The Likelihood of Collapse

- Modern Chinese Economy and the Financial Crisis

By

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Abstract:

This thesis aims to forecast the likelihood for Chinese economy to experience a currency crisis in the near future. The thesis discusses the development of the theoretical models (four generations) and several mainstream empirical models. In addition, the modified KLR Signal model is used for forecasting. The main modification is to use the cumulative density function to replace the "Signal" mechanism in the original KLR model. The estimation show that Chinese economy has a moderate likelihood to face a currency crisis and the Chinese government should focus on releasing the debt pressure in order to turn the condition better.

Key words:

Leading Indicators, KLR signal model, Currency Crisis Forecast, Chinese Economy

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1 Introduction and Motivation

Ever since financial activities started taking place in human history, the crisis has become an endless topic: from the tulip mania (1637) to the credit crisis (1772), from the great depression (1929-39) to black Monday (1987), from the Asian Crisis (1997) to the Subprime Crisis (2008) over and over again it appears.

Madhani (2010) in his study on the business cycle theory mentions both the downward and upward movement in Gross Domestic Product (GDP) are expected around its long-term growth trend. However, knowing this does not seem to help us in protecting ourselves. The above examples have already shown us that the economic contractions can easily become a disaster engulfing human feats. This paper focuses on finding mechanisms to foresee any signals or hints that the economic world gives us about the crisis, specifically on a currency crisis so we can build up defense before the storm or at least slow it down.

Among different kinds of crises such as a banking crisis, currency crisis, foreign debt crisis and systematic financial crisis, I focus on the currency crisis, not only because it has a relatively more mature theoretical framework but also because recently, we suffered from it the most: Germany/UK (1992), Mexico (1994), Asian (1997), Russia (1998) and Argentina (2002). All these crises had a significant impact on the countries/regions and

this is just about one decade after the early 90s. More importantly, Reinhart and Kaminsky (1996) believes a currency crisis increases the probability of a banking crisis or a default crisis. Based on historical experience Reinhart (2002) also points out once the currency crisis occurs for an emerging economy, a systematic financial crisis is not far away. Therefore, it is fair to say the currency crisis is more like a warm-up for a bigger crisis.

On the other side, Chinese market is a very good example of an emerging market. It is also becoming a powerful entity in the world. Its strong economic performance is especially impressive. Economists had made many forecasts about its future economic performance which include the possibility of going through a severe Financial Crisis in the future. I am also interested in this. Because if you look at this entity: based on IMF Report for China (2018), its GDP per capita is over $8600 as of 2017; it ranks the second in nominal GDP and first in GDP (PPP); in China NBS (2018) database I find the GDP growth rate in China has been above 6.7% ever since 1992. Furthermore, based on the data in the World Bank Labor Force Report (2016) China has the world's biggest population of over 1.3Bn and the world's largest working force of 803.6MM. Based on these publicly available numbers, it is hard to imagine what it would be like for the Chinese economy to crash.

China's economy changed a lot in the recent 50 years. Loren and Rawski (2008) think China used to be a closed economy with low technology, low productivity, limited capital and huge amount of labor. Starting from 1978, impacted by the Chinese economic reform,

Hunt (2003) finds China started to open its market to foreign investments and permitted entrepreneurs to start businesses and this is an obvious sign of privatization and globalization. In 2001, joining the WTO was believed to be another turning point for the Chinese economy by Branstetter and Lardy (2006). They mention that China tried to import high tech products and export its advantages of cheap, massive labor force to the rest of the world. Therefore, if we assume decades ago that Chinese government can still take a dominant role using monetary and fiscal policy to control the economic situations domestically. It is hardly possible to replicate this strategy within the globalization environment today. Given such a rapid change in recent decades and combining the business cycle theory, it is natural to think of the possibility for China to experience a currency crisis. This paper seeks to understand whether there is going to be a crash or a soft landing for the Chinese economy. More specifically, in the near future, how likely is there going to be a currency crisis in China?

I use an expanded KLR signal model which is established by Kaminsky, Lizondo and Reinhart (1998) to calculate the probability for China to have a currency crisis in 2018 given corresponding macroeconomic inputs. The model can be used for any other entities as well with corresponding inputs. The estimated result for China shows that the country is on a medium level warning status. The paper will be outlined as below: Section 2 will be the literature survey part which covers a lot of similar work from other economists including: the main ideas they got, the reasoning behind their models and the conclusions they had. The discussion will be further divided into theoretical part and empirical part.

Section 3 is the model outline which will explicitly explain the model used and its rationale. Section 4 is the Data Description which contains the data source and processing. Section 5 will show the estimations from the model and interpretations based on the results. It also covers the discussion about the model limitations. Section 6 concludes the paper based on the estimated results and a review about the paper.

2 Literature Survey

2.1 Theoretical models

Since the currency crisis does hurt people a lot, many works by economists have been made on examining the mechanism behind currency crisis. First, the currency crisis is a situation about whether a country's central bank has sufficient foreign exchange reserves to maintain the country's fixed exchange rate. Among all the researches and models about currency crisis, they can be categorized in four "generations".

2.1.1 First Generation Model

Paul Krugman (1979) constructed the first-generation model in his 1979 paper "A model of Balance-of-Payments Crisis". He believes the expansion of fiscal policy leads to a massive government deficit which trigged the increase of M2. Speculator can then attack the domestic currency with short positions and in order to maintain the stable exchange rate, the government has to go short on the foreign currency until the foreign exchange reserves exhausts. The government will either give up the fixed exchange rate or deflate the domestic currency. Either one could lead to a crisis in the economy. His model suggests the "economic fundamentals" are the key indicators to the currency crisis. In addition, the unlimited government deficit is the main driver to break the external equilibrium. He believes the "economic fundamentals" can include current account

deficits, gradual decline in currency exchange reserves, and overvaluation of the exchange rate which all can be treated as early warning indicators for a speculative attack. Therefore, it is very important to keep these fundamentals "healthy" in order to maintain the confidence of the public.

2.1.2 Second Generation Model

The "Black Wednesday" in 1992, UK, commented by Kennedy and Irwin (1999) has trigged the development of the second-generation model. When the UK decided to join the ERM (European Exchange Rate Mechanism) in 1990, they agreed that all members are responsible to stabilize their own currency in a given range. However after Germany unified, the German government decided to increase the interest rate in order to release the inflation pressure. This makes it very difficult for countries which use low interest rates to stimulate the economy (including the UK) to stabilize their exchange rate in the given range. Based on the study from Helene (2016), speculators including George Soros saw the arbitrage opportunity in this mechanism and started to go short on the pounds in the foreign exchange market which made the UK exit the ERM and lose $3.4Bn dollars.

Unlike the assumptions in the first generation model, when the crisis happened in the UK, the early warning indicators cannot explain why the Crisis happened. This implies the stability of the economic fundamentals is not the necessary condition for the stability of the currency exchange rate. The most representative piece of work for the

second-generation model comes from Maurice Obstfeld (1994) and Maurice Obstfeld (1996). The key assumption in his model indicates the concept of "self-fulfilling" which means the crisis will self-fulfill when certain measures underperform. The bad performance will lead to a downturn in the public's confidence and expectation about the government which further deteriorates the economy.

Another key assumption in the Obstfeld's (1994) model is the introduction of game theory focusing on the relationship between the government and the "Currency Market traders". By analyzing this self-fulfilling model, Obstfeld illustrates the features of this self-fulfilling model in a dynamic way and comes to the conclusion of "multiple equilibria". The result indicates the government would set up multiple objectives when they set up economic policies and this will lead to multiple equilibria. The Government has both the motives to stabilize the exchange rate and destabilize the exchange rate. Then, the game theory will step in, the central bank and the market traders will choose an equilibrium based on the information they have and the information they assume the opponent would have. The equilibrium will affect the next move for both parties on and on which will generate a set of dynamic equilibriums and damage the public confidence and expectations.

Obstfeld (1994) believes when the cost of stabilizing the exchange rate is greater than the cost of destabilizing the exchange rate, the central bank would give up fixing the exchange rate and the crisis would take place.

Obstfeld (1996) also considered the effect of contagion. He believes country-specific ransom events may be internationally correlated and the evidence of regional contagion effects on capital inflows is presented by Calvo and Reinhart (1995).

2.1.3 Third Generation Model

In 1997, another financial crisis attacked many Asian markets. A report from Euro Money (1997) mentions it started with a currency crisis in Thailand and the government had to stop pegging the local currency to the U.S. dollar which made the currency crisis fiercely spread throughout Southeast Asia and caused further damage to the stock market.

Interestingly, before the crisis, many Asian countries were experiencing a very positive boom in their economies. Narisa's (1999) review shows in Thailand from 1985 to 1996, its average GDP growth was about 9% and its inflation kept somewhere stable. Meanwhile, in Kleiner's (2001) book she talks about the "Miracle on the Han River" which refers to the period of rapid economic growth in South Korea from 1953 to 1996. However, after the crisis, Thailand's economy was catastrophically damaged, the real estate bubble broke, debtors cannot make payments, current account deficit increased, exports decreased. The Thailand stock market dropped 75% based on the report from Liebhold (1999). On the other side, the report from Goel (2009) mentions the national

debt-to-GDP ratio in South Korea more than doubled (approximately 13% to 30%) after the crisis.

Therefore, it is quite hard to use the first and second-generation models to explain what happened in the 1997 financial crisis. Since the "Economic Fundamentals" are healthy and there is no negative expectations in the air before the crisis. Therefore, Krugman (1999) raised another point which he believed is missing from previous models: In developing countries, Moral Hazard widely exists. He believes the existence of "Moral Hazard" is due to massive recessive guarantee which the government posted on corporations and financial institutions. This will lead a large amount of capital going into real estate and the stock market. Krugman called this Financial Excess and this will not only trigger an economic bubble but also make the domestic economic structure very fragile. He concludes that once the bubble is broken, the financial crisis will reveal itself.

At the same time, Hongying Wang (1999) believes the herd behavior also plays an important role in this crisis. He mentioned:

The cause of the crisis was to be found … driven by high financial expectations in Asia and the assurance of IMF bailouts in case of disasters, international investors poured capital into those economies without careful consideration …when a minor disturbance occurred, they suddenly lost confidence and pulled out their capital. Simple panic and herd mentality created the crisis and led to its quick spillover throughout the region

It means countries like South Korea and Indonesia have similar weak banking systems and exceeded credit usage, a gradual decrease in exports and decrease in foreign currency reserves like Thailand. So when the crisis happened in Thailand, people in South Korea and Indonesia got alarmed and started to think about the situation and millions of people started to withdraw their investment when they saw a similar danger in these two countries. Eventually, people lost confidence which led to a crisis in South Korea and Indonesia as well.

2.1.4 Fourth Generation Model

There is also the fourth-generation model for a Currency crisis. Brought up by Krugman (2001) based on the previous 3 generations. The model believes if the domestic corporations are highly funded by foreign debt, then it is easier to be attacked. The higher the level of external debt for a corporation the bigger the balance sheet effect will be. The rationale behind it is when a corporation holds too much external debt; the foreign debtor will have low expectation about this country's economy. The investment will decrease and that will deflate the domestic currency. The value of the company will depreciate and the loan will decrease which will lead to a total decrease of the investment in the whole society and make the economy go into recession. However, the fourth generation model is not mature enough, a lot of assumptions and frameworks still need to be completed.

2.2 Empirical Models

In the empirical study, academia researchers and policy makers have been searching for multiple ways to prevent the crisis from happening. Many models have been established and tested as well. In 2004, Andrew Berg, Eduardo Borensztein, and Catherine Pattillo (2004) tested the performance of the early warning system models (EWS) such as KLR model established by Kaminsky, Lizondo, Reinhart (1998) and DCSD model built by Berg (1999) and his group, against the altrernative indicators like bond spreads, agency ratings and the overall currency crisis risk scores published by analysts. The result shows the EWS model significantly outperformed the non-model alternative indicators which reinforce the view that even the EWS models can contribute in the crisis forecasting.

Andrew Berg and Catherine Pattillo (1998) also evaluated 3 EWS models for predicting currency crisis that were proposed before 1997 to find out if these models are used in 1996 how much we can prepared before the crisis. Their findings indicate the KLR model outperformed the FR model which is from Frankel and Rose's (1996) work. It also outperformed the STV model which is from Sachs, Tornell and Velasco (1996) in forecast effectiveness. Therefore, this paper focuses on the discussion and expansion on the KLR model only.

2.2.1 KLR Signal Model

Kaminsky, Lizondo and Reinhart established the KLR Signal Model in 1998. One year after, Kaminsky Graciela (1999) made further enhancements on the model which makes the KLR Signal Model one of the world's most popular early warning system models.

Next, I will introduce the process of KLR Signal Model in specific details. Then in the next few chapters, I will use KLR model as the base and build up the model I used for crisis forecast. Therefore, a better understanding of the KLR model will help the reader understand the model I used.

First, the KLR defined the status of a currency crisis is when a country has a big decrease in foreign reserves or a big depreciation in its currency due to speculative attacks. So Kamisky, Lizondo and Reinhart (1998) established an index to define whether there is a crisis or not:

$$I_t = \omega_t \frac{\Delta e_t}{e_t} + (1 - \omega_t) \frac{\Delta R_t}{R_t}$$

Where I_t is the index at month t,

ω_t is the weight at month t,

e_t is the exchange rate at month t,

R_t is the foreign reserves at month t

When there is a big decrease in foreign reserves or a big depreciation in its currency, the index will increase and the domestic currency is under the pressure of selling. So they

defined when I_t is above a certain threshold e.g $I_t > \bar{I} + 3\sigma_I$ it means there is a currency crisis. Where $\bar{I}$ is the expectation of I and σ_I is the standard variance of I.

The core concept of the KLR model is to exploit the experience and data from historical crisis in order to find out the leading indicators for the prediction. I agree with this intuition since most of the time when the crisis happened; there will be something in common and these similarities are contained in certain indicators. Using historical data, especially data during the crisis will help us find out which indicators are playing an important role results the crisis. The KLR model starts with a large variety of indicators and grouped them into 6 broad categories and one effect: the external sector, the financial sector, the real sector, the public finances, institutional and structural variables, political variables and the contagion effects.

Their process also heavily relies on work by previous researchers and the selection of the previous papers tends to focus on the quantitative assessment instead of the qualitative assessment. After screening 17 papers, they selected 15 leading indicators are chosen By them, including Real exchange rate, Real interest rate, Imports, M2 multiplier, output, Bank Deposits, "Excess" M1 balances, Exports, Terms of trade, International Reserves, Stock prices, Real interest differential, M2/international reserves, Lending rate/deposit rate and Domestic credit/GDP.

Furthermore, the model shows how Kamisky, Lizondo and Reinhart (1998) find the "Similarities" in the chosen leading indicators across the historical periods. The KLR signal model gives a threshold for each leading indicators based on historical data. The Logic of setting up the threshold is very innovative. The model introduced the concept of "Signal" which means if an indicator has a value that exceeds the threshold then it indicates within a certain time that there will be a crisis. The model sets the period to 24 months. Once the indicator sends out such a signal at time t, there will be two results: a crisis happened within 24 months after time t or there are no crises within 24 months after time t. Similarly, if at time t, there is no signal from the same indicator, for the next 24 months there will still be the same two results. See the matrix below from the original paper from Kaminsky, Lizondo and Reinhart (1998):

	Crisis (within 24 months)	No crisis (within 24 months)
Signal was issued	A	B
No signal was issued	C	D

This matrix shows all the possible performance for each indicator with its signals. For situation A and D, the signals are functioning well. Since their performance coincides with the following fact. However, situation B and C are not.

For a perfect indicator, it Kamisky, Lizondo and Reinhart (1998) believe it should only provide situation A and D. Therefore the model defined

$$\text{“}[B/(B+D)]/[A(A+C)]\text{”}$$

as the “Noise to Signal Ratio”, B/(B+D) is the probability of having a wrong signal, A/(A+C) is the probability of having a correct signal. The threshold which provides the lowest “Noise to Signal Ratio” will be used as the threshold in KLR signal Model.

However once considering using KLR to make conclusions, the set of signals for each indicator at a given time is not very handy. So in 2006, Juzhong Zhuang (2004) and his group developed a comprehensive index which separate the above 15 indicators into six categories as the KLR model did. They also provided both the weighted average index and the un-weighted average index for comparison purposes:

$$I_{i,t} = \frac{\sum_{i=1}^{n} \frac{S_{i,t}}{NSR_i}}{\sum_{i=1}^{n} \frac{1}{NSR_i}} \quad \text{And} \quad I_{i,t} = \frac{\sum_{i=1}^{n} S_{i,t}}{n}$$

Based on the size of the comprehensive index at each time point it is possible to tell how likely there is going to be a currency crisis.

3 Model Outline

Admittedly, the KLR Signal Model is an innovative model and empirically it shows relatively better performance. However, I still have several concerns about the KLR Signal Model:

3.1 Issues with the KLR Signal Model

Firstly, Kaminsky, Lizondo and Reinhart (1998) suggested" *...the results indicate that an effective warning system should consider a board variety of indicators, since currency crises seem to be usually preceded by multiple economic problems"* The question is whether or not to include more indicators if possible? On one hand, more indicators means more information which will lead to more accurate estimation. On the other hand, more indicators might trigger the issue of over fitting. Since what I am doing is trying to forecast instead of replicating the history. So I should decrease the chance of over fitting in the model.

My opinion about the model is that the indicators should cover as many aspects (possible influential sectors) as possible but only choose the representative indicators in the sector to carry the information in that specific aspect.

A more important concern is about the signal model and the threshold establishment. Admittedly, I find using the noise signal ratio to define the threshold is very ingenious. In addition, the idea of using "Signal" to be the measurement is also innovative. However, my concern is "whether this is appropriate for crisis forecasting?" I agree with the ideas that there must be some indicators which will show anomalies right before the crisis. However, I think the threshold and the concept of a "signal" implied a "jump" in the results. For example, given a certain indicator if it has value 49 at time t_1 and 51 at time t_2 ($t_2>t_1$) and given 50 as the threshold. Then at time t_1 there is no "Signal" and at time t_2 there is a "signal" even the two values are very much close to each other. We might lose some information by using the signal model which will sharply cut off the potential hints from the market. A continuous model on the other hand, is more conservative in forecasting the crisis. E.g. the multiple regression model in Sachs, Tornell and Velasco's (1996) model.

In addition, the signal can only indicate if there is an anomaly or not. However, it does not show the degree of the anomaly. Let us assume within the 15 selected indicators in the KLR model, we see 8 of them issue the signals and the rest 7 does not issue the signals. However, the 8 indicators with a signal have just exceeded the threshold but the rest 7 are way below the threshold. In this case, intuitively by looking at the value we would think it is unlikely to conclude that there will be a currency crisis. However, in practice the comprehensive index might conclude this case as "Dangerous". Therefore, the signal and threshold mechanism in KLR model does not show the full picture of the information; it

limits the information for decision makers and shapes the information in a way that is convenient for decision-making.

3.2 Modified KLR Signal Model

Therefore, I established a new Index system in order to remediate the concerns above.

3.2.1 Indicator selection

First step is to select indicators in the model. This is very important, useful indicators will make the model more effective. Historically, so many indicators are chosen and used. Intuitively, International Reserves has an important role in currency crisis. Insufficient International reserves have led to currency crisis for more than once in human history. Bilson (1979) in his 1979 paper talked about the relationship between currency devaluation and international reserves/base money. In his work, Bilson used international reserves/base money as the leading indicator and it shows the devaluation is more likely to occur when there is a significant increase or a widely spread decrease in this leading indicator. In 1996, J Sachs, A Tornell, A Velasco (1996) and Kaminsky, Reinhart (1996) both used M2/international reserves as the leading indicator in their research about crisis forecasting. Respectively, they looked at the 20 emerging countries from 1985 to 1994 annually and a mixed set of countries from 1970 to 1995 monthly. M2/ international reserves and the real interest rate give the best performance in Kaminsky and Reinhart's (1996) model and M2/ international reserves offers good performance in SVT model as well. Therefore, I will

include M2/international reserves in my model. In fact, in the estimation result below, the performance of M2/international ratio coincides with the above results.

In the selection phase, the principles for selecting the indicators are: 1). based on the categorization in the original KLR model I tried to cover all the categories so that the indicators will cover as much information as possible. 2). the indicators should be proved to be significant in predicting the crisis in pervious literatures. So reviewing others' work is very important here. 3), data availability should be considered, some indicators with not enough availability had to be excluded

The M2/international reserves can be treated as the representative of the financial sector. Additionally, I choose real interest rate, domestic credit/GDP, interest rate spread and Inflation in the financial sector. As I mentioned above, real interest rate has a good performance in Kaminsky and Reinhart's (1996) model. On the other hand, in the study of Noh-Sun Kwark (2002) he indicates the interest rate spread also contains the leading behavior over the business cycle. Although it is still not a very popular indicator in previous works, I still choose to include the interest rate spread in my model due to its "leading" characteristics. I use average CPI as the proxy to measure inflation. Inflation has been widely used as a leading indicator for financial crisis. E.g. Frankel and Saravelos' (2010) paper points out the inflation is significant in predicting crisis especially in the short term. Domestic credit/GDP appears to be significant in predicting the crisis in Sebastian Edwards' (1989) paper and Frankel and Rose's (1996) work. However, in Ceyla Pazarbasioglu and

Inci Ötker's (1994) study Domestic Credit/GDP does not seem to be significant in the forecast. One concern from me about Ceyla Pazarbasioglu and Inci Ötker's (1994) work is the research only contains 5 countries (actually it is 4 given Denmark had been excluded from the regression given it does not have a devaluation). Another similar research on developed countries is from Jan Babecký (2012) and his group, they look at the EU and OEDC countries (altogether 36 in the current version) over the 1970-2010 periods at the quarterly frequency. Their conclusion is:

"…the domestic credit growth turns out to be the key early warning indicator…" Therefore, I decided to include this indicator in my model.

Next in the external sector, I choose real exchange rate and the terms of trade as my leading indicators. The real exchange rate had been widely used in crisis predictions and concluded to be significant: Edwards (1989), Frankel and Rose (1996), Kamin (1988), Kaminsky and Reinhart (1996), Klein and Marion (1997) etc. On the other hand the terms of trade is not so popular in the research, however Kaminsky, Lizondo and Reinhart (1998) believe the trade balance is considered to be important in predicting the crisis. Therefore, terms of trade will be used as a proxy for the trade balance since the absolute value of the balance of trade is not very meaningful in my model. Also we will use the negative of terms of trade as the indicator, since in Guillaumont's (1980) paper he mentions a deterioration in TOT will lead to a worsen position for the country in trading which is more likely to have a currency crisis.

In the real sector, I selected real GDP growth rate and the unemployment rate as the

indicators. Kamin (1988) found the real GDP growth rate appeared to be significant in his results in 1988. I use negative real GDP growth rate as the indictor here since the increase in the real GDP growth is considered to have a negative effect on the crisis. Unemployment has been considered as a lagging indicator widely; however in Kaminsky, Lizondo and Reinhart's (1998) paper they believe the decrease in the ratio of employment/unemployment has a statistically significant enhance in the probability of a successful speculative attack. Eichengreen, Rose and Wyplosz (1995) also find the significance of employment growth in predicting crisis.

In public finance sector, I selected fiscal deficit/GDP, government consumption/GDP and credit of public sector (use government gross debt as the proxy). These 3 describes the public finance condition for a given country. Comparing with other sectors, there are not many discussions on the public sector. However, Inci ÖtkerCeyla Pazarbaşioĝlu (1996) include fiscal deficits as a leading indicator and the result shows the significance of it. Edwards (1989) also looks into both fiscal deficits and credit of public sector and he finds both of them significant in prediction. Moreno's (1995) research finds an opposite result. In the paper he does not find the significance of fiscal deficits if he excludes Japan from his sample. My concern about Moreno's result is his analysis is not saying too much about the different behavior an indicator will have to lead up crisis but more about the speculative attack itself. For government consumption/GDP, Sachs, Tornell and Velasco (1996) find it significant in their research.

In Institutional/Structural sector and Political sector, most appeared indicators in previous literature are dummy variables which is not very meaningful in my model. Therefore, I do not include these two sectors in my research.

3.2.2 Model establishment

After the long discussion of selecting the 12 indicators, step 2 is to set up the index system I mentioned earlier. I use the historical data for each indicator and build up a normal distribution using the sample mean and sample standard variance. One major assumption here is that all these indicators will follow a normal distribution with big database. This is a relatively strong assumption since based on central limit theorem (CLT) all the data shall be independent which our time series data does not perfectly fit. In addition, that is why I choose the indicators which either a relative index (Rate) or a percentage of some other indicators (Ratio): I tried to use such a way to exclude the trend, the seasonality and the correlation within the time series.

Once I have the distribution for indicator x

$$I_x \sim N(\bar{I_x}, \sigma_x)$$

For current period t, I can find F ($I_{x,t}$) where F (x) is the cumulative density function of the above normal distribution which F ($I_{x,t}$) = P ($I_x < I_{x,t}$). Then we will have 12 "probabilities" for the currency period: P_1, $P_2 \ldots P_{12}$ (P_x = F ($I_{x,t}$))

Here I use a continuous cumulative density function to solve the concern about the threshold and the signal. Moreover, the "probabilities" I got can measure the "degree" of the anomaly. A probability of 70% and one with 40% will show significant difference in the comprehensive index calculation. In this modified model, the historical data only provided a distribution that our current input can compare with. The quotation mark on the "probabilities" means these are not true probabilities; these are just relative likelihoods for measuring and comparing purposes.

3.2.3 Index and criterion set up

Using the 12 "Probabilities", we can come up with a comprehensive index and use it for decision-making. The comprehensive indices I use here contain an un-weighted arithmetic average of the 12 "probabilities" and a weight average of them:

$$I_t = \sum_{i=1}^{12} \frac{P_i}{12}$$

And

$$I_t = \sum_{i=1}^{12} (P_i * W_i) \text{ Where } \sum_{i=1}^{12} W_i = 1$$

The indices I have here is also in a percentage format. However, be aware that it cannot be translated directly like a percentage. E.g. if $I_t = 50\%$, it does not mean the probability of currency crisis from happening is 50%. It will be used to compare with the threshold we set up using historical data. With the result of the comparison, we can conclude the estimation and go to decision-making.

4 Data Description

The data I use has multiple sources. Based on the indicators I selected, the Real GDP Growth Rate, Government Gross Debt/GDP, Unemployment Rate and the Average CPI are from IMF World Economic Outlook (2018). The Real Exchange Rate and Terms of Trade are from The World Bank Global Economic Monitor (2018). The Interest Rate Spread and the Domestic Credit/GDP are from The World Bank World Development Indicators (2018). Government Spending/GDP and Government Deficit are from OECD (2017). The Real Interest Rate is from The World Bank Open Data (2018). The M2/International Reserve is from CEIC (2018).

Due to data availability limit, some indicators have only annually data. So the data I used is a mix of annually data, quarterly data and monthly data. The data is used based on the most frequent principle meaning the monthly data will be preferred to the quarterly and the quarterly will be preferred to the annually. For indicators which do not have sufficient data, we shall keep that indicator's result blank instead of assign "0" to it.

The data focuses on 7 countries: the People's Republic of China, the United States, Mexico, Thailand, Indonesia, Hungary and the Republic of Korea. I will use these countries performance in 1997 Asian financial crisis to estimate the threshold for the

comprehensive index. For that purposes I will use the data from 1960 to 1997. For the forecast part, the data range is from 1960 to 2017.

Details about the data used are in *Table 1* below:

Table 1 Indicator Description

Leading Indicators	Description
M2/International Reserves	1960-2017, annually
Real Exchange Rate	1991-2017, monthly
Negative Terms of Trade	1991-2017, monthly
Real Interest Rate	1961-2017, annually
Domestic Credit/GDP	1960-2017, annually
Interest Rate Spread	1960-2017, annually
Negative Real GDP Growth Rate	1980-2017, annually
Inflation Rate(Average CPI)	1980-2017, annually
Fiscal Deficit/GDP	1970-2017, annually
Employment Rate/Unemployment Rate	1980-2017, annually
Government Gross Debt/GDP	1980-2017, annually
Government Consumption/GDP	1980-2017, annually

5 Estimation

5.1 Preparation Phase

In the preparation phase, I will assign the weights for 12 indicators in the comprehensive indices (CI) and calculate the threshold for CI using a historical crisis – the Asian crisis in 1997.

Firstly, I assigned the weights for the indicators in comprehensive indices. *Table 2* contains the weight assignments. For the weighted CI, I consider half of the 12 indicators are more significant than the other half. The criterion is based on the frequency they are used and tested to be significant in Kaminsky, Lizondo and Reinhart's (1998) research. Namely: M2/International Reserves, Real Exchange Rate, Real Interest Rate, Domestic Credit/GDP, Negative Real GDP Growth Rate and Fiscal Deficit. For the more impactful half, they will receive twice as much as the weight of the other half. Within the more impactful half, they share equal weights which is also true for the less impactful half.

Then I use the data between 1960 and 1997 to test the model also to use such a real crisis event to set up the threshold for the CIs. I got the results in *Table 3*. As we know, during 1997, the Asian crisis hit Thailand, Korea and Indonesia badly. In the results from the model, we can clearly see for these 3 countries both the weight index and the un-weighted index are significantly higher than other countries especially Mexico and Hungary which

does not suffer a lot from this crisis. When we look at China, the index is also relatively high but not as much as the above three countries. If we look back to see what happened in China, we will find in the book of Liu (2017) *"…there was also heavy speculation in the Western press that China would soon be forced to devalue its currency to protect the competitiveness of its exports"*.

"…however, the RMB's non-convertibility protected its value from currency speculators, and the decision was made to maintain the peg of the currency, thereby improving the country's standing within Asia…"

"…Unlike investments of many of the Southeast Asian nations, almost all of China's foreign investment took the form of factories on the ground rather than securities, which insulated the country from rapid capital flight…". Therefore, if we only look at the economic conditions China had during that period, a currency crisis is expected which also coincides with my results in *Table 3*. However, the fact also indicates more indicators should be included such as the type of FDI and qualities of the currency (e.g. convertibility).

Another surprising number is the CI for the US. Its weighted index is higher than Indonesia and its un-weighted index is even higher than Korea. I can find the fact in Pettis (2001) book that *"The "Asian flu" had also put pressure on the United States. Its market did not collapse, but they were severely hit. On 27 October 1997, the Dow Jones industrial plunged 554 points or 7.2%, amid ongoing worries about the Asian economies. The New York Stock Exchange briefly suspended trading. The crisis led to a drop*

in consumer and spending confidence. Indirect effects included the dot-com bubble, and years later the housing bubble and the subprime mortgage crisis." So the fact is also very consistent with the result I have.

The difference between the weighted index and the un-weighted index is quite significant for most of the countries. This confirms my assumption that some of the indicators have a higher impact in the crisis forecasting.

On indicators perspective, the M2/International Reserves, Negative terms of trade, Real Interest Rate, Domestic Credit/GDP and Negative Real GDP Growth Rate are the most significant. Public Sector indictors do not show much significance.

So in general, when we are using the data in 1997 to test the above countries the result is quite consistent with the fact. And based on the results, I will set up the thresholds as follows:

I > 60%, Severe warning

45 %< I<60%, mild warning

I<45%, no warning

Based on the results, Thailand, Korea, Indonesia and the US will get high severe warning. China will receive a medium level warning. Mexico and Hungary will not be warned.

5.2 Estimation Phase

5.2.1 Results for China

Next, I use the data from 1960 to 2017 to make estimation about China. I will use the thresholds that we just set up to define which level of warning China will receive before they move ahead. The result is in *Table 4*. It is easy to see that with an indices around 55% - 60%, China will receive a medium level warning. And if we compare this forecast result with the index in 1997, we will find the situation in China today is even a bit more severe that it was 20 years ago. The main indicators which lead to such a situation are high real exchange rate, high domestic credit per GDP, lower real GDP growth and high government Gross Debt per GDP. It is clear to see the debt pressure is the main potential factor to jeopardize the Chinese economy in the future.

5.2.2 Interpretations about the Forecast

5.2.2.1 Real GDP Growth Rate

Maybe someone will ask why China has low real GDP growth. Please note that this low growth is relative to its historical performance and the high GDP growth since 1991 increased the expected value in the distribution. In this case, our model considers the relatively low GDP growth rate as an anomaly and increase the CI. However, intuitively the GDP is very hard to keep in a high rate forever and eventually it will start to decrease to a low level. However, we shall not expect the GDP growth to be high forever like what we used to see in Chinese economy and a low Real GDP growth rate does not mean a high

likelihood for crisis in our model. An example is the developed countries, they no longer have very high real GDP growth but we cannot get high "probability" on Real GDP Growth Rate indicator because they have been stable in such a low level for a long time.

5.2.2.2 Real Exchange Rate

Next I am looking at the real exchange rate appreciation. Considering the rapid growth in Chinese GDP, would the appreciation in exchange rate due to the Balassa-Samuelson effect? Based on Imai's (2018) study, *"…a decomposition of the annual 4.6% real exchange rate appreciation reveals that the magnitude of the Balassa-Samuelson effect was relatively small at 1.2 percentage points. The more important factor was real appreciation in the price of tradables (a rise in the price of China's tradables relative to U.S. tradables) at 4.4 percentage points…"* I think the Balassa-Samuelson effect is not the best explanation for the rapid growth in real exchange rate. The stability period in 1996-2004 is should be the cause to make the increase in real exchange rate look so rapid today. Therefor I think it is natural to see the real exchange rate in China is in a relatively high level. Furthermore, I would expect the real exchange rate in China will keep increase due to China's exporting power. However, this does not look like an anomaly to me.

5.2.2.3 Domestic Credit/GDP and Government Gross Debt/GDP

However, I think the Domestic credit has really become an issue in Chinese economy. The real estate price has increased to an unbelievable high level in some of China's big cities. In Zhu's (2016) book about the Chinese real estate price between 2004 and 2014, the

increase in Beijing is 374%, in Shanghai is 346%, in Guangzhou is 505% and in Shenzhen is 420%. This triggers huge amount of mortgage. The big population and the rigid demand for housing in China can hardly cool down the prices. In my perspective, the domestic credit expansion should be the priority for Chinese government.

For the growing government gross debt/GDP, Chinese government seems to notice this issue already. From Lee's (2017) review on the 19th Communist Party Congress in China, he mentions *"...the country's debt-to-GDP ratio grew from around 180 percent in 2011 to 255.9 percent by the second quarter of 2017..." and "...Local governments were identified as a major risk to China's financial stability, partly due to their lending from the "shadow banking" sector and debt accumulated over the past years to upgrade infrastructure across the country ..."*. Therefore it is not hard to understand why Xi wants to deleverage and cutting off the shadow banking.

5.3 Review Phase

Admittedly, the model is not perfect. First of all, I only found annually data for some leading indicators. The estimation accuracy will be lower than using quarterly and monthly data. This might cause the index to be undervalued or overvalued. Furthermore, the comprehensive indices will generate lower or higher threshold and give the country a warning earlier or later than it should be.

Second point is the assumption we used in the model part, we assumed a normal distribution for each indicator we used. As I mentioned this is a very strong assumption, in order to relax it we can use either a parametric or a non-parametric method to identify the approximately distribution for each indicator using their historical data. This will definitely offer our results better accuracy however this will also significantly increase the complexity of the operation.

Third point is the model does not have very good compatibility. Since we need the historical data to build up the probability distribution for each indicator which makes the dummy variables are not very meaningful in this model. So a lot of leading indicators in the Structural sector or in the Political sector cannot be included in the model. Moreover, the contagion effect is not included due to the same reason. One idea for the dummy variables is to set up a multiplier to reflect the effect for each country and it should be defined by the other countries which have a material interaction with its economy and politics.

Fourth point is about the weights we used in the model, the preference for high weights is based on the frequency and significance in previous paper. There shall be a better process to define the weights. Like I mentioned in KLR model, Juzhong Zhuang (2004) and his group uses the inverse of the total "noise-signal ratio" in each category to define the weight.

Fifth, based on the 1997 test results, the public sector indicators are not showing significance. The model can further refine by replacing them with other indicators and bring more economic rationale for the indicators chosen.

The last point is about the data used. I used all the data available for each indicator. However, one concern is whether I should be more selective on the time range chosen to build up distributions for each indicator. Since for a certain country, its economy can experience different conditions and history background in several decades. If we include the data from the periods when the country is using a totally different economic and political policy from now. It will be hard to get meaningful results. However, I have not seen a similar discussion in previous literatures.

6 Conclusion

Ever since the first crisis, people have never stopped their pace to conclude “rules” in economic activities. Models were created to make people feel more confident about the future and this is pretty much what I did here. I aim to establish a model to forecast what is going to happen in future China. After reviewing some literature from other scholars, I choose use the idea of KLR model as a based to build up my own system.

The result from my model shows China in 2017 has a string economy but should receive a medium level warning about the currency crisis and the main contributors are high real

exchange rate, high domestic credit per GDP, lower real GDP growth rate and high Government Gross Debt per GDP. This shows a high debt pressure both domestically and internationally and the relatively higher exchange rate can potentially decrease is export and create trade deficit. These two parts will be the main challenges for Chinese decision makers.

The model used a unusual way to establish the likelihood in crisis forecast. This shows a direction for future researches and the paper also listed several points for further refine. Also please note the early warning system is a tool for crisis early warning purposes, it contains limitations and the results shall be analyzed with other alternative indicators. Multiple factors shall be taken into account for decision-making when using the model.

Appendix

Table 2 Weight for two comprehensive Indices

Leading Indicators	Un-weighted	Weighted
M2/International Reserves	1/12	1/9
Real Exchange Rate	1/12	1/9
Negative Terms of Trade	1/12	1/18
Real Interest Rate	1/12	1/9
Domestic Credit/GDP	1/12	1/9
Interest Rate Spread	1/12	1/18
Negative Real GDP Growth Rate	1/12	1/9
Inflation Rate(Average CPI)	1/12	1/18
Fiscal Deficit/GDP	1/12	1/9
Employment Rate/Unemployment Rate	1/12	1/18
Government Gross Debt/GDP	1/12	1/18
Government Consumption/GDP	1/12	1/18

Table 3 Result for the 1997 Asian Crisis Testing

Leading Indicators	Thailand	Korea	Indonesia	US	Mexico	Hungary	China
M2/International Reserves	78.98%	85.06%	95.01%	92.57%	16.95%	19.86%	33.20%
Real Exchange Rate	97.82%	37.43%	98.37%	92.82%	53.59%	89.36%	96.19%
Negative Terms of Trade	97.54%	99.76%		90.50%	17.85%		
Real Interest Rate	65.62%		47.59%	82.87%	9.42%	25.84%	73.56%
Domestic Credit/GDP	99.92%	92.07%	98.33%	99.73%	25.38%		93.40%
Interest Rate Spread	55.64%		13.46%		23.86%	7.86%	99.80%
Negative Real GDP Growth Rate	99.99%	79.21%	88.57%	23.25%	15.89%	19.43%	61.08%
Inflation Rate(Average CPI)	50.73%	32.57%	15.55%	21.35%	22.55%	60.26%	18.75%

Fiscal Deficit/GDP		88.66 %		98.72 %		62.55%	21.35 %
Employment Rate/Unemployment Rate		26.34 %	82.68%	7.90%	48.41%	83.93%	70.97 %
Government Gross Debt/GDP		34.84 %				4.04%	0.00%
Government Consumption/GDP	0.00%	76.02 %	3.71%		4.95%	63.18%	43.14 %
Comprehensive Index-Un-Weighted	71.81%	65.20 %	60.36%	67.74 %	23.89%	43.63%	55.59 %
Comprehensive Index-Weighted	75.97%	68.96 %	66.67%	67.74 %	24.01%	43.56%	57.60 %

Table 4 Result for the 2017 China Forecast

Leading Indicators	**China**
M2/International Reserves	25.39%
Real Exchange Rate	94.88%
Negative Terms of Trade	2.50%
Real Interest Rate	61.83%
Domestic Credit/GDP	99.89%
Interest Rate Spread	72.22%
Negative Real GDP Growth Rate	84.29%
Inflation Rate(Average CPI)	28.17%
Fiscal Deficit/GDP	26.16%
Employment Rate/Unemployment Rate	74.56%
Government Gross Debt/GDP	99.56%
Government Consumption/GDP	0.26%
Comprehensive Index-Un-Weighted	55.81%
Comprehensive Index-Weighted	59.01%

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