

Discovering Significant Factors on African Systemic Financial Crises during and post Bretton Woods system

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Introduction

This report studies the Global Financial Stability dataset collected by the Behavioral Finance & Financial Stability project at Harvard Business School. The objective is to understand the dynamics of financial stability. The dataset specifically focuses on the Banking, Debt, Financial, Inflation and Systemic Crises that occurred, from 1860 to 2014, in 80 countries across the world. The global financial crisis brought to the forefront of academic and policy discussion on the question of how to ensure the stability of the financial system. As a prerequisite for that, we would need to understand what are the significant factors that associated to Systemic Crises. A systemic crisis is a domino effect in which a financial trouble spreads between institutions and markets until it affects the whole monetary/financial system with dire global economic consequences. This report focuses on a subset of the dataset that contains the information on African countries from 1944 - 2014 (during and post Bretton Woods system). This report starts with an introduction on the dataset as well as the background information for the knowledge domino, followed by an Exploratory Data Analysis in order to derive a Preliminary Conclusion with no assumptions. In the Confirmatory Data Analysis section, Generalized Linear Model

(GLM), Generalized Linear Mixed Model (GLMM) and Generalized Estimating Equation Model (GEE) are performed in order to validate the relationships between financial factors and Systemic Crises. The Conclusion and Discussion section will summarize and compare the results from Exploratory Data Analysis and Confirmatory Data Analysis, as well as discussing the limitations on the approach.

Keywords: Financial stability, System Crisis, African Economics, Bretton Woods system

Data Description

The Dataset applied in this study is collected over many years by Carmen Reinhart, Ken Rogoff, Christoph Trebesch, and Vincent Reinhart on the Behavioral Finance & Financial Stability Project at Harvard Business School (dataset available at: <https://www.hbs.edu/behavioral-finance-and-financial-stability/data/Pages/global.aspx>). This dataset includes information regarding on banking crises, exchange rate crises, stock market crises, sovereign debt growth crisis dates for more than 70 countries from 1800 - 2014. For the study in this report, we focus on the African Countries in this dataset (The 13 Countries are: Algeria, Angola, Central African Republic, Ivory Coast, Egypt, Kenya, Mauritius, Morocco, Nigeria, South Africa, Tunisia, Zambia and Zimbabwe). The information sources for this dataset are: World Bank, International Monetary Fund (IMF), International Bank for Reconstruction and Development (IBRD) and Government Originations. The Missing data are mostly due to not collecting such information as a colony, or during chaotic situations such as Decolonization and Civil War. Therefore, it is reasonable to assume that the missing information is Missing at Random (MAR).

The reasons for focusing on African Countries are:

1. African Countries are relatively underdeveloped. Most of the countries completed the decolonization process in late-19th century (shown in Figure 1). Moreover, they share many similarities that made them comparable, including small scale of Economics, significant trade deficit, and financial fragility.
2. From Statistical prospective, focusing on African Countries can give us a more balanced dataset to analyze (Shown in Figure 2 and 3). If we focus on all the 80 Countries from 1944 to 2014, Systemic Crises occurred less than 2% of the time. However, when focusing on the 13 African Countries, 10% of the years were associated with Systematic Crises.
3. From Motivation prospective, many of the Developed Countries have relatively well-developed financial system with complete risk management. Therefore, it is more favorable to understand the dynamics of financial stability within the content of Africa.

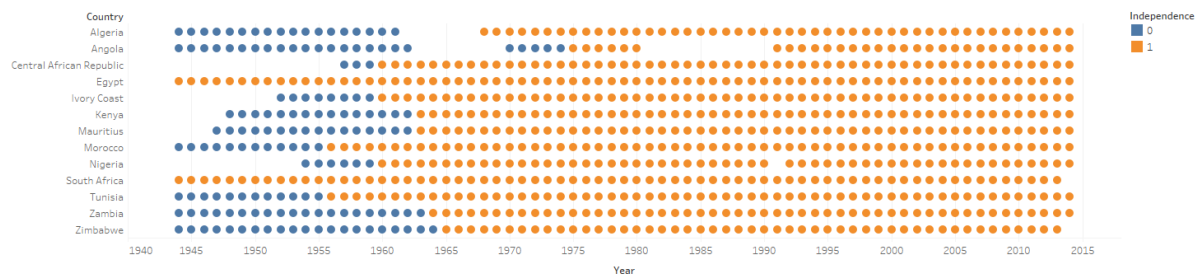


Figure 1: 13 African countries' independence indicator from 1944-2014. Blue as Not Intendent and Orange as Independent. Missing dots represent no information available at the year.

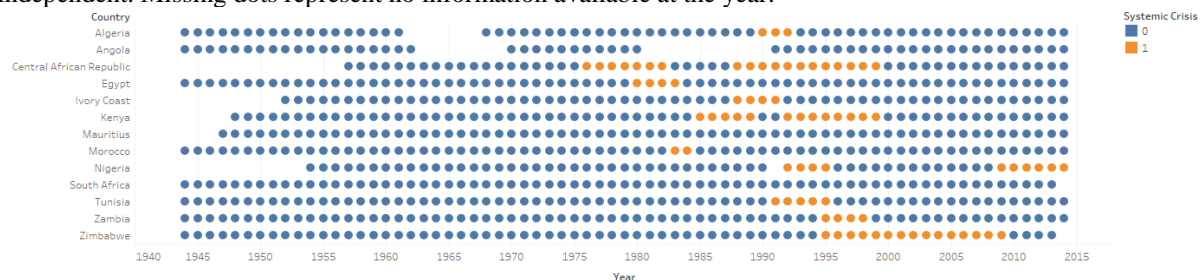


Figure 2: 13 African countries' Systemic Crisis indicator from 1944-2014. Blue as No Crisis and Orange as Crisis. Missing dots represent no information available at the year.

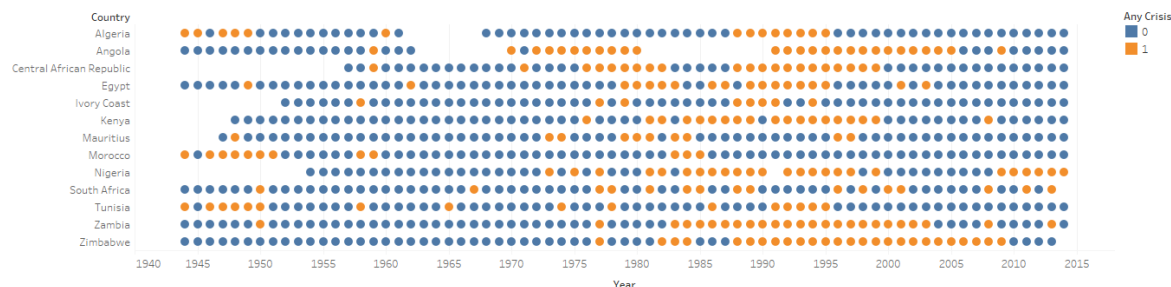


Figure 3: 13 African countries' any type of Crisis (Systemic, Currency, Debt, Banking, and Inflation) indicator from 1944-2014. Blue as No Crisis and Orange as Crisis. Missing dots represent no information available at the year.

The reasons for focusing on 1944-2014 are:

1. The World Bank and International Monetary Fund (IMF) was established under Bretton Woods Agreement in 1944, and most of the African Countries started collecting information under a global standard since then. Therefore, the availability and usability of the data is generally better after 1944.
2. From statistical prospective, because US Dollar value is relatively stable during and post the Bretton Woods system (During the system USD is fixed at 1/35 of an ounce of gold, and post the system USD is stable because of the strong US Economy during the time). Therefore, it is reasonable to use exchange rate to US dollar to measure Systemic Crisis and Currency Crisis during this time.

The detailed list for variables covered in this study is shown in table below:

Variable	Description	Type
Case	Country ID	ID
Country	The name of the country	ID
Year	The year of the observation	Integer
exch_usd	The exchange rate of the country vs the USD	Continuous
gdp_weighted_default	The total debt in default vs the GDP	Percentage

Variable	Description	Type
inflation_annual_cpi	The annual CPI Inflation rate	Continuous
domestic_debt_in_default	"0" means that no sovereign domestic debt default occurred in the year and "1" means that a sovereign domestic debt default occurred in the year	Binary
sovereign_external_debt_default	"0" means that no sovereign external debt default occurred in the year and "1" means that a sovereign external debt default occurred in the year	Binary
systemic_crisis	"0" means that no systemic crisis occurred in the year and "1" means that a systemic crisis occurred in the year.	Binary
currency_crises	"0" means that no currency crisis occurred in the year and "1" means that a currency crisis occurred in the year	Binary
inflation_crises	"0" means that no inflation crisis occurred in the year and "1" means that an inflation crisis occurred in the year	Binary
banking_crisis	"0" means that no banking crisis occurred in the year and "1" means that a banking crisis occurred in the year	Binary
independence	"0" means "no independence" and "1" means "independence"	Binary

Table 1: Descriptions and types for all the variables in the Africa Economic, Banking and Systemic Crisis Dataset.

Exploratory Data Analysis

Data Summaries:

Measurements/ Variable	exch_usd	Log(exch_usd+ 0.01)	gdp_weighted _default	inflation_annual_ cpi	Log(inflation_annual_cpi +18)
Minimum	0	-4.605	0	-17	0.120
1st Quartile	0.33	-1.071	0	3	3.034
Median	3.89	1.360	0	6	3.191
Mean	52.83	0.597	0.0056	25702	3.333

Measurements/ Variable	Log(exch_usd+ exch_usd	Log(exch_usd+ 0.01)	gdp_weighted _default	inflation_annual_ cpi	Log(inflation_annual_cpi +18)
3rd Quartile	17.76	2.878	0	12	3.416
Maximum	744.306	6.612	0.4	21989695	16.906
Standard Deviation	121.650	3.441	0.038	750278.6	0.777

Table 2: Summary statistics for all the continuous explanatory variables in the Africa Economic, Banking and Systemic Crisis Dataset.

The above table shows summary statistics for the continuous variables in this dataset. It can be observed that the `exch_usd` and `inflation_annual_cpi` contain few extreme observations. Since they represent valuable content, such as Hyperinflation in Zimbabwe (2007 – 2009). Therefore, such observations should not be excluded. In order for a better model fitting in the later section, we will apply log-transformation on these variables. The Currency Crisis effect can be shown in the figure below, when a Country does not have sufficient foreign exchange reserves to maintain a fixed exchange rate (agreed under Bretton Woods System), the exchange rate will typically burst in a short amount of time, showing as vertical lines in the figure.

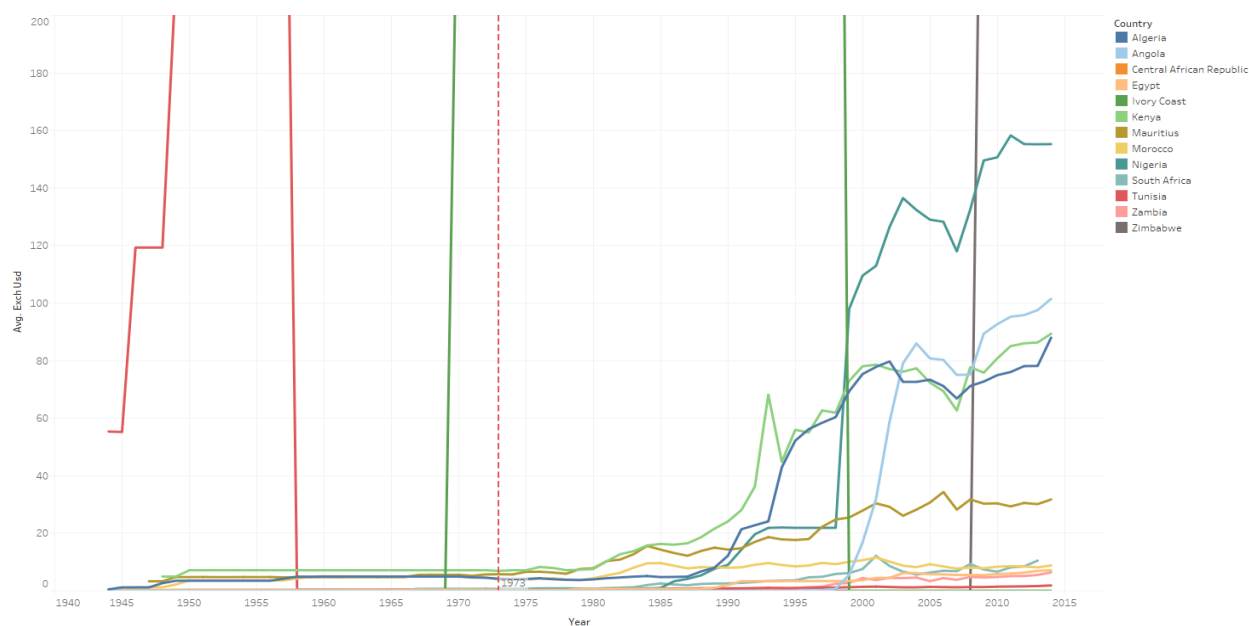


Figure 4: 13 African countries' Exchange rate to USD from 1944 to 2014, y-axis capped at 200 to better display for the majority of the Countries. Vertical red dash line shows the termination of the Bretton Woods Agreement.

Variable/ Measurement	# of 0	# of 1	% of 1
domestic_debt_in_default	817	42	4.89%
sovereign_external_debt_default	702	157	18.28%
currency_crises	727	132	15.37%
inflation_crises	744	115	13.39%
banking_crisis	768	91	10.59%
Independence (1 as Independent)	155	704	81.96%
systemic_crisis	780	91	10.59%

Table 3: Summary statistics for all the binary explanatory variables and the response variable in the Africa Economic, Banking and Systemic Crisis Dataset.

The above table shows the counts and percentages on the binary variables in this dataset. For variables other than independence, 0 represent positive (no crisis/no debt), and 1 represent negative (crisis/ debt). However, for the independence variable, it is the opposite case. We can conclude from the table that crises occurred among 10% - 15% of the time recorded.

Univariate analysis:

In order to further investigate the relationships between each variable on Systemic Crisis, a set of univariate analysis has been performed. 2 * 2 tables and Chi-square test has been computed for binary response variables, and T-test/ Wilcoxon test has been applied for continuous response variables.

The Chi-square test result indicates that all the binary variables are significantly associated with Systemic Crisis. In addition, it is noticed that when the countries are independent, no Systemic

Crisis has ever occurred. However, based on Fig 1 and 2, it seems that all the Countries became independent before 1975, which is within the timeframe of Bretton Woods Agreement. Also, based on the 2 * 2 table, none of the Systemic Crises occurred when Bretton Woods Agreement was in effect (1944 – 1973). Therefore, independence information is more likely to be a confounding factor and will not be passed to the Confirmatory Data Analysis. It can also be noticed that Banking Crisis has a significant impact on Systemic Crisis. When a Banking Crisis occurred, a Systemic Crisis is associated for more than 80% of the time, which is significantly higher than other types of Crisis.

Chi-Square test on binary variables v.s. Systemic Crisis

2 * 2 Table				
Variable/ Test Result	0 (Systemic Crisis)		1	Chi-Square test P-Value
domestic_debt_in_default	0	748	69	0.002
	1	32	10	
sovereign_external_debt_default	0	661	41	1.852e-12
	1	119	38	
currency_crises	0	670	57	0.00218
	1	110	22	
inflation_crises	0	692	52	3.366e-08
	1	88	27	
banking_crisis	0	762	6	2.2e-16
	1	18	73	
independence	0	155	0	2.409e-05
	1	625	79	

Table 4: 2 *2 tables and P-Value for binary variables in the Africa Economic, Banking and Systemic Crisis Dataset.

T-test/ Wilcoxon test on continuous variables v.s. Systemic Crisis

Variable/ Measurement	Wilcoxon-test p-value	t-test p-value
gdp_weighted_default	0.6182	0.6485
Log(exch_usd+0.01)	2.694e-06	8.999e-05
Log(inflation_annual_cpi+18)	1.529e-06	0.007139

Table 5: Wilcoxon-test and t-test p-values for continuous explanatory variables in the Dataset.

The Box Plots in Figure 5 indicate that both Exchange Rate and Inflation CPI have large variations. When a Systemic Crisis occurs, the Exchange Rate is likely to be higher. It can also be observed in Figure 4 that, despite of 3 Currency Crises, the Exchange Rates are extremely stable for the majority Countries under the Bretton Woods Agreement (1944-1973).

Preliminary Conclusions

We can conclude from the above analysis that:

1. Bretton Woods system is effective on preventing Systemic Crisis. (Figure 1)
2. Banking Crisis has a significant impact on Systemic Crisis. (Table 4)
3. Exchange rate are relatively stable for the majority Countries under BrettonWoods Agreement.
4. When a Systemic Crisis occurs, it is likely to continue for a number of years. (Figure 1)

Confirmatory Data Analysis:

In this section, we fitted a Generalized Linear Model (GLM), a Generalized Linear Mixed Model (GLMM) and a Generalized Estimating Equation Model (GEE) respectively in order to further investigate the association on Systemic Crises.

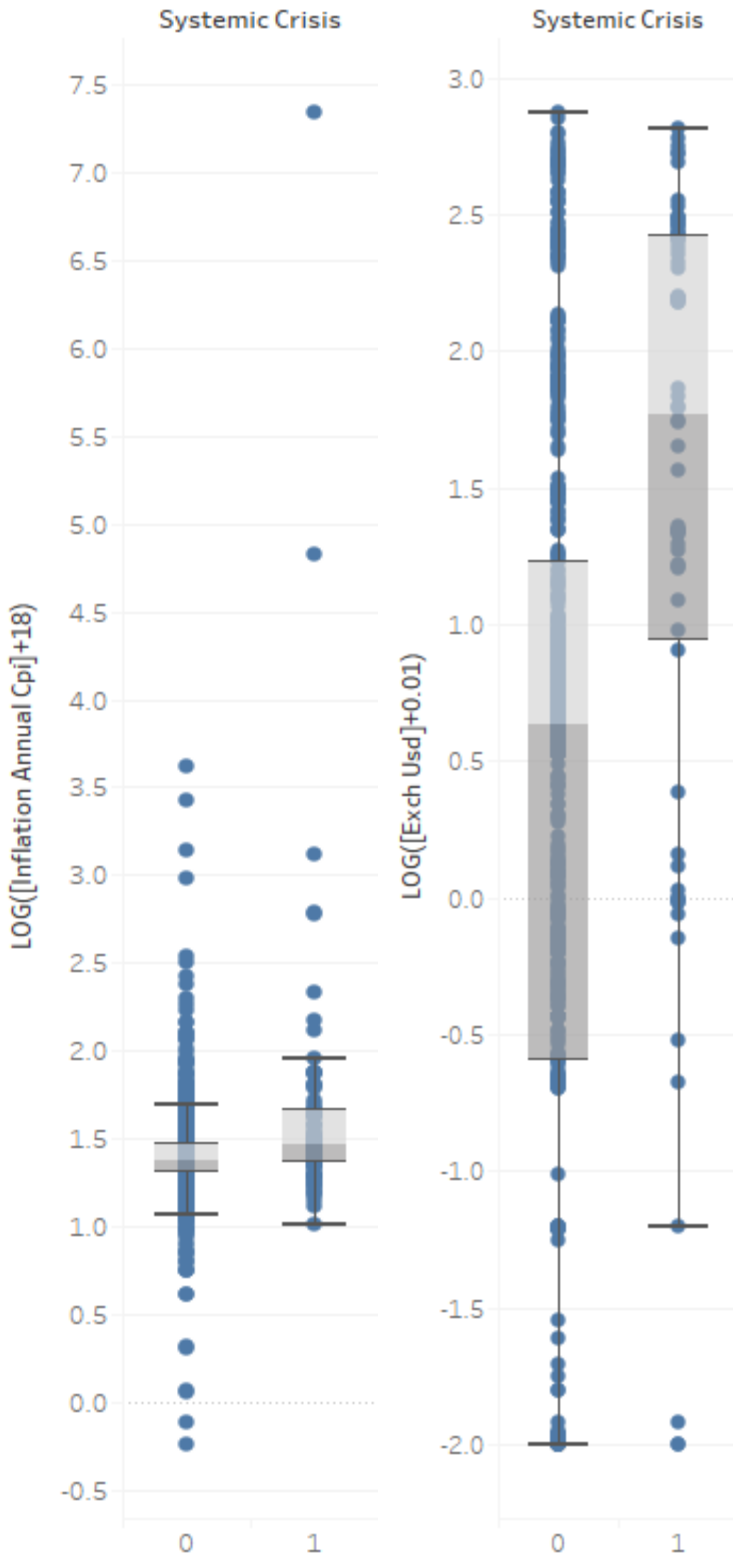


Figure 5: Box Plots on log-transformed Inflation and Exchange Rate Measurements.

Terminology

Bretton Woods system: A monetary management agreement regarding commercial and financial relations among the United States, Canada, Western European countries, Australia, and Japan at the end of World War II. Under the agreement, countries promised that their central banks would maintain fixed exchange rates between their currencies and the US Dollar, while the US Dollar value was 1/35 of an ounce of gold, which was redeemable for any member at any time. Global financial associations International Monetary Fund (IMF) and the International Bank for Reconstruction and Development (IBRD) were also established under this agreement.

Sovereign

Domestic/External Debt: A central government's debt issued by the national government to domestic/foreign holders in a foreign currency in order to finance the issuing country's growth and development.

Currency Crises: When a country's central bank has insufficient foreign exchange reserves to maintain the country's fixed exchange rate.

Generalized Linear Model (GLM):

We started with implementing a full model (all the explanatory variables except independence and `gdp_weighted_default`) and applied stepwise selection to obtain the optimal step GLM model, which contains `domestic_debt_in_default`, `sovereign_external_debt_default` and `banking_crisis`. The deviance test between full model and stepwise model resulted a p-value of 0.6176. Therefore, we will use the smaller stepwise optimal model. The Dispersion parameter is 0.972 under quasibinomial family, which is reasonably close to 1 and indicates that over-dispersion is not an issue under the model. Because the explanatory variables are all binary, the choice of Link function between Logit and Probit is not likely to make a significant difference. We then plot the cook's distance and noticed 4 influential observations as in Figure 5. After refitting the optimal stepwise model with influential observations removed, we were able to conclude that `domestic_debt_in_default`, `sovereign_external_debt_default` and `banking_crisis` are statistically significant under the Generalized Linear Model.

Coefficients:

	Estimate	Std. Error	t value	Pr(> t)	
(Intercept)	-5.3666	0.5138	-10.445	< 2e-16	***
<code>domestic_debt_in_default</code> t1	-2.9563	0.8263	-3.578	0.000366	***
<code>sovereign_external_debt_default</code> t1	1.9723	0.6547	3.013	0.002666	**
<code>banking_crisis</code> 1	6.6971	0.5781	11.584	< 2e-16	***

Generalized Linear Mixed Model (GLMM):

We started with the implementing a full model (all explanatory variables except independence and `gdp_weighted_default`) and applied `drop1()` function to select the optimal model based on AIC. As noted in Figure 1, none of the countries had Systemic Crisis at the starting point.

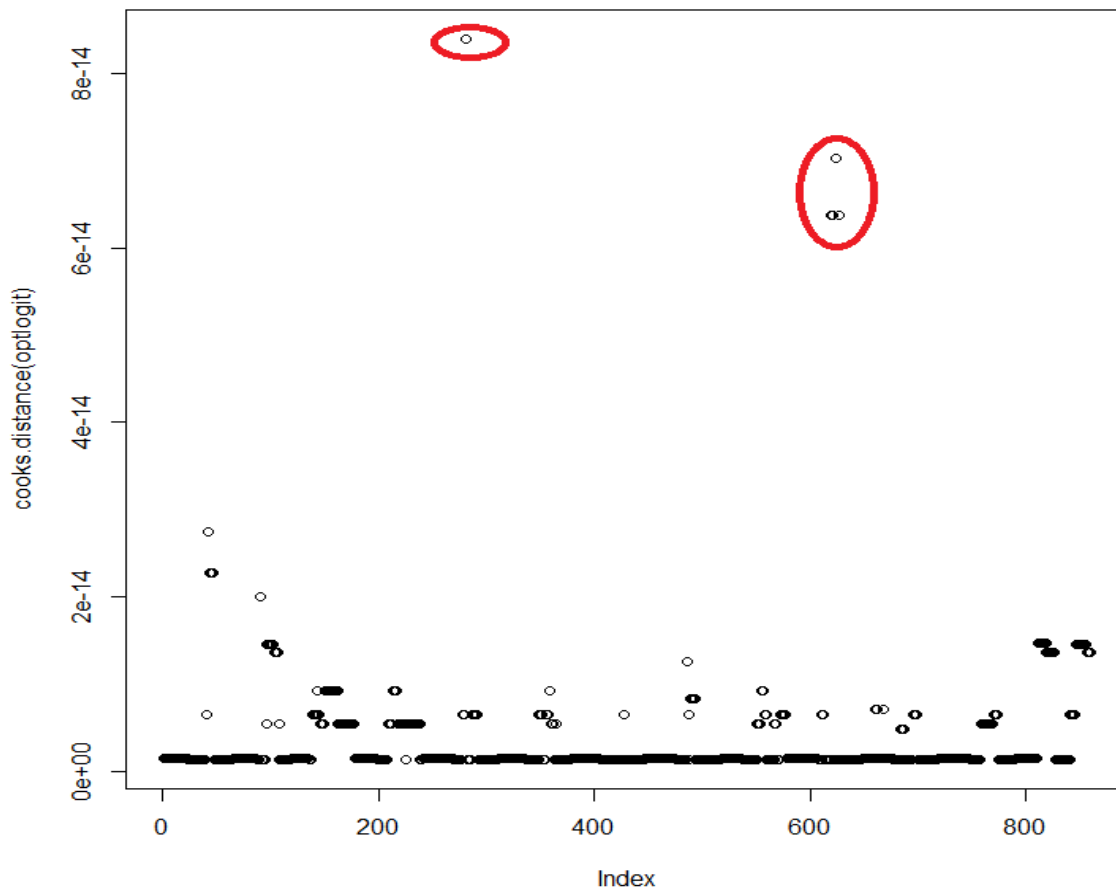


Figure 6: Cook's distance plot on step-wise selected GLM model.

Therefore, we will not fit a random effect on the intercept. Based on the optimal GLMM model, we can conclude that `domestic_debt_in_default`, `sovereign_external_debt_default` and `banking_crisis` are statistically significant under the Model.

	Value	Std.Error	DF	t-value	p-value
(Intercept)	-4.888952	0.3629891	841	-13.468591	0.0000
<code>domestic_debt_in_default1</code>	-2.447693	0.5666001	841	-4.319965	0.0000
<code>sovereign_external_debt_default1</code>	1.556383	0.3071720	841	5.066814	0.0000
<code>currency_crisis1</code>	0.373431	0.3174600	841	1.176310	0.2398
<code>inflation_crisis1</code>	-0.383163	0.3497263	841	-1.095607	0.2736
<code>banking_crisis1</code>	5.925981	0.2597745	841	22.812020	0.0000

Generalized Estimating Equation Model (GEE):

We fitted a GEE model using the same set of variables in the optimal GLMM model. By the logic of Economics, the Economy development along the time is not likely to be independent, especially when they are in the same region. Therefore, we chose the M-dependent correlation structure since adjacent time periods are likely to be related. As a result from model fitting, we conclude that `banking_crisis` is statistically significant under the Model.

Coefficients:

	Estimate	Robust S.E	Robust z	p-value
(Intercept)	0.002399	0.0021745	1.103402	0.2698
<code>domestic_debt_in_default1</code>	-0.018958	0.0453824	-0.417752	0.6761
<code>sovereign_external_debt_default1</code>	0.005576	0.0126659	0.440290	0.6597
<code>currency_crises1</code>	0.013766	0.0163094	0.844069	0.3986
<code>inflation_crises1</code>	-0.017398	0.0149719	-1.162052	0.2452
<code>banking_crisis1</code>	0.925106	0.0369459	25.03945	2.3006e-138

Final conclusions and discussions

Based on the results in the Exploratory Data Analysis and Confirmatory Data Analysis sections, we can conclude that: Banking Crisis and Debt Crisis (Sovereign Domestic/External Debt) are strongly associated with Systemic Crisis. Therefore, it is important for Government and Policy Makers to pay extra attention when a Banking Crisis occurs, as African Countries do not have a stable and secure financial system. Government Expenditure and Debt should also be carefully controlled.

We also made several important observations in this study:

1. Under the Bretton Woods Agreement (1944-1973), no Systemic Crisis occurred, and the exchange rate had been stable for the most of the African Countries.

2. There has been large variations in inflation CPI and exchange rate, and the magnitude of change can be huge in a short amount of time.

However, there are also several limitations for this study:

1. We do not have sufficient information for African Countries earlier than 1900.
2. The Crises variables in this dataset are all binary. As a result, the seriousness of these crisis cannot be measured and thus cannot be studied.
3. The conclusions in this study is not likely to be generalized to other countries, especially developed countries. First, the definition of crisis might not hold retrospectively. For example, in prior to the Bretton Wood System, currency wars were considered as an effective tool for boosting the Economy in Western European Countries. Depreciation of the currency can increase the export and boost the Economy. Therefore, an Inflation Crisis and dramatic change in Exchange Rate do not represent the same for African Countries, since Western Countries has a much more significant share in the International Trade.

Bretton Woods Dilemma

After reading this study, one might be interested in why not continue with the Bretton Woods System, as it is so effective in ensuring Financial Security. Unfortunately, despite that setting US dollar at 1/35 of an ounce of gold can stabilize the Economy, it also bonded the amount of currency in circulation by the production speed of gold, which has not significantly increased over the last century. When the Economy is growing rapidly, a large amount of currency in circulation is needed, and this is the most significant cause for the termination of the Bretton Woods System.