major exporter of oil, experienced large gains in revenue. As a result of the increase in oil prices, the government turned towards domestic interests and the state expanded its role in businesses. However, at the end of the 1970s, it appeared that oil prices would decline. Thus, a currency devaluation occurred in November 1978 in order to increase the competitiveness of non-oil tradeable goods. However, the decrease in prices only came in 1982 (Hill, 1996, 16).

From 1982 to 1986, falling oil prices and a need to repay maturing 15 year loans led to a decline in economic growth. Due to good results in the agriculture sector and smart investments by the Indonesian government, though, the economy continued to grow at an annual average rate of 4%. The government was forced to decrease spending on infrastructure and expenditures and devalue the rupiah in April 1983 due to a slowing economy. However, at the same time, non-tariff barriers to trade increased the costs to the nascent industrial sector. Only in 1986 did the Indonesian government began to open up the economy to free trade. From 1987 to 1992, the economy had an average annual growth rate of 6.7%. At this point in time, Indonesia became a major industrial exporter and "manufacturing overtook agriculture in terms of value added in 1991." Thus, Indonesia was able to survive the debt crisis of the 1980s and become one of the newly industrialized economies in the 1990s (Hill, 1996, 16-17).

Korea's economy followed a different path to success starting in 1945 with the end of Japanese economic dependence. After liberation from Japanese colonial rule, Korea experienced economic stagnation. This was for the most part due to the partition between South and North Korea, the removal of support from the Japanese economic bloc, and hyper-inflation due to expansion of the money supply. More specifically, the partition resulted in the separation of human resources in the South from major commodities and power production in the North. Additionally, the outflow of Japanese human capital and resources led to the loss of technical knowledge and disruption of trade flow. Moreover, rapid monetary expansion and hyper-inflation fed speculation and blocked industrial investment. From 1945 to 1949, the currency expanded approximately fifteen fold. As a result, manufacturing and food production decreased dramatically. Although industrial production started to increase from 1946 to 1949, the Korean War led to sudden decrease in production. During the Korean War, production was once again at 1946 levels and South Korea was forced to rely on assistance from the U.S. and the UN (Cha et. al., 1996, 5-9).

The Korean War ended when the armistice was signed in July of 1953. At this point, South Korea started to rebuild its industrial plants and infrastructure. Focus shifted from reconstruction to economic stabilization at the start of 1957. Since domestic inflation was higher than that of the U.S. and Japan, the official exchange rate was generally overvalued even with large devaluations of the won during this period. Moreover, a system of multiple exchange rates developed and was not eliminated until the early 1960s. During this period, because the rates changed based on the source of foreign exchange, the official rate was, for all intents and purposes, irrelevant. At the same time, import substitution was encouraged by the government via tariffs and quantitative restrictions. Exports declined due to insufficient domestic production capacity and private entrepreneurs who looked to U.S. aid dollars for profit instead of exports. Interest rates were also kept low in order to encourage capital investment. During this period, the economy grew by an average annual rate of 4%. Economic growth was spurred in part by a shift towards manufacturing as South Korea experienced structural changes (Cha et. al., 1996, 10-13).

From 1961 onwards, the military government began to focus on shifting from an inward-looking policy to a strategy emphasizing export-based industrialization. However, in the first three years, the Korean government did not emphasize the policy reforms that came with an export-oriented industrialization strategy. Indeed, while the government tried to unify the exchange rates, it did not reign in monetary expansion. However, a change came in the form of a new civilian government that took over in 1965. The new government reformed the exchange rate by devaluing the won and following a unitary floating rate. This led to the relative stability of the official exchange rate from 1965 to 1979. However, due to intervention by the central bank, the unitary floating rate regime became a crawling peg. At the same time, the government began following export promotion strategies. Indeed, these sound policies led to an impressive average annual growth rate of 9.6 percent by the Korean economy (Cha et. al., 1996, 16-20).

The rapid economic growth in the 1970s was balanced by exogenous forces. The first and second oil shocks increased inflation and deteriorated balance of payments due to Korea's dependence on oil imports. Two major devaluations during this period correspond with the first and second oil shocks, respectively. Through lowering deficits, Korea was able to curb its inflation by stabilizing prices. As a result, by the early 1980s, Korea began to experience large amounts of growth with GDP growing by over 12% annually. Moreover, during this period, Korea began financial liberalization, import liberalization, and opening of its capital accounts. It was so successful from 1986 to 1988 that it ran a current account surplus (Cha et. al., 1996, 33-39).

In this paper, the analysis of Blanco and Garber (1986) is extended in three ways. First, the Blanco & Garber model is applied to a greater number of devaluations occurring over a larger period of time. Originally, Blanco and Garber look at a period of eight years and three devaluations. In the Indonesian case study, exchange rates are examined for a period of twenty years and a series of seven distinct devaluations from the 2nd quarter of 1969 up through the 3rd quarter of 1989. Korea is studied for a period of sixteen years and a series of five distinct devaluations from the 3rd quarter of 1954 to the 1st quarter of 1980. Secondly, the currency crises encompass devaluations that are both smaller and larger in magnitude than the devaluations examined in the Blanco and Garber case study. Lastly, the analysis is applied to different types of exchange rate regime and different periods. In the original Mexican case study, the model is applied to a fixed exchange rate regime. Presently, in the case of Indonesia, the model is applied to a fixed exchange rate period (1969 to 1979) and then a fixed exchange rate period and multiple currency basket period (1969 to 1989). In the multiple currency basket, the U.S. Dollar is given a weight of 0.9, which closely resembles the fixed rates. In the Korean case study, the model is applied to a fixed exchange rate regime (1964 to 1980).

From the results, several conclusions can be deduced. First, it can be determined that the model is only marginally adequate for the prediction of the probability of a devaluation one period ahead. For Indonesia, the probabilities of devaluation are on the order of 10^{-5} although the probabilities do spike consistently right before a devaluation. Additionally, the model is able to better predict the probability of a devaluation for the fixed exchange rate period as compared to the fixed exchange rate and multiple currency basket period for Indonesia. The probabilities for Korea are on the order of 10^{-3} and do not present an obvious pattern of spiking before a devaluation although the probabilities are higher than average the period before a devaluation. Secondly, as a result of the small probabilities, the model is not a good predictor of the expected exchange rate and of the confidence interval for the predicted exchange rate.

This paper is divided into 5 sections. In section II, a more in-depth history of the exchange rate systems of Indonesia and Korea is presented. In section III, a theoretical model is constructed and solved, giving discrete solutions for the probability of an exchange rate devaluation and expected magnitude of the new exchange rate. In section IV, the model is applied to the Indonesian and Korean case studies. Section V concludes the paper.

II. Historical Context

This section provides a history of the development of exchange rate regimes in Korea and Indonesia. It is evident that both countries experience similar reforms in exchange rate policies with the following pattern: a fixed exchange rate period with discrete devaluations, a currency basket that is primarily pegged to the U.S. Dollar, and a transition to a flexible exchange rate system following the Asian Financial Crisis of 1997. Within this historical framework, the purpose of this research is to model how agents formulate expectations about the probability of devaluations during different time periods and across different exchange rate regimes.

Indonesia

The Indonesian Rupiah was introduced in November 1949 as a new national currency prior to Indonesia's declaration of independence from the Netherlands in December of 1949. At the outset, the Indonesian Central Bank pegged the Rupiah to the

U.S. Dollar. In 1965, plagued by rampant inflation, the new Indonesian Rupiah was introduced at a rate of 1000 old Indonesian Rupiah to 1 new Indonesian Rupiah (Pick, 1981). In Figure 1 presented below, the quarterly exchange rate data based on end-of-quarter exchange rates for Indonesia from 1967Q1 to 2007Q4 is presented. As can be seen in Figure 1, there are four distinct periods: a fixed exchange rate period (1967 to 1978), a currency basket period (1978 to 1989), a managed floating period (1989 to 1997), and a floating period (1997 to 2007).

Figure 2 shows the end-of-quarter exchange rates for the fixed exchange rate period and the currency basket period. The timings and magnitudes of devaluation episodes over 5.00% for the rupiah from 1967-1989 are presented in Table 1. From 1967 to 1970, the Indonesian Rupiah was devalued six times with the final peg being 326 Indonesian Rupiah:1 US Dollar. During this time period, the devaluations over 5% ranged from 6.29% to 58.78% increases. In April 1970, the Indonesian Rupiah was merged into a two-tiered system: a flexible general exchange rate (378 Rupiah/US Dollar) and a flexible credit foreign exchange rate (326 Rupiah/US Dollar). In December 1970, the flexible credit foreign exchange rate was eliminated only to be reintroduced again in August 1971. From April 1970 to the end of the single currency peg period in November 1978, there were a series of four devaluations over 5% that ranged from 8.57% to 53.16%.

TABLE 1

INDONESIA EXCHANGE RATE DEVALUATIONS

OVER 5% FROM 1967Q1 to 1978Q4

Date	Ex. Rate at time t (Rupiah:US$)	Ex. Rate at time t-1 (Rupiah:US $)	Devaluation %
1967Q3	148	137	8.03%
1967Q4	235	148	58.78%
1968Q1	266	235	13.19%
1968Q2	302	266	13.53%
1968Q3	321	302	6.29%
1970Q2	378	326	15.95%
1971Q3	415	378	9.79%
1971Q4	450.57	415	8.57%
1973Q1	500.635	450.57	11.11%
1978Q4	814.244	531.644	53.16%
1980Q2	828.069	786.992	5.22%
1982Q4	763.904	719.808	6.13%
1983Q2	1040.570	757.766	37.32%
1985Q3	1187.59	1116.08	6.41%
1986Q3	1981.51	1331.83	48.78%
1987Q1	2113.58	2007.25	5.30%
1987Q4	2340.790	2111.41	10.86%
1988Q4	2329.41	2201.41	5.81%

In November 1978, the peg with the U.S. Dollar was severed and replaced by a weighted basket peg of major currencies and trading partners. Frankel and Wei (1994) determined that the U.S. Dollar had a 95% weight in the rupiah multiple currency basket peg based on weekly movements from January 1979 to May 1992. Another similar study by Kwan (1995) determined that the U.S. Dollar had a 99% weight in the Indonesian rupiah multiple currency basket based on weekly movements from January 1991 to May 1995.

The Rupiah switched to a managed floating exchange rate system in September 1989. In August of 1997, the managed floating exchange rate system was replaced by a free floating exchange rate system. Major devaluations can be observed from Figure 2 during the fixed exchange rate and multiple currency basket period in the following months: November 1978 (fourth quarter 1978), April 1983 (second quarter 1983), and September 1986 (third quarter 1986) (Cowitt, 1985 as cited in “Indonesia”). For Indonesia, the largest quarterly devaluation up until the East Asian Economic Crisis of 1998 was 58.78% in fourth quarter of 1967 when the Central Bank devalued the Rupiah from 148 Rupiah to the U.S. Dollar to 235 Rupiah to the U.S. Dollar.

Quarterly exchange rate data for Indonesia was collected from the International Financial Statistics (IFS) database compiled by the International Monetary Fund. In order to follow a model where agents react to domestic credit and monetary changes that are established at the beginning of each time period, quarterly exchange rate series were constructed via end-of-quarter data. Exchange rate data from the IFS database was collected from the first quarter of 1967 through the fourth quarter of 2007 for Indonesia. 1967 is the first date at which end-of-quarter exchange rate data become available for Indonesia. In this study, the Blanco and Garber model is initially applied to three distinct time periods, the fixed period (1967Q1 to 1978Q3), the fixed and floating period (1967Q1 to 1989Q3), and the total available data period (1967Q1 to 2007Q4), in order to determine its applicability to the different exchange rate regimes. Because the basket currency peg is so heavily weighted towards the US Dollar during the MCBP period, it is possible to include an extended period as part of the analysis for the model.

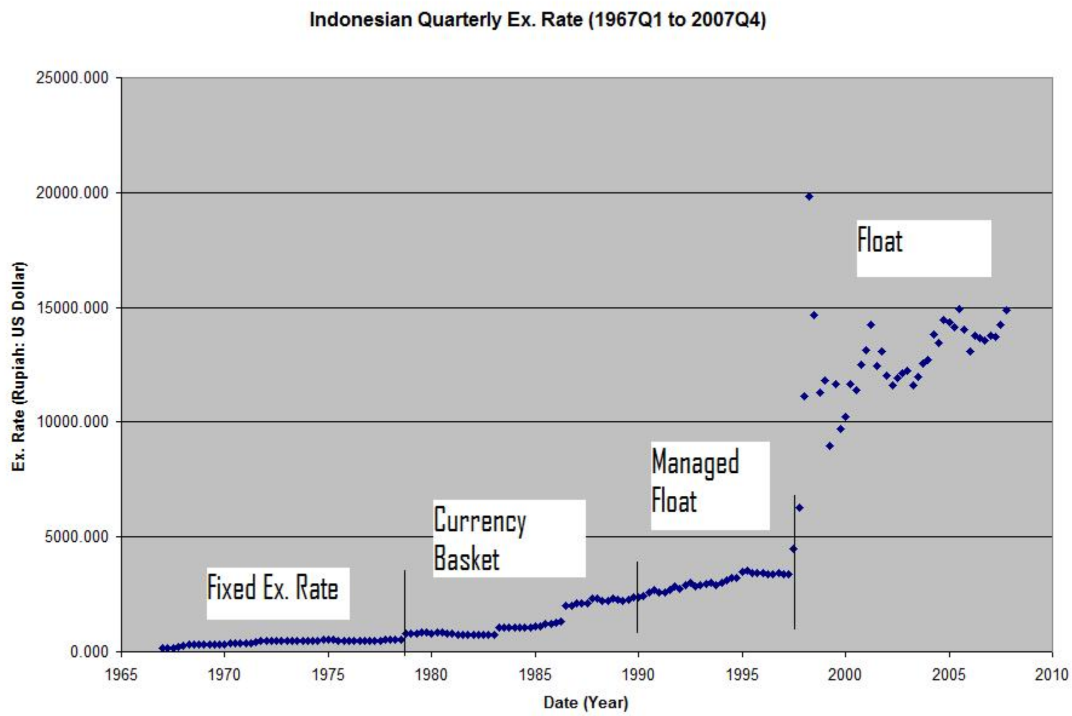

Figure 1: Indonesian Quarterly Exchange Rate Plot

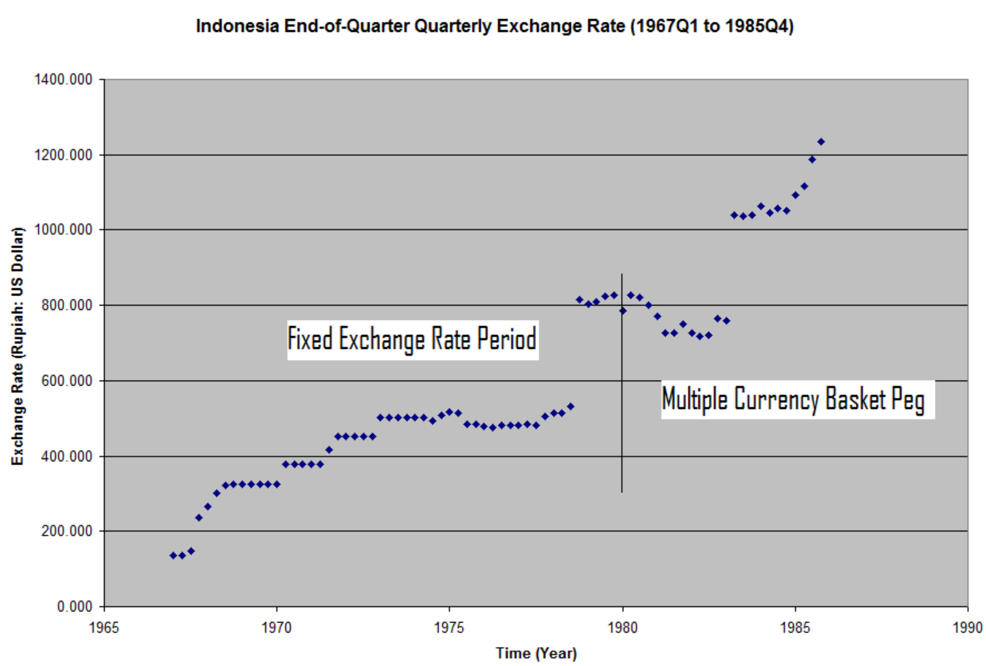

Figure 2: Indonesian Quarterly Exchange Rate Plot (Fixed and Multiple Currency Basket Periods)

Korea

The Korean Won was first introduced between 1902 and 1910. It was replaced by the Yen during Japanese occupation. After World War II, in 1945, the Korean Won was re-established as the national currency at an initial rate of 15 Won: 1 US Dollar. In Figure 3 presented below, the quarterly exchange rate data based on end-of-quarter exchange rates for Korea from 1957Q1 to 2007Q4 can be seen. Additionally, Figure 4 presents end-of-quarter exchange rate data for Korea during the fixed and multiple currency basket periods. In Figure 3, four distinct exchange rate regimes can be observed: a fixed exchange rate period (1957 to 1980), a currency basket period (1980 to 1990), a market average rate period (1990 to 1997), and a floating period (1997 to 2007). The timings and magnitudes of devaluation episodes over 5% from 1957-1980 are presented in Table 2.

TABLE 2

KOREA EXCHANGE RATE DEVALUATIONS OVER 5% FROM 1957Q1 to 1978Q4

Date	Ex. Rate at time t	Ex. Rate at time t-1	Devaluation %
1960Q1	65	50	30.00%
1961Q1	130	65	100%
1964Q2	255.77	130	96.75%
1969Q4	304.45	288.8	5.42%
1971Q2	370.8	322.25	15.07%
1971Q4	405.296	370.8	9.30%
1973Q1	481.213	433.09	11.11%
1974Q4	592.585	473.665	25.11%
1980Q1	733.317	637.588	15.01%
1980Q2	798.601	733.317	8.90%
1985Q3	944.667	872.297	8.30%
1987Q4	1124	1031.13	9.01%

From 1945-1951, Korea experienced a series of seven devaluations ranging from 38.8% to 800% with the final peg being made in 1951 at a rate of 6000 Won: 1 US Dollar. The first Korean Won was replaced by the Hwan in 1953 based on a conversion of 1 Hwan: 100 Won (Pick*,* 1981). However, this did not solve inflationary problems, and six devaluations followed between 1953 and 1961, ranging from a 25% devaluation of the Hwan to a 200% devaluation of the Hwan. In June 1962, the second Korean Won replaced the Hwan at a rate of 10 Hwan: 1 Won. In Figures 3 and 4, all exchange rates are expressed in second Korean Won to 1 U.S. Dollar.

In February 1980, the peg to the US Dollar was abandoned in favor of a multiple currency basket peg (MCBP). For Korea, the exchange rate in time t was based on the following equation:

$$\beta B_1 + (1- \beta) B_2 + \alpha$$

where B_1 is won-dollar exchange rates that reflect changes in special drawing rights (SDR) basket, B_2 is won-dollar exchange rates that reflect changes in the independent basket, the betas are the weights of the baskets, and α is a policy factor. Composition of the independent basket and relative weights between the two baskets were never revealed. Kim, Jin Chun (1992) determined that the independent basket was made up of major trading partners (USA, Japan, Germany, Canada) and most of the weight in the basket was given to the U.S. Dollar and the Japanese Yen. He also conjectured that similar weights were given to the two baskets. Kim, In-Chul (1985) and Oum (1989) estimated the optimal weights within currency basket which minimize variance of the Won's real effective exchange rate. According to their results, the sum of the two weights given to the United States and Japan was greater than 90% (Collignon. 1999).

As can be seen in Figure 4, during the single currency peg period, major devaluations occurred in May 1964 (second quarter 1964) and December 1974 (fourth quarter 1974). The devaluations from June 1962 to February 1980 ranged from 5.42% to 96.75%. Subsequently, a major devaluation occurred in the first quarter of 1980 when the single currency peg was abandoned for the multiple currency basket peg. The Korean government then established a market average rate (MAR) to replace the MCBP in March 1990. In December 1997, a free floating exchange rate system was established (Cowitt, 1985 as cited in "South Korea") as denoted in Figure 2. In the following quarter, the Korea economy underwent an economic crisis.

Quarterly exchange rate data for Korea was collected from the International Financial Statistics (IFS) database compiled by the International Monetary Fund. In order to stay true to a model where agents react to policy changes in domestic credit and domestic money that are established at the beginning of each time period, quarterly exchange rate series were constructed via end-of-quarter data. Exchange rate data from the IFS database was collected from the first quarter of 1957 through the fourth quarter of 2007 for Korea. 1957 is the first date at which end-of-quarter exchange rate data become available for Korea. In this study, the model is applied to three distinct time periods: the fixed period (1957Q1 to 1980Q1), the fixed and floating period (1957Q1 to 1990Q1), and the total available data period (1957Q1 to 2007Q4).

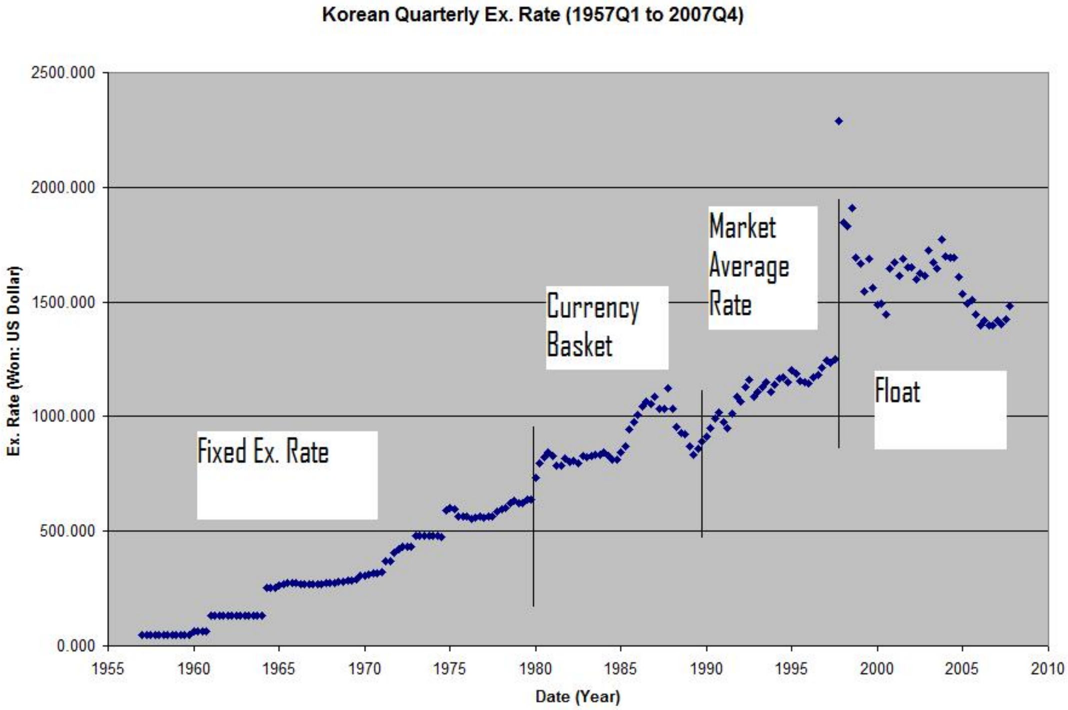

Figure 3: Korean Quarterly Exchange Rate Plot

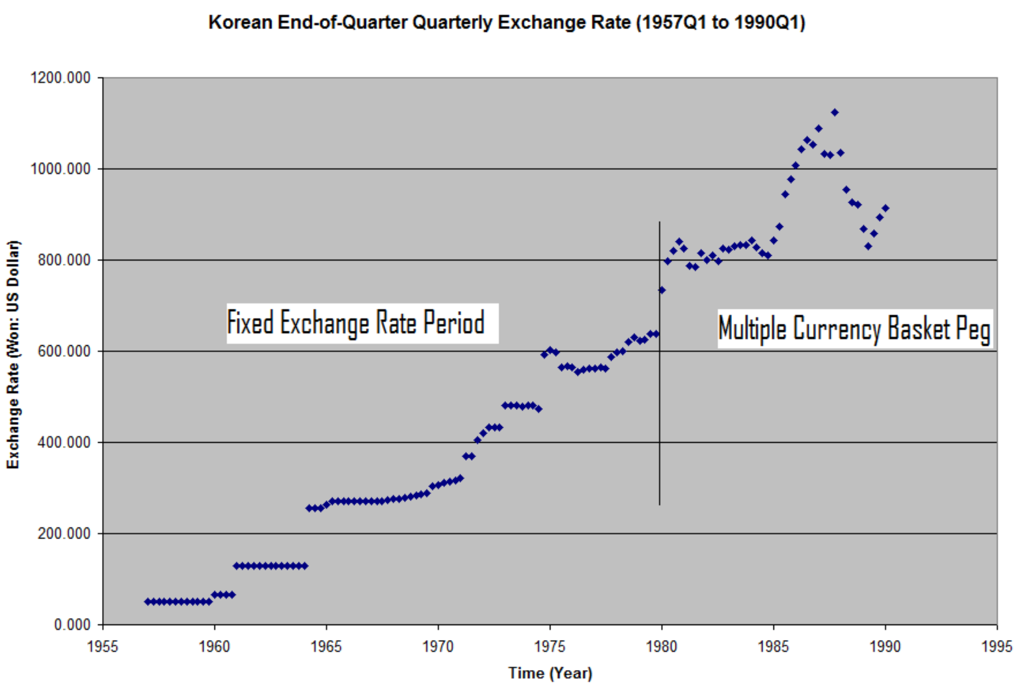

Figure 4: Korean Quarterly Exchange Rate Plot During Fixed and Currency Basket Periods

III. The Model

In this section, a generalized form of the Blanco & Garber model is presented. In Section a., a qualitative, intuitive explanation behind an exchange rate regime collapse is discussed and the empirical approach to the model is outlined. With this background, in Section b., the formal model is presented and analyzed.

a. Intuition

In order to gain a better understanding of the model, the building blocks, a domestic money market, a policy rule for devaluation, and a policy rule for domestic credit creation, are explained in this section. Then, the probability and timing of the collapse of the fixed exchange rate are explained in terms of these building blocks. In this economy, the fixed exchange rate is maintained through control of domestic credit growth rate. The central bank controls the rate at which money is printed and lent out to domestic borrowers, including the government and local banks. In this situation, the main target is fiscal policy and minimizing deficits. Thus, if the government runs up a deficit, it relies on the central bank to print money. In return, the central bank will receive government bonds. However, because money supply must remain constant in order to sustain the fixed exchange rate, foreign reserves must be sold to remove excess domestic currency from circulation and preserve the proportion of domestic currency to foreign reserves.

The domestic money market is an essential part of determining the fixed exchange rate. In the money market, demand for money is positively dependent on aggregate output level and negatively dependent on domestic interest rate since domestic interest rate represents the opportunity cost to holding money. As domestic interest rate increases, rational agents have more incentive to trade in money for domestic bonds. The money supply is backed by a sum of domestic credit and foreign reserves and is controlled by the central bank of the government. In money market clearing, the money supply and money demand are in equilibrium.

The policy rule for devaluation is the second component of the model. If domestic credit expansion is occurring too quickly, agents will become wary of the current fixed exchange rate and start trading in domestic currency for foreign reserves. As this happens, the foreign reserves start to deplete contributing to a snowball effect. The central bank decides to stop selling reserves and defending the exchange rate when the reserves reach a critical lower bound. At this point, the central bank establishes a new fixed exchange rate. This new fixed exchange rate is dependent on policy variables and can be tracked over all periods in time although it remains in the background until the time of the devaluation. When the new exchange rate is established, the currency must be devalued to the extent where demand for domestic currency increases and individual agents trade in foreign currency for domestic currency, increasing the level of foreign reserves held by the government. At the same time, speculators also realize a net gain. If the currency were appreciated, demand for foreign reserves would increase and the excess supply of domestic currency in circulation would not be resolved.

It is also necessary to establish an additional exchange rate. The permanently floating exchange rate would be the postattack exchange rate set by the central bank if it decided on a floating regime. After the speculative attack, the reserves would be at the lower bound. Thus, the permanently floating exchange rate marks the lower bound on the value of the new fixed exchange rate.

The third part of the model is the policy rule for domestic credit creation. The domestic credit rule monitors the excess supply of money in the economy based on the money market equilibrium, covered interest parity, and purchasing power parity. The excess supply of money is modeled as a process with white-noise that is representative of the fluctuations of the excess supply of money. A large excess supply of money is indicative of domestic credit expansion while a great amount of noise is representative of disturbances and instability that increase the likelihood of a currency devaluation. Indeed, a stationary process for excess supply of money demonstrates commitment by the central bank to the current fixed exchange rate and also minimal domestic credit creation.

The shadow exchange rate in the next period is dependent on the excess supply of money process and the white-noise in the next period. The probability of an attack in the next period is determined by the probability that the shadow exchange rate in the next period is greater than the fixed exchange rate. An expected exchange rate in the next period can be determined by the average of the fixed exchange rate and the new exchange rate if a devaluation were to occur weighted by the probabilities of no collapse and collapse, respectively. With this intuition laid out, the formal model is examined in the next sub-section.

b. Formal Model

In this section, the Blanco & Garber model for predicting future exchange rate devaluations under a fixed exchange rate regime is outlined. The three main components of the model are the following: a domestic money market, a policy for devaluation, and a policy for credit creation. Beginning with the money market, equilibrium requires that:

$$m_t - p_t = \beta + \Omega y_t - \alpha i_t + \omega_t \quad (1)$$

where m_t, p_t, and y_t are the logarithms of money stock, domestic price level, and the aggregate output level, respectively. The left hand side of (1) is the supply of real balances and the right hand side is a Cagan money demand function where α represents the interest rate semielasticity of the demand for money, Ω represents the income elasticity of money demand, i_t is the domestic interest rate, and ω_t is a shock to the money demand function.

For simplicity, covered interest parity and purchasing power parity are assumed to hold so that:

$$i_t = i_t^* + Ee_{t+1} - e_t \tag{2}$$

$$p_t = p_t^* + e_t + u_t \tag{3}$$

where e_t and u_t are the logarithms of the nominal and the real exchange rate, respectively and asterisks denote foreign variables. The term u_t can also be interpreted as a deviation from purchasing power parity. Ee_{t+1} signifies the expectation of the logarithm of nominal exchange rate in the next period, t + 1, based on information available at time t.

The second part of the model requires a policy for devaluation. The current exchange rate is pegged at $\bar{e}$. It is assumed that the central bank halts intervention in the foreign exchange rate market when the reserves reach a critical lower bound, $\overline{R}$, which is measured in foreign currency units. The critical lower bound, $\overline{R}$, need not be zero and will be determined empirically via a multistep, grid search estimation process. If reserves reach this critical lower bound, a devaluation will occur, and a new fixed rate, $\hat{e}_t$, is established by the central bank and is a function of the stochastic state variables. Whenever $\bar{e}$ is still viable, $\hat{e}_t$ is an unseen or shadow exchange rate. In other words, $\hat{e}_t$ is a variable that can be estimated but not observed or known *a priori* by the researcher.

Blanco and Garber's innovation was to develop a method to estimate agents' expectations about this unobservable variable.

Devaluation will occur when the current reserve level, R_t, has dipped below the critical level of reserves, $\overline{R}$. Thus, at that point in time, it is necessary to determine what government policy would be implemented and thus what the relationship is between the new fixed rate, $\hat{e}_t$, and the original rate, $\bar{e}$. If the reserve level at the current time, R_t , has dipped below the critical level of reserves, $\overline{R}$, and $\hat{e}_t$ were set to be lower than $\bar{e}$, the foreign reserves would continue to decrease. This would result from agents selling their domestic currency back to the central bank in exchange for foreign currency due to further overpricing of the domestic currency and the disparities between government fiscal policy and the exchange rate policy. Thus, $\hat{e}_t$ must be set to a value greater than $\bar{e}$ when a collapse occurs so that demand for domestic currency will increase and agents will desire the exchange of foreign currency for domestic currency. Additionally, this relationship ($\hat{e}_t > \bar{e}$) incorporates the idea that agents gain from causing a speculative attack against the currency. When $\hat{e}_t$ is established as the new exchange rate, speculators will profit via capital gain and are now willing to exchange more domestic currency for foreign currency. Examining this relationship from a different perspective, only when $\hat{e}_t > \bar{e}$ will the fixed exchange rate collapse. Otherwise, the government will be forced to maintain the current level of reserves, R_t. Thus, based on the devaluation policy created, the central bank will continue to sell international reserves until $\overline{R}$ is reached, at which point, the bank will devalue the currency to $\hat{e}_t$.

As part of the process of producing a new viable exchange rate, it is necessary to understand the relationship between $\hat{e}_t$ and $\tilde{e}_t$, the post-collapse exchange rate determined by market forces if the exchange rate system were allowed to permanently float. In a floating exchange rate system, reserves would always remain at $\overline{R}$ because the floating exchange rate would adjust according to money market supply and demand. In order for the new exchange rate, $\hat{e}_t$, to be feasible, the central bank must create a policy where $\hat{e}_t \geq \tilde{e}_t$. If the central bank decided to maintain the fixed rate regime and attempted to devalue by setting $\hat{e}_t < \tilde{e}_t$, there would be an excess supply of domestic money and an increased demand for foreign reserves because of overvaluation of domestic currency. The central bank would not be able to sell more foreign currency reserves because reserves would be required to fall below their critical level, $\overline{R}$. Thus, $\hat{e}_t$ must be greater than or equal to $\tilde{e}_t$.

The shadow flexible exchange rate is an important part of the model, so we proceed to derive it. Through the substitution of equation (2) and equation (3) into equation (1), one can obtain the following:

$$\tilde{h}_t = -\alpha E e_{t+1} + (1+\alpha)\tilde{e}_t \tag{4}$$

where $\tilde{h}_t$ is the excess supply of money in the economy and $\tilde{e}_t$ is the permanently floating exchange rate at time t. $\tilde{h}_t$ is equivalent to $\log[D_t + \overline{\mathrm{R}}\mathrm{e}xp(\bar{e})] - \beta - \Omega y_t + \alpha i_t^* - p_t^* - u_t - \omega_t$, where D_t represents the domestic credit component of the monetary base. $\overline{R}$ is converted from foreign currency into domestic currency utilizing $\bar{e}$.

Here, $\tilde{h}_t$ represents the excess supply of money in the economy during a floating exchange rate regime. h_t is the excess supply of money in the economy during a fixed exchange rate regime; it is symbolic of the initial value of $\tilde{h}_t$ that would occur at time *t* if the government switched to a free floating regime at t. Theoretically, it would be important to differentiate between $\tilde{h}_t$ and h_t since h_t is dependent on a reserve limit $\overline{R}$ that can change over time whereas reserves are static in a free floating exchange rate regime. Also, $\tilde{h}_t$ is a stochastic process and the other variables that enter into $\tilde{h}_t$ may change in a fixed rate regime as compared to a floating rate regime. However, we assume that the $\tilde{h}_t$ and h_t processes are driven by the same stochastic processes since $\tilde{h}_t$ cannot be observed.

After the money demand parameters are estimated, the h_t process is computed using time series techniques. It is necessary to estimate the excess supply of money in the economy because the term of interest is the error term, v_t, of the time series regressions. The error term, v_t, can represent shocks to the excess supply of money in the economy between periods. If a shock is very large, the probability of devaluation increases. In the computation of the h_t process, the initial assumption is that $\overline{R} = 0$. However, $\overline{R}$ will be adjusted after each iteration to more closely reflect what the actual value of $\overline{R}$ should be. The h_t process is determined by regressing h_t on several lags of itself in both levels and first differences in order to determine which regression gives the most significant estimates for the coefficients. The h_t process will follow the general form below:

$$h_t = \theta_1 + \sum_{j=0}^{N} \theta_{2+j} h_{t-(1+j)} + v_t \tag{5}$$

In the next step, the residuals or the error terms (v_t) from the regression are calculated. After that, substituting equation (5) into equation (4) and then applying the method of undetermined coefficients to guess $\tilde{e}_t$, one can obtain an equation for the shadow flexible exchange rate. Because we are utilizing stochastic principles in a stationary environment, it is possible to assume that the policy rule will be a linear function. A more accurate approach would be to optimize a government function over the range of possible exchange rates. However, Blanco & Garber find that a closed form solution cannot be obtained even when only three policy rules are imposed. Therefore, the new fixed exchange rate can be modeled as the following:

$$\hat{e}_t = \tilde{e}_t + \delta v_t \tag{6}$$

where δ is a nonnegative parameter. δ is a non-negative term that represents the scaling factor for the noise term (δv_t), which represents how much shocks contribute to $\hat{e}_t$. δ is a non-negative term in order to form a viable policy rule. If v_t were negative, $\hat{e}_t$ would be less than $\tilde{e}_t$. Theoretically this would mean that reserves are at their minimum and setting the new exchange rate lower than $\tilde{e}_t$ (which is associated with $\overline{R}$ since net foreign reserves do not change in a permanent floating situation) would increase the demand for reserves and the government would not be able to satisfy the demand for reserves. Therefore, this would mean that $\hat{e}_{t-1}$ was greater than $\tilde{e}_t$ and so a devaluation occurred in period *t-1*. Thus, only when $v_t > 0$ can a devaluation occur based on the model.

The probability of a speculative attack is based on the probability that $\hat{e}_{t+1} > \bar{e}$. Substituting the shadow floating rate equation into equation (6) and plugging in $\hat{e}_t$ into $\Pr(\hat{e}_{t+1} > \bar{e})$, one can rearrange the equation in terms of v_{t+1}. Thus, a probability of devaluation can be obtained that is similar to the following:

$$Pr(\hat{e}_{t+1} > \bar{e}) = Pr(v_{t+1} > k_t) = 1 - F(k_t) \tag{7}$$

Where F(.) is a cumulative distribution function for v.

Knowing this probability density, expectations can be predicted for future exchange rate based on the following equation (Blanco & Garber 1986):

$$E(e_{t+1}) = F(k_t)\,\bar{e} + [1 - F(k_t)]E(\hat{e}_{t+1}|v_{t+1}>k_t) \tag{8}$$

One can substitute equation (7) into $E(\hat{e}_{t+1}|v_{t+1}>k_t)$ to find an equation in terms of μ, θ, δ, α, h_t, and $E(v_{t+1}|v_{t+1}>k_t)$, where $E(v_{t+1}|v_{t+1}>k_t) = \int_{k_t}^{\infty} \frac{vg(v)dv}{1-F(k_t)}$. Therefore, since v is normally distributed with zero mean and standard deviation, σ, the unconditional forecast of the exchange rate in the next period can be solved for.

Based on this model, the probability of a devaluation $(1- F(k_t))$ increases drastically a period before the devaluation. Additionally, the unconditional forecast estimates should have similar values to the forward exchange rate. The density function, g(v), can then be utilized to determine the confidence intervals for the unconditional forecasts. Previously, the unknown money demand parameters have already been estimated. From these parameters, the h_t series is calculated ignoring the unknown disturbance parameter. Putting it all together, $\overline{R}$ and δ can be re-estimated using equation (12). Lastly, one can use the forward rate equation, $f_t = E_te_{t+1} + \varepsilon_t$, where ε_t is a disturbance or the error term, f_t is the forward rate, and E_te_{t+1} is the expected exchange rate in the next period, to continue the re-estimation process. The goal is to minimize ε_t and make it well-behaved. This process is completed in order to optimize the estimated forward expected exchange rate in the next period. After this process occurs, a shadow exchange rate, $\hat{e}_t$, for each period t can be determined based on an optimal $\overline{R}$ and δ.

IV. Case Study Results

In this section, the data that is collected specifically for Indonesia and Korea in order to estimate the model's parameters is presented in section a. Afterwards, the Blanco & Garber model are applied to Indonesia and Korea in sections b. and c., respectively, and the results are analyzed accordingly.

a. Data

In order to analyze the fixed rate regimes in the context of the Blanco & Garber model, it is necessary to gather key financial variables. Relevant data collected for Korea and Indonesia from the IFS database include the following variables: domestic credit, money, consumer price index (CPI), deposit rates, lending rates, GDP deflator, total reserves minus gold, gold, and GDP. The CPI All Items City Average (foreign prices) and 3 month certificate of deposit interest rates (foreign interest rates) were obtained from the IFS database for the United States from 1957Q1 to 2007Q4. Equation (1) utilizes the following financial variables: money, the consumer price index, deposit rates or lending rates, and the GDP. The excess supply of money in the economy under a floating regime (Equation (4)) utilizes the following financial variables: domestic credit, total reserves, foreign interest rate, foreign prices, and the fixed exchange rate.

Annual Gross Domestic Product volume indices based on a standard 2000 reference year are available from 1958 in Indonesia and from 1952 in Korea. However, Quarterly Gross Domestic Product (GDP) figures are only available from the first quarter of 1997 for Indonesia and from the first quarter of 1960 for Korea. In order to increase the time span over which quarterly GDP figures are available and thus increase the time period over which estimated probabilities of currency devaluations can be calculated, it is necessary to interpolate quarterly GDP time series from annual GDP data. The "denton" module within the statistical program, Stata, can be utilized for this purpose. This module interpolates a quarterly flow series from annual data using the proportional Denton method (Denton, 1971). Ginsburgh (1973) also described four more complicated methods to arrive at a quarterly flow series from annual totals. The original Blanco and Garber (1986) model employs the Ginsburgh method to arrive at quarterly flow series from annual totals. For Indonesia, the interpolated quarterly GDP volume index utilizing the Denton method is plotted along with the quarterly GDP volume indices based on data from the IFS database from 1997Q1 to 2006Q4. The resulting figure is presented below in Figure 5. Additionally, the Denton quarterly GDP volume index is plotted along with the annual GDP volume indices obtained from the IFS databases from 1961Q1 to 2006Q4 in Figure 6.

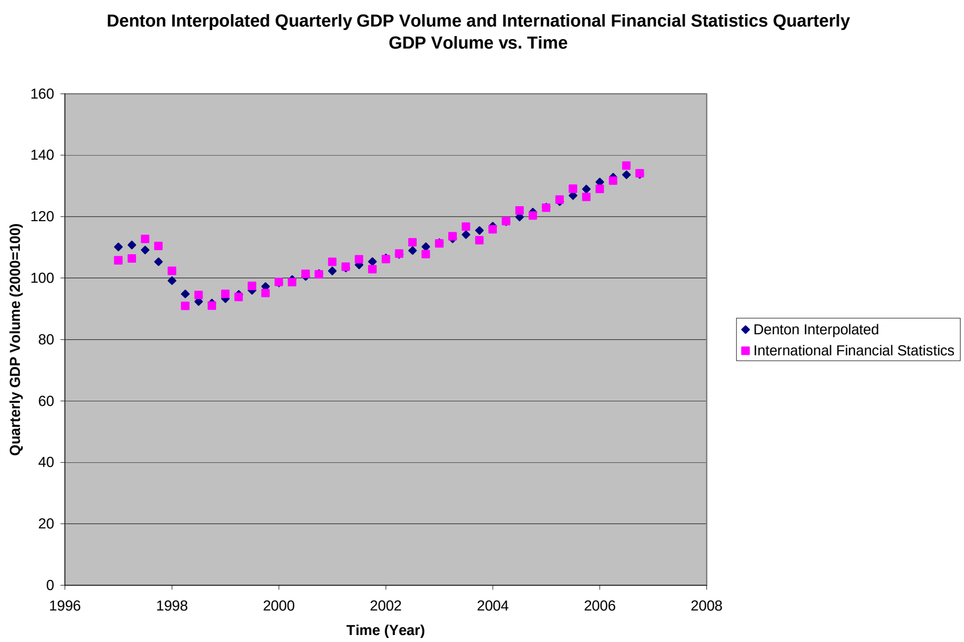

Figure 5: Denton Interpolated and IFS Quarterly GDP Volumes vs. Time

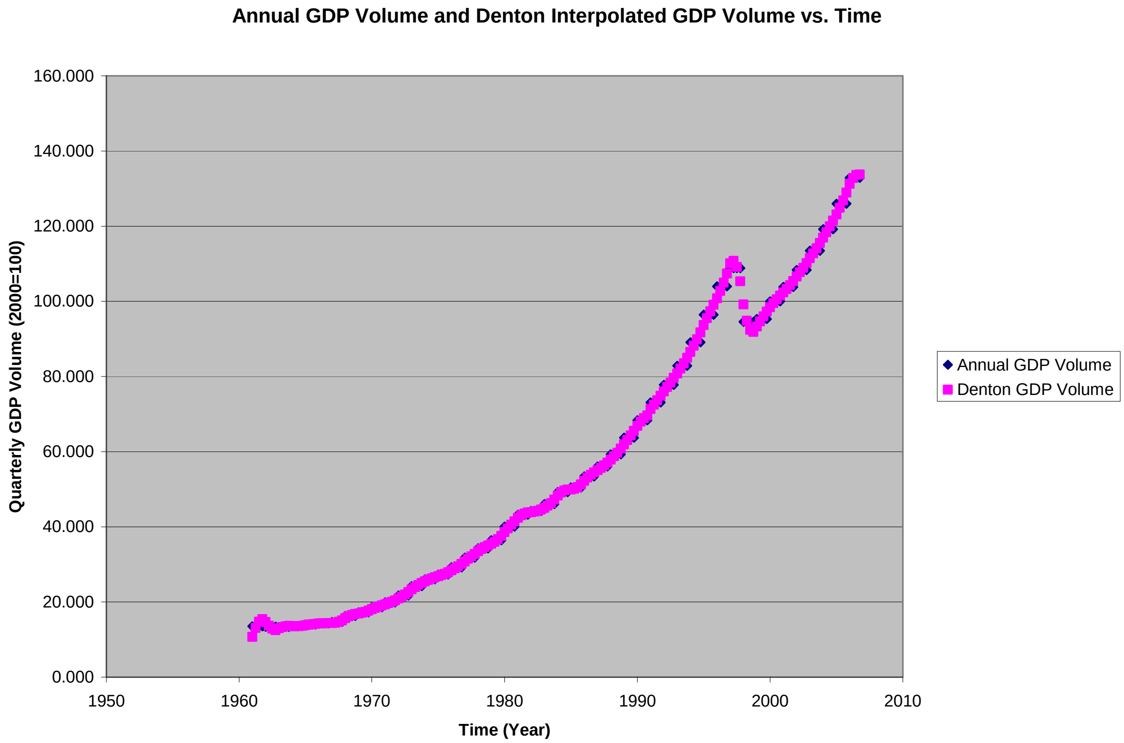

Figure 6: Denton Interpolated and IFS Annual GDP Volumes vs. Time

Based on available data, there was difficulty finding interest rates that were as historic as the other variables utilized in the model. From the IFS database, time dependent deposit money bank (DMB) rates (1 year or more) for Korea are only available from the first quarter of 1969 and lending rates on DMB loans are only available from the third quarter of 1980. However, for Korea, DMB rates were found in an alternative source from the 1961 to 1987 (Edwards and Frankel, 2002, 619-622). During this time, DMB rates were controlled by the Korean government (Edwards and Frankel, 2002, 619-622). In 1984, the deposit money banks in Korea consisted of the following: seven nationwide commercial banks, ten local banks and forty-two branches of foreign banks as well as six special banks whose aims were to carry out the goals of government policies (Park, 1984). For Indonesia, from the IFS database, working capital loan rates are available from the first quarter of 1986 and three month deposit rates are available from the second quarter of 1974.

One of the main data issues is the lack of forward exchange rate data in Korea and Indonesia during the fixed exchange rate periods as a comparator for expected exchange rates in the next period. The forward exchange rate market was formally established in Korea on July 1, 1980 for exchange between the Korean Won and the U.S. Dollar, the Pound Sterling, the Deutsche Mark, and the Japanese Yen (International Monetary Fund, 1981, 251 and 253). For Indonesia, no formal forward market was in existence as of 1989 (Price Waterhouse, 1990). However, starting in the 1970's, foreign exchange banks and nonfinancial institutions were able to conduct swap transactions (IMF, 1980, 202). Additionally, the most historic forward exchange rate data obtained from DataStream for the WM Reuters forward rates only starts in 1996 for both Indonesia and Korea. Thus, as opposed to forward rates available for Mexico in the Blanco and Garber paper, for Korea and Indonesia, there are no good proxies for next-quarter exchange rate expectations. As a result, I propose to use the end-of-quarter rate exchange rate in period *t+1* as a proxy for the forward exchange rate.

b. Indonesia

For Indonesia, equation (1) was estimated utilizing data available from the IMF's IFS database. In equation (1), the $-\alpha i_t$ term represents the opportunity cost of holding money where α is the interest rate semielasticity. There are various ways to capture the opportunity cost of holding money. Regressions were run with the opportunity cost of holding money measured by the following: interest rates for 3 month deposits, inflation rates from the CPI, and rate of currency depreciation. The objective in running regressions with inflation rates and depreciation rate as the opportunity cost variable is to avoid the possibility of spurious correlations because interest rate data will be utilized later in the model to generate a time series for the forward exchange rate. Moreover, another concern is that the interest rates for bank liabilities were controlled by the Indonesian government for a significant portion of the fixed exchange rate period (up to the second quarter of 1985) and thus the deposit rate does not represent the market opportunity cost of holding money until the third quarter of 1985.

Regressions were estimated for the following time periods: from the second quarter of 1974 to the fourth quarter of 2006; from the second quarter of 1974 to the third quarter of 1997 (pegged period, multiple currency basket peg period, and managed floating period); from the fourth quarter of 1997 to the fourth quarter of 2006 (floating period). Due to data limitations, Indonesian 3-month deposit interest rates were only available starting in the second quarter of 1974 and were not available for the first and second quarter of 1986. As a result, regressions generated for data in the fixed exchange rate period start in the second quarter of 1974 and regressions generated using Indonesian three month deposit rates as the interest rate term in equation (1) exclude the first and second quarter of 1986.

Based on the results, only regressions that were generated with the three-month deposit rate had negative estimates of the interest rate semielasticity. These regressions are the best estimates, because if α is nonnegative, it means that an increase in interest rate will cause an increase in the demand for money. This is illogical because as the opportunity cost of holding money increases, the demand for money should decrease. The reason that the regressions with inflation and depreciation did not perform well is because the actual rather than the expected rates are used. In order for the h_t series to be properly computed and for the model's assumptions to hold, it is necessary for the future to matter.

From among the regressions, the regression generated with data for the fixed exchange rate and currency basket periods and with three month deposit rates provided the best results. However, the results for other subperiods provided nearly identical results with respect to the income elasticity, Ω, and similar estimates for the semi-elasticity of interest rates, α. These results are presented in Table 3 below. The income elasticity and constant are significant at all levels while the interest rate semielasticity is significant at the 5% level. Based on previous literature, the semi-elasticity parameter is generally much higher than 0.54, especially for developed countries where the money markets are more liquid. For example, the United States post-World War II semielasticity parameter was estimated to be approximately 5 by Ball (2001). Prior to this, Lucas (1988) determined income elasticity to be around unity and the semielasticity parameter to vary between 5 and 10 for U.S. from 1958-1988. From 1900-1980 U.S. data, Stock and Watson (1993) estimated income elasticity to be around unity and the semielasticity parameter to be approximately 10. However, α that was estimated for Indonesia by James (2005) is much lower than 0.54. In the model presented by James, the real money demand is a first order lag that is a function of the log of income, domestic interest rates, foreign interest rates, and a deterministic trend term. James's data is from the first quarter of 1983 to the fourth quarter of 2004. Thus, James' estimates are different because of the difference in time periods utilized to generate the regressions. James (2005) concluded that the domestic interest rate semielasticity is 0.160 and the income elasticity is 1.526. Thus, it appears that the estimated terms generated from the regression are within the range of those found by James for Indonesia.

TABLE 3

INDONESIA ESTIMATES OF THE DEMAND FOR MONEY PARAMETERS
(1974Q2 to 1997Q3, excluding 1986Q1 and 1986Q2)

Parameter	Estimate
Ω	1.42 (.02770)
α	0.54 (.2257)
β	.634 (.0944)
R^2	0.9766

NOTE. – The numbers in parentheses are standard errors.

Based on the parameters in Table 3, the excess supply of money for a fixed exchange rate regime, h_t ($\log[D_t + \overline{\mathrm{R}}\mathrm{e}\,xp(\bar{e})] - \beta - \Omega y_t + \alpha i_t^* - p_t^* - u_t - \omega_t$), was calculated for three different time periods: the fixed period, the fixed and multiple currency basket peg period, and for the total period (fixed and floating). The initial guess for $\overline{R}$ was 0 based on the assumption that once the level of foreign reserves hits 0, the government will not borrow from other governments. Afterwards, h_t was regressed as several lags of itself in both levels and first differences to determine which regression gave the most significant estimates for the coefficients. From this, it was determined that a first order autoregressive process provided below is the best fit:

$$h_t = \theta_1 + \theta_2 h_{t-1} + v_t \qquad (9)$$

Then, the regressions were run without the foreign interest rate term (αi_t^*) to determine if the coefficients were significantly different from regressions where the foreign interest term was included. The reason these additional regressions were run was because it is uncertain how liquid the exchange rate is between the Indonesian Rupiah and the U.S. Dollar and thus, it is possible that the foreign interest rate term does not represent the opportunity cost of holding money. The estimates from both regressions are presented below in Table 4. From running an F-test, one can conclude that the two θ_1's are not significantly different from each other and the two θ_2's are also not significantly different from each other. Thus, the foreign interest rate term can be excluded.

TABLE 4

INDONESIA ESTIMATES OF THE h_t PARAMETERS

$h_t = \theta_1 + \theta_2 * h_{t-1} + v_t$

(1969Q3 to 1978Q3)

Parameter	Estimate
WITH αi_t^*	
θ_1	-.0623
	(.0615)
θ_2	.9329
	(.0346)
R^2	0.9456
σ_v	.1104
WITHOUT αi_t^*	
θ_1	-.0658
	(.0631)
θ_2	.9323
	(.0348)
R^2	0.9452
σ_v	.1110

NOTE. – The numbers in parentheses are standard errors.

In the next step, the residuals or the error terms (v_t) from the regression presented in Table 4 are calculated. After that, utilizing equation (9) and substituting into equation (4) and then applying the method of undetermined coefficients to guess $\tilde{e}_t$, one can obtain an equation for the shadow flexible exchange rate which is the following:

$$\tilde{e}_t = \mu\alpha\theta_1 + \mu h_t \qquad (10)$$

where $\mu=1/[(1+\alpha) - \alpha\,\theta_2]$. Because we are utilizing stochastic principles in a stationary environment, it is possible to assume that the policy rule will be a linear function as laid out in Equation 6. δ was initially estimated by running the regression $\hat{e}_t - \tilde{e}_t = \delta v_t$. The results are presented in Table 5 below. Based on the results, it appears that another method must be found for estimating the δ parameter as it is not significant at any level in the regression. Since the method of estimation for δ ultimately failed, the initial guess for δ was derived from the Blanco and Garber paper as δ = 1.956.

TABLE 5

INDONESIA ESTIMATES OF THE *δ* PARAMETERS

$\hat{e}_t - \tilde{e}_t = \delta v_t$

(1969Q3 to 1978Q3)

Parameter	Estimate
δ	.0294 (.6409)
Constant	4.061 (.0745)
R^2	0

NOTE. – The numbers in parentheses are standard errors.

For Indonesia, the probability of devaluation follows Equation 7 with k_t being equivalent to: $[1/(\mu+\delta)][\bar{e} - \mu\alpha\theta_1 - \mu(\theta_1 + \theta_2 h_t)]$. Based on the data, the estimated parameters, and the initial guesses for $\overline{R}$ and δ, it appears that the probability of a devaluation is zero for the estimations during the fixed exchange rate period (1969Q3 to 1978Q3). However, this may be due to the initial guesses for $\overline{R}$ and δ not being in the range of convergence.

Furthermore, based on Equation 8, the unconditional forecast of the exchange rate in the next period can be solved for. This is the following for Indonesia:

$$Ee_{t+1} = F(k_t)\,\bar{e} + [1-F(k_t)][\,\mu\theta_1(1+\alpha) + \mu\theta_2 h_t] + (\mu+\delta)\frac{\sigma(\mu+\delta)\exp[-.5(k_t/\sigma)^2]}{\sqrt{2\pi}} \quad (11)$$

In this situation, the expectations for future exchange rate are the fixed exchange rate since the probabilities of a devaluation are nearly 0 for the fixed and multiple currency basket periods.

Based on the Blanco and Garber model, different values for $\overline{R}$ and δ are estimated in order to minimize the stochastic disturbance (error) in the forward rate equation, $f_t = E_t e_{t+1} + \varepsilon_t$. This can be accomplished through the following two methods: 1) writing a computer program to estimate $\overline{R}$ and δ conditional on minimizing error through multiple iterations or 2) utilizing a grid search repeatedly to minimize the error, increasing the resolution of the grid each time. Initially, a computer program was written in Matlab that utilized matrices and optimization to solve for minimum reserve levels, $\overline{R}$, and the non-negative parameter, δ. However, many issues were encountered with debugging and treatment of singular matrices. Thus, as an alternative, the grid search was implemented. Sets of $\overline{R}$ and δ values were selected and for each possible pair of $\overline{R}$ and δ, the expected exchange rate in the next time period, $E_t e_{t+1}$, was estimated. Without a previous data set to utilize, $\overline{R}$ and δ values were picked arbitrarily based on estimates from the Blanco and Garber research on the Mexican peso published in 1986 and based on domestic credit in the Indonesian economy. The $\overline{R}$ values selected included the following values: -$50 billion, $-25 billion, $0 billion, $25 billion, and $50 billion while the δ values included the following values: 1.956, 5, 10, and 15. A total of 20 possible pairs were generated from the sets of $\overline{R}$ and δ values. In Table 6, the error terms, ε_t, from the forward equation are presented for the 20 combinations of $\overline{R}$ and δ. The error terms were calculated by estimating the expected exchange rate in the next period, Ee_{t+1}, and subtracting it from the proxy for forward exchange rates, $\overline{e}_{t+1}$. As can be seen from Table 6, the combination that generated the smallest error term was $\overline{R}$ = $0 billion and δ = 10. However, the error is still fairly large (277313.3). Afterwards, three more successive grids with better resolution were applied until $\overline{R}$ and δ could be approximated to three significant digits. It was determined that the optimal $\overline{R}$ is $0.00 billion and δ is approximately 11.5; the error term for this optimization is 263936.8.

From the estimated values of $\overline{R}$ and δ, one can calculate the probability of a devaluation occurring in the period *t+1* based on Equation 7. These probabilities are plotted along with a scaled version of exchange rate (exchange rate/100,000) versus time in Figure 7 in order to be able to see when devaluations occur and whether or not the probabilities spike before the occurrence of a devaluation. The maximum probability of a devaluation for the optimized conditions is approximately .9% at the first quarter of 1977. Thus, the probabilities are rather small as compared to Blanco and Garber's results where maximum probabilities of devaluations occurring in the next period is 29.4%. Additionally, as one can see in Figure 7, the maximum probability of a devaluation (1977Q1) does not occur right before a major devaluation. Moreover, before the largest devaluation of the time period (November 1978), the probability of a devaluation in the next period actually decreases. However, there is an increase in the probability of a devaluation in the periods leading up to the devaluation in the 2nd quarter of 1983 and then a decrease in the probability of a devaluation in the next period after the currency crisis occurred. Additionally, there is a small increase in the probability of a devaluation two periods before the devaluation in the 3rd quarter of 1986. Thus, since these results are promising, we go on to examine the shadow exchange rate, $\hat{e}_t$, which is solved for via Equation 6. $\tilde{e}_t$ can be determined via Equation 10. The results are presented in Table 7 in the Appendix. Unfortunately, as can be seen from the results, the estimates for the shadow exchange rate are very low and as a result, $\hat{e}_t$ never exceeds $\bar{e}$. As compared to Blanco and Garber's results for Mexico where $\hat{e}_t$ was of the same magnitude as $\bar{e}$, in the results for Indonesia, $\hat{e}_t$ is on the order of 100 to 10^{-7} times smaller than $\bar{e}$. Additionally, one notices that the shadow exchange rate, $\hat{e}_t$, tends to follow the probability of a devaluation in the next period. On closer examination, by adjusting the value of h_t to be more positive, one can achieve better estimates for the shadow exchange rate, $\hat{e}_t$. Thus, the largest problem lies in the modeling of the excess supply of money in the economy and perhaps a modified version of the model can account for this in the future.

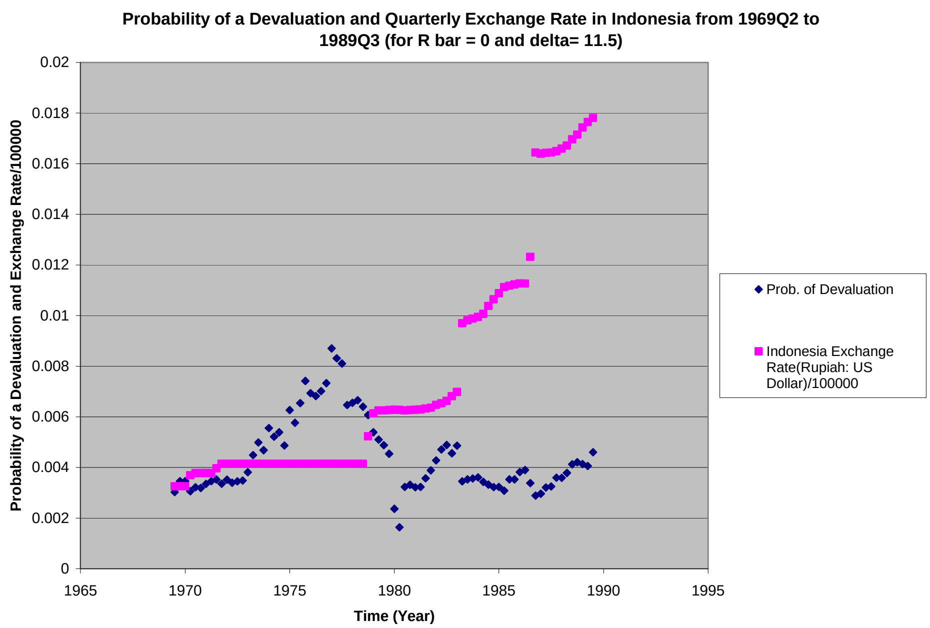

Figure 7: Indonesian Scaled Exchange Rate and Probability of Devaluation versus Time

TABLE 6 INDONESIA LEAST SQUARES ERROR ESTIMATES FOR $\varepsilon_t = f_t - Ee_{t+1}$					
	$\overline{R}$ =-$50	$\overline{R}$ = -$25	$\overline{R}$ = $0	$\overline{R}$ =$25	$\overline{R}$ =$50
δ = 1.956	284303.6	284303.6	284303.6	284303.6	284303.6
δ = 5	284303.6	284303.6	284303.5	284303.6	284303.6
δ = 10	284296.4	284297.9	277313.6	284299.9	284303.6
δ = 15	280805.6	281186.3	304558.4	281799.2	284255.8

NOTE. – The minimum reserve levels, $\overline{R}$, are denoted in billions of U.S. Dollars.

c. Korea

For Korea, the money demand equation was estimated utilizing parameters available from the IMF's IFS database and a similar process was followed with regressions for the opportunity cost of holding money being: interest rates for deposits of one year or more at the DMB, inflation rates from the CPI, and rate of currency depreciation. The interest rates for bank liabilities were controlled by the Korean government up until 1987 and thus the deposit rate does not represent the market opportunity cost of holding money for that portion of time.

Regressions were estimated for the following time periods: from the first quarter of 1970 to the fourth quarter of 2006; from the first quarter of 1970 to the first quarter of 1980 (single currency peg period); from the second quarter of 1980 to the fourth quarter of 2006 (multiple basket period, managed floating period, and floating period). Due to data limitations, Korean DMB interest rates were only available starting in the first quarter of 1970. As a result, regressions generated for data in the fixed exchange rate period start in the first quarter of 1970.

The regression generated with data for the fixed exchange rate period and with the three month deposit rates provided the best results. These results are presented in Table 6 below. The income elasticity and constant are significant at all levels while the interest rate semielasticity is significant at approximately the 10% level. Based on previous literature, the semi-elasticity parameter is in the range of 1.7 for developing countries where the money markets are less liquid. However, Cheong (2003) estimated that the domestic interest rate semi-elasticity for Korea is 3, which is much higher than the estimate of 1.7. In the model presented by Cheong, the long-run money demand is a function of income or wealth, the rate of return on assets alternative to money and the own rate of return on money. His data set spans from the second quarter of 1973 to the fourth quarter of 1997 so it is comparable to the data set used to generate the results presented in Table 8. Cheong (2003) concluded that the domestic interest rate semielasticity is 3 and the income elasticity is 1.36. Thus, it appears that the estimated terms generated from the regression are lower than those found by Cheong.

TABLE 8

KOREA ESTIMATES OF THE DEMAND FOR MONEY PARAMETERS
(1970Q1 to 1980Q1)

Parameter	Estimate
Ω	1.13 (.0770)
α	1.68 (1.005)
β	1.31 (.2953)
R^2	0.9766

NOTE. – The numbers in parentheses are standard errors.

After the money demand parameters were estimated, the excess supply of money in the economy, h_t ($\log[D_t + \overline{\mathrm{R}}\mathrm{e}\,xp(\bar{e})] - \beta - \Omega y_t + \alpha i_t^* - p_t^* - u_t - \omega_t$), was computed for different time periods. Afterwards, the h_t process was computed for Korea. From this, it was determined that the following h_t process was most appropriate:

$$h_t - h_{t-1} = \theta_1 + \theta_2 (h_{t-1} - h_{t-2}) + v_t \qquad (12)$$

Then, the regressions were run without the foreign interest rate term (αi_t^*) to determine if the coefficients were significantly different from when the foreign interest term was included in the regression. Both regressions were run with the assumption that the critical level of reserves was 0. The estimates from both regressions are presented below in Table 9.

TABLE 9

KOREA ESTIMATES OF THE h_t PARAMETERS
$h_t - h_{t-1} = \theta_1 + \theta_2 * (h_{t-1} - h_{t-2}) + v_t$
(1964Q3 to 1980Q1)

Parameter	Estimate
WITH αi_t^*	
θ_1	.0130
	(.0215)
θ_2	.3722
	(.0537)
R^2	0.1652
WITHOUT αi_t^*	
θ_1	.0131
	(.0535)
θ_2	.3670
	(.0535)
R^2	0.1605

NOTE. – The numbers in parentheses are standard errors.

For Korea, because the time series regression for the h_t processes differs from that of Indonesia, the shadow flexible exchange rate estimation is different from that of Indonesia. The residuals, v_t, are calculated for the Korea h_t process. After that, utilizing equation (12) and substituting into equation (4) and then applying the method of undetermined coefficients to guess $\tilde{e}_t$, one can obtain an equation for the shadow flexible exchange rate which is the following:

$$\tilde{e}_t = \mu[(1+\alpha)^2\theta_1 + (1+\alpha+\theta_2)h_{t-1} - (1+\alpha)\theta_2 h_{t-2} + (1+\alpha)v_{t+1}] \qquad (13)$$

Where $\mu = 1/[(1+\alpha) - \alpha\,\theta_2]$. Then, the probability of a devaluation is the probability that $\hat{e}_{t+1} > \bar{e}$. The probability of devaluation follows Equation 7 with k_t being equivalent to: $[1/(\mu(1+\alpha)+\delta)][\bar{e} - \mu(1+\alpha)^2\theta_1 - \mu(1+\alpha+\theta_2)h_t + \mu(1+\alpha)\theta_2 h_{t-1})]$. Based on Blanco and Garber's paper, the initial guess for δ was derived from the Blanco and Garber paper as δ = 1.956. However, based on all of the data, estimated parameters, and initial guess for $\overline{R}$ and δ, it appears that the probability of a devaluation is nearly zero for estimations of the entire period of estimation. As in the case of the estimation for Indonesia, this is probably a result of bad initial guesses or initial guesses that are not close to the optimal values for $\overline{R}$ and δ.

Furthermore, based on Equation 8, the unconditional forecast of the exchange rate in the next period can be solved for. This is the following for Korea:

$$Ee_{t+1} = F(k_t)\,\bar{e} + [1-F(k_t)][\mu\theta_1(1+\alpha)^2 + \mu(1+\alpha+\theta_2)h_t - \mu(1+\alpha)\,\theta_2 h_{t-1}] +$$

$$[\mu(1+\alpha)+\delta]\frac{\sigma(\mu+\delta)\exp[-.5(k_t/\sigma)^2]}{\sqrt{2\pi}} \quad (14)$$

Because the initial guess produces a devaluation probability in the next period close to 0, the expected exchange rate in the next period will be the fixed exchange rate in this period.

Once again, a grid search was employed. The $\overline{R}$ values were selected as -\$5 billion, \$0 billion, and \$5 billion while the δ values were set to 1.956, 5, 7, and 10. Each combination of $\overline{R}$ and δ was tested for a total of 12 pairs. In Table 10, the error terms (ε_t)

are presented for the 12 combinations. This is accomplished by estimating the expected exchange rate in the next period, Ee_{t+1}, and subtracting it from the proxy for forward exchange rates, $\bar{e}_{t+1}$. As one can see from Table 10, the best combination to minimize the error is $\bar{R}$ = \$0 billion and $\delta = 10$. The error however is still large. Afterwards, three more grids with better resolution were applied in order to achieve three significant figures for both $\bar{R}$ and δ. Thus, it was determined that the optimal $\bar{R}$ is \$0.500 billion and δ is 11.9.

From these conditions, one can determine the probability of a devaluation occurring in the period *t+1* based on Equation 7. The probabilities of devaluation and a scaled version of the exchange rate are plotted versus time in Figure 8 in order to be able to see if the probabilities can accurately predict the occurrence of a devaluation. Immediately, one notices that the probabilities of devaluation are fairly randomly scattered and that the probabilities tend to increase over time, which is unusual since the periods between currency devaluations are fixed and the probability of a devaluation should decrease during these periods. The maximum probability of a devaluation for the optimized conditions is approximately .34% estimated at the end of the second quarter of 1981. As compared to Blanco's and Garber's results, the probabilities are rather small although these results are comparable to those for Indonesia as discussed in the previous section. Also, the maximum probability of a devaluation (1981Q2) does not occur right before a major devaluation. However, there is an increase in the probability of a devaluation in the periods leading up to the devaluation in the 4th quarter of 1974 and then a subsequent steady decrease in the probability of a devaluation in the next periods after the currency crisis occurred. These results do not seem credible since, as stated before, the probability appears to randomly spike even when the currency is in a stable state. However, we should still look at the shadow exchange rate, $\hat{e}_t$, which is solved for via Equation 6. $\tilde{e}_t$ can be determined via Equation 13. The results will be presented in Table 11 in the Appendix.

TABLE 10 KOREA ERROR ESTIMATE LEAST SQUARE VALUES $\varepsilon_t = f_t - Ee_{t+1}$			
	$\overline{R}$ =-\$5	$\overline{R}$ = \$0	$\overline{R}$ = \$5
$\delta = 1.956$	185120	26195.28	26195.28
$\delta = 5$	910462.3	26195.28	26195.25
$\delta = 7$	1838109	26156.41	26176.34
$\delta = 10$	3162734	24808.92	25353.21

NOTE. – The minimum reserve levels, $\overline{R}$, are denoted in billions of U.S. Dollars.

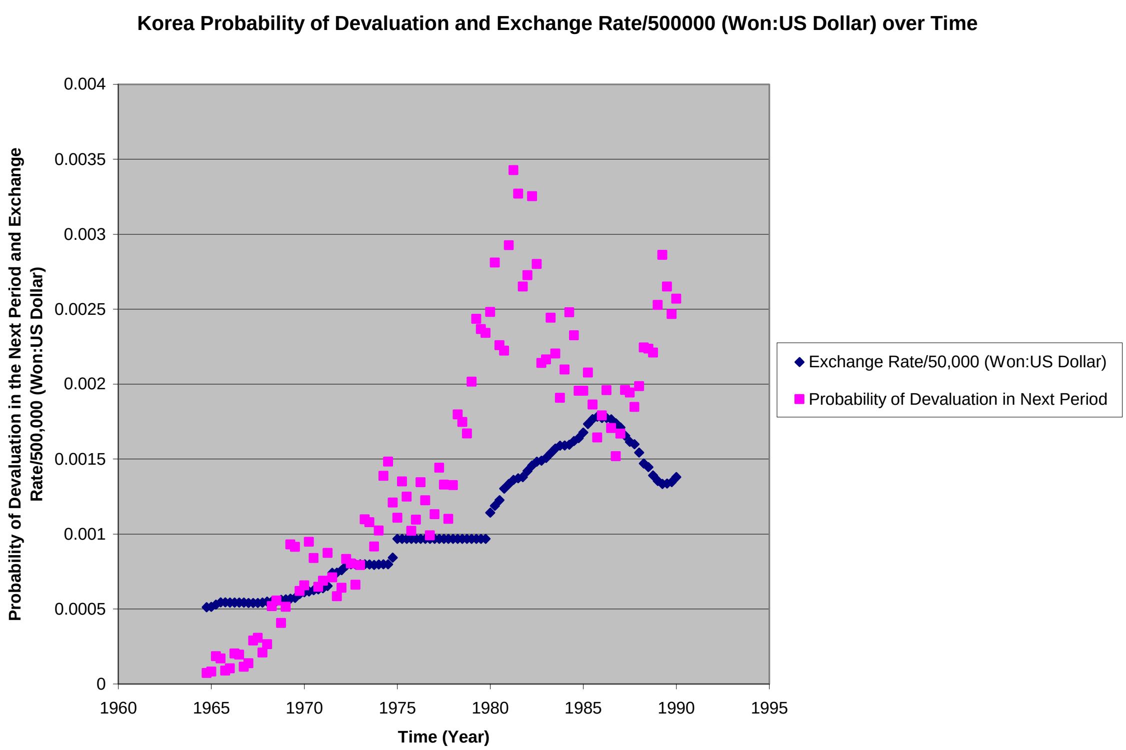

Figure 8: Korean Scaled Exchange Rate and Probability of Devaluation versus Time

V. Conclusion and Future Studies

The purpose of this paper was to analyze the fixed and multiple currency basket exchange rate systems for Korea and Indonesia utilizing the Blanco and Garber model in order to predict the probability, timing, and magnitude of a speculative attack one period ahead.

The current results are not promising. The probabilities of currency devaluation are less than 0.9% and 3.5% for Indonesia and Korea, respectively. Thus, for all intents and purposes, it appears that the probabilities of a devaluation are zero. However, for Indonesia, the probabilities of devaluation peak before actual devaluations. For Korea, the probabilities of devaluation appear to be more random and scattered, peaking even when no devaluation occurred in the next period. The probabilities of currency devaluation are small because the shadow exchange rates for the next period, $\hat{e}_{t+1}$, are very low. Possible reasons for this problem are discussed below. As a result of the low probabilities of devaluation, the calculated expected exchange rate in the next period (Ee_{t+1}) is very close to the official fixed exchange rate ($\bar{e}$) because the expected exchange rate in the next period is heavily weighted towards the current official exchange rate.

There are several reasons for why the Blanco and Garber model may not extend to Korea and Indonesia as modeled in this paper. Firstly, Blanco and Garber look at a relatively small fixed exchange rate period whereas the time periods examined in this paper extend over a longer time span and also include multiple currency basket pegs. In examining a longer time period, it is likely an unreasonable assumption that $\overline{R}$ remains static. Indeed, as the needs of the government shift and the money market variables adjust to exogenous forces, $\overline{R}$, should change accordingly. A potential solution to the problem would be to examine one or two large devaluations at a time for Indonesia and Korea so that $\overline{R}$ is more likely to remain constant during the time period examined. Moreover, as stated previously, a crawling peg was adopted by the South Korean government from 1965 to 1979. Perhaps a more appropriate method for modeling the exchange rate devaluations during this time would be to follow a variation of the model derived by Cumby and van Wijnbergen.

Additionally, another issue surrounds the estimation of h_t. One immediate concern was the available data from the IFS database. Whereas interpolated quarterly GDP in real terms was utilized by Blanco and Garber in modeling speculative attacks on the Mexican Peso (Blanco & Garber, 1986), in this paper, quarterly GDP volume and interpolated GDP volume were utilized for Korea and Indonesia, respectively. However, at issue is a larger problem that Blanco and Garber point out in their 1986 paper. The Blanco and Garber model does not differentiate between excess supply of money under a fixed exchange rate regime, h_t, and the excess supply of money under a floating exchange rate regime, $\widetilde{h}_t$. Indeed, if $\overline{R}$ changes during the fixed rate regime, h_t will change whereas in a floating system, reserve levels would not change. Moreover, domestic credit, D_t, and other variables may react differently under a fixed rate regime as compared to a permanent float. Additionally, in the Blanco and Garber model, the h_t process and domestic credit are assumed to be exogenous variables. A solution to this potential problem could be to add a feedback relation between the exchange rate and the h_t process.

Another area for improvement is the current estimation of the forward rate. At present, the forward rate is estimated as the official exchange rate in period t+1 for both Korea and Indonesia because the forex markets were not established until 1980 for Korea and the 1990s for Indonesia. This poses a problem because forward rates represent expectations for exchange rates in the next period, aligning with the Blanco and Garber model where decisions made by speculators are predicated on probabilities of collapse and manifested in supply and demand in the forward exchange rate market. The official exchange rate does not reflect expectations and is set by the central bank. A better estimation would be to utilize the black market rates published by Pick from the 1960s, substituting the black market exchange rates in t+1 as proxies for the forward rates.

Overall, it can be concluded that based on the results, the Blanco and Garber model can marginally predict a currency devaluation for a fixed currency and multiple currency basket peg for Indonesia and perhaps for Korea. However, the model is not effective in predicting the new exchange rate when a devaluation does occur nor is it good at predicting the expectations for exchange rates in the next period. Although I suspect this has to do with the estimation of h_t and the h_t process, the problem needs to be examined more in depth in future analysis.

VI. References and Further Readings

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VII. Appendix 1. Tables

TABLE 7 INDONESIA FIXED EXCHANGE RATE AND SHADOW EXCHANGE RATE 1969Q3 to 1989Q3		
Time	$\bar{e}$	$\hat{\mathbf{e}}_t$
Q3 1969	326	0.095925
Q3 1969	326	0.095925
Q4 1969	326	0.199937
Q1 1970	326	0.03786
Q2 1970	326	0.037175
Q3 1970	369.333	0.103535
Q4 1970	378	0.039161
Q1 1971	378	0.088433
Q2 1971	378	0.073844
Q3 1971	378	0.130225
Q4 1971	396.5	0.053776
Q1 1972	415	0.111559
Q2 1972	415	0.037733
Q3 1972	415	0.073934
Q4 1972	415	0.069274
Q1 1973	415	0.228134
Q2 1973	415	0.84626
Q3 1973	415	0.510511
Q4 1973	415	0.04939
Q1 1974	415	1.54563
Q2 1974	415	0.063061
Q3 1974	415	0.235766
Q4 1974	415	0.032353
Q1 1975	415	5.946812
Q2 1975	415	0.058499
Q3 1975	415	1.25227
Q4 1975	415	1.693543
Q1 1976	415	0.106469
Q2 1976	415	0.203159
Q3 1976	415	0.398615
Q4 1976	415	0.543846
Q1 1977	415	4.684323
Q2 1977	415	0.21167
Q3 1977	415	0.26303
Q4 1977	415	0.010429
Q1 1978	415	0.279812
Q2 1978	415	0.298276
Q3 1978	415	0.132537
Q4 1978	415	2.421445

Q1 1979	523.182	0.457252
Q2 1979	614.32	0.180863
Q3 1979	625.376	0.155016
Q4 1979	625.59	0.095681
Q1 1980	626.936	1.85E-05
Q2 1980	628.36	0.000384
Q3 1980	627.199	420.8518
Q4 1980	625.738	0.172104
Q1 1981	626.679	0.083731
Q2 1981	628.336	0.125005
Q3 1981	629.728	0.558675
Q4 1981	633.081	0.53841
Q1 1982	635.883	0.937913
Q2 1982	647.336	1.069042
Q3 1982	653.595	0.598961
Q4 1982	662.875	0.160084
Q1 1983	681.877	1.026661
Q2 1983	698.188	0.194433
Q3 1983	969.722	0.513149
Q4 1983	981.295	0.422536
Q1 1984	987.853	0.462217
Q2 1984	994.566	0.202485
Q3 1984	1006.54	0.324214
Q4 1984	1038.36	0.299098
Q1 1985	1064.32	0.454384
Q2 1985	1088.58	0.231066
Q3 1985	1112.16	2.581068
Q4 1985	1118.69	0.449427
Q1 1986	1122.89	1.445177
Q2 1986	1127.02	0.704475
Q3 1986	1126.72	0.229275
Q4 1986	1232.38	2.708174
Q1 1987	1644.12	0.8285
Q2 1987	1639.25	2.063273
Q3 1987	1642.87	0.924056
Q4 1987	1643.88	3.500148
Q1 1988	1649.4	1.008516
Q2 1988	1659.82	2.323976
Q3 1988	1671.47	4.725666
Q4 1988	1696.38	2.079716
Q1 1989	1715.14	1.365919
Q2 1989	1743.06	1.275674
Q3 1989	1764.29	10.25639

TABLE 11
KOREA FIXED EXCHANGE RATE AND SHADOW EXCHANGE RATE
1964Q4 to 1990Q1

Time	$\bar{e}$	$\hat{\mathbf{e}}_{\mathbf{t}}$
Q4 1964	255.770	0.000102
Q1 1965	257.343	4737.281
Q2 1965	264.460	0.001328
Q3 1965	271.963	1.72E-05
Q4 1965	271.837	0.000272
Q1 1966	271.730	533.5785
Q2 1966	271.260	0.001112
Q3 1966	271.180	8.12E-05
Q4 1966	271.180	0.000459
Q1 1967	270.047	1623.061
Q2 1967	270.093	0.006489
Q3 1967	270.270	0.000454
Q4 1967	271.657	0.003603
Q1 1968	274.617	1240.382
Q2 1968	274.760	0.011765
Q3 1968	276.077	0.001654
Q4 1968	281.127	0.00833
Q1 1969	282.123	851.9024
Q2 1969	284.123	0.008106
Q3 1969	286.870	0.000749
Q4 1969	299.527	0.002818
Q1 1970	305.780	28.12403
Q2 1970	308.793	0.002277
Q3 1970	312.447	0.001299
Q4 1970	315.203	0.00676
Q1 1971	319.520	3.231868
Q2 1971	327.027	0.007565
Q3 1971	370.800	0.002902
Q4 1971	371.243	0.015353
Q1 1972	379.463	6.197681
Q2 1972	394.327	0.012403
Q3 1972	399.083	0.002745
Q4 1972	398.703	0.039846
Q1 1973	398.873	11.26649
Q2 1973	398.897	0.013415
Q3 1973	398.363	0.005104
Q4 1973	397.153	0.0237
Q1 1974	398.237	7.817237
Q2 1974	398.987	0.061169
Q3 1974	399.000	0.011702
Q4 1974	421.667	0.026358

Q1 1975	484.000	2.488665
Q2 1975	484.000	0.006775
Q3 1975	484.000	0.003969
Q4 1975	484.000	0.016256
Q1 1976	484.000	2.556748
Q2 1976	484.000	0.006233
Q3 1976	484.000	0.002903
Q4 1976	484.000	0.038094
Q1 1977	484.000	5.261766
Q2 1977	484.000	0.007415
Q3 1977	484.000	0.004267
Q4 1977	484.000	0.084396
Q1 1978	484.000	17.62589
Q2 1978	484.000	0.019045
Q3 1978	484.000	0.0354
Q4 1978	484.000	0.246805
Q1 1979	484.000	3.327697
Q2 1979	484.000	0.021818
Q3 1979	484.000	0.072357
Q4 1979	484.000	1.099095
Q1 1980	571.010	5.920275
Q2 1980	594.067	0.002659
Q3 1980	613.333	0.132753
Q4 1980	651.320	6.018188
Q1 1981	667.173	4.471695
Q2 1981	680.950	0.046321
Q3 1981	685.890	0.007028
Q4 1981	690.100	0.049874
Q1 1982	710.073	8.133339
Q2 1982	728.277	0.012961
Q3 1982	741.300	0.002001
Q4 1982	744.687	0.030896
Q1 1983	753.430	2.192463
Q2 1983	769.540	0.020403
Q3 1983	785.247	0.015839
Q4 1983	794.777	0.116175
Q1 1984	795.727	2.931087
Q2 1984	798.173	0.039252
Q3 1984	810.517	0.01157
Q4 1984	819.487	0.042576
Q1 1985	838.723	0.992832
Q2 1985	867.043	0.017575
Q3 1985	882.947	0.020009
Q4 1985	891.367	0.099292
Q1 1986	887.083	0.831787

Q2 1986	887.050	0.007339
Q3 1986	882.180	0.010773
Q4 1986	869.503	0.098064
Q1 1987	855.687	0.888568
Q2 1987	827.797	0.036528
Q3 1987	807.543	0.034532
Q4 1987	799.243	0.069106
Q1 1988	771.463	0.291046
Q2 1988	735.643	0.04731
Q3 1988	722.973	0.036066
Q4 1988	695.793	0.179796
Q1 1989	677.460	0.878093
Q2 1989	666.877	0.02326
Q3 1989	668.563	0.031686
Q4 1989	672.923	0.151194
Q1 1990	690.367	0.432609