Journal of Empirical Studies
2018 Vol. 5, No. 1, pp. 20-44
ISSN(e): 2312-6248
ISSN(p): 2312-623X
DOI: 10.18488/journal.66.2018.51.20.44

LEADING INDICATORS AND FINANCIAL CRISIS: A MULTI-SECTORAL APPROACH USING SIGNAL EXTRACTION

Mpho Bosupeng[1]

[1]*Newcastle Business School, The University of Newcastle, 409 Hunter Street, Newcastle, NSW 2300, Australia*

Article History
Received: 15 October 2018
Revised: 21 November 2018
Accepted: 24 December 2018
Published: 2 January 2019

Keywords
Signal extraction
Financial crisis
Threshold
Indicator.

JEL Classification:
C53, G01.

ABSTRACT

Using signal extraction, this study identifies leading indicators of financial crisis over the period 1980-2015 in developing and advanced economies. The study evaluates vulnerability in the external, public and financial sector in developing countries. The results postulate that the level of imports is the principal leading indicator for detecting a forthcoming crisis in developing nation's external sector. In the public sector, the best indicators for predicting a crisis in South Africa are in the order: maturity of debt; external debt; debt-GDP ratio; interest rate payments; short-term debt and government expenditure. In Namibia, the best indicator for predicting crisis is total expenditure and interest rate payments. Comparatively, Russia's crises are better predicted by the following variables: debt ratio; interest rate payments; short-term debt; expenditure and external debt. The two best indicators were debt ratio and interest rate payments. In the financial sector, the common risk indicator among developing economies is the lending rate. The external balance sheet assessment shows that in developed countries, predictors of a financial emanate from portfolio investments and direct investments. For the UK, the best indicators of a looming financial crisis are: direct investment liabilities; portfolio debt liabilities and direct investment debt instruments.

Contribution/Originality: This study is one of the first contributions in early warning systems that assesses vulnerability in multiple sectors of an economy which are external, public and financial sectors. To the best of the author's knowledge, this study is also the first to determine external balance sheet assessment in developed nations.

1. INTRODUCTION

The 1997 Asian currency crises which began in Thailand sparked interest in developing early warning systems. The lack of foreign currency to support high foregin debt by the Thai government raised curiosity as to whether the crises could have been predicted. Kaminsky *et al.* (1998) postulate that there is a need to develop a warning system to monitor whether the country is on the brink of a crisis. Theoretical foundation of indicators of loooming crises is indicated by Krugman (1979) highlighting weaknesses in economic fundamentals. Krugman's model stipulate that under a fixed exchange rate regime, an increase in credit causes a decline in international reserves. A government attempting to prevent its currency from appreciating will experience high inflation.The loss in reserves causes a speculative attack on the local currency due to risk aversion and loss avoidance of investors charaterised by high capital outflows. Therefore the loss in international reserves is an indicator of a imminent crisis.

Simultaneously, an increase in domestic credit is a good signal for imminent crisis. The indicators of a looming currency are not limited to these factors only. High government expenditure induces domestic demand for money and this causes fiscal imbalances. Following Krugman, there have been many developments attempting to predict a crisis. Further studies show that when monetary policy implementation is transparent and predictable, a change in the exchange rate regime from fixed to float is led by a speculative attack since fixed exchange rates are backed with large reserves (Agenor *et al*., 1991). The change is an alarm to investors that the currency could collapse due to overvaluation. Nonetheless crisis vulnerability may develop without major changes in the trends of economic fundamental for example the subprime bubble during the 2007-2008 Global Financial Crisis (Kaminsky *et al*., 1998). Krugman also did not account for external conditions that can contribute to a crisis outbreak. Gulcin and Sutherland (1995) devised a model where under a fixed ecxchange rate regime, an increase in foreign interest rates induced high domestic interest rates and declining output. If the interest rate differential increases beyond the threshold, domestic output declines sharply therefore a change in regime is necessary. Therefore the output, and interest rate differential are indicators of a imminent crisis. Similary in the financial sector high interest rates disrupts the banking system by reducing lending. This may necessitate authorities to devalue the domestic currency or drastically reduce interest rates (Velasco, 1987; Kaminsky *et al*., 1998). The signals of a collapsing banking sytem include significant number of nonperforming loans, high central bank credit to banks and a sharp decline in deposits (Kaminsky *et al*., 1998). Expectations of a collapse of the fixed exchange rate regime, causes a decline in unemployment, higher wages and lagging output necessitating a change in regime for higher productivity (Obstfeld, 1994). In the course of the development of early warning systems, there is consensus that no matter the advancement of the model, the crises forecasts will be inaccurate (Abiad, 2003). Early procedures for prospecting a crisis are signal extraction and probit models. The signal approach is based on examining the trend of indicators (Kaminsky *et al*., 1998; Kaminsky, 1999; Kaminsky and Reinhart, 1999). The definition of a crisis is based on significant decline in reserves and depreciation of the domestic currency.

2. LITERATURE REVIEW

In the aftermath of the 2008 global financial crisis, which affected major advanced economies and developing countries, governments were forced to bail out and recapitalize their failing banking systems. Such intervention resulted in large fiscal deficits at the same time as their economies slowed after the burst of the property bubble. Due to failure to finance debt, many economies have find it increasingly important to construct financial monitoring tools that can forewarn the build-up of such financial turmoil (Dawood *et al*., 2017). Research on early warning sectors generally focuses on the vulnerabilities to the banking sector (Oet *et al*., 2013; Ionela, 2014; Kimmel *et al*., 2016; Coudert and Idier, 2017). Financial imbalance theory is the principal theory used to explain financial stress (Borio and Lowe, 2002a;2002b;2004; Borio and Drehmann, 2009; Oet *et al*., 2013). Financial imbalances are defined as deviations of financial variables from their mean, so they represent pressures in the financial system (Gramlich and Oet, 2011).

A systemic banking crisis could cost a significant portion of a country's Gross Domestic Product (GDP) (Davis and Karim, 2008). An Early Warning System (EWS) should assist policy makers in avoiding or reducing the effects of such a crisis (Dabrowski *et al*., 2016). A leading indicator is a variable that exhibits unusual behavior in the periods preceding a crisis (Kaminsky *et al*., 1998). Leading indicators are used in EWS for providing a warning of an imminent crisis. Various indicators include credit levels, asset prices, financial regulation, interest rates, exchange rates and GDP (Lainà *et al*., 2015). Ponomarenko (2013) applied recently developed early warning indicator systems to a cross section of emerging markets. The author employed the standard approach to the assessment of performance (Kaminsky *et al*., 1998). The signal was issued when the indicator of interest exceeds a threshold. According to the estimates, credit growth and investment turned out to be particularly reliable indicators for forecasting asset price cycle. Early warning indicator systems for emerging countries should account for capital

flows (Ponomarenko, 2013). According to Ari (2012) there are three main elements of an early warning system model: methodology, crisis index and explanatory variables. The logit/ probit models (Eichengreen *et al*., 1995; Frankel and Rose, 1996; Demirgüç-Kunt and Detragiache, 1998;2000; Tsai, 2013; Guru, 2016) the signal approach (Kaminsky *et al*., 1998; Kaminsky, 1999; Kaminsky and Reinhart, 1999; Oka, 2003) and the Markov-switching approach (Martinez-Peria, 2002) are the most common methods used in the literature. Other studies utilize a regression tree for example (Ghosh and Ghosh, 2003). The multivariate logit-probit seems to be more adequate for the construction of an EWS since it directly evaluates the conditional probability of a crisis given a set of early warning indicators (Abiad, 1999). Frost and Saiki (2014) postulates that capital account openness is associated with a lower probability of currency crises but not in emerging market economies.

Obstfeld *et al*. (2009a;2009b) found that reserves/M2 ratio predicted depreciations but not financial crises. There is evidence that reserves did not predict the 2008 Global Financial Crisis (Blanchard *et al*., 2009; Rose and Spiegel, 2009;2010;2011). Only Frankel and Saravelos (2012) support foreign currency reserves as an early warning signal for the 2008 financial crisis. Zigraiova and Jakubik (2015) postulates that early warning systems are better predictors of a looming crisis in the long-run over the short horizon. Potential crisis in financial markets were better predicted using the stock market instability index (Kim *et al*., 2009). While there has been significant progress predicting forthcoming crisis, there is a gap in the literature in evaluating crisis from a multi-sectoral perspective. Previous studies crisis prediction is often unrealiabe due to limited scope and not assessing various sectors of the economy. This study contributes by assessing three sectors of selected economies which are external, public and financial. To the best of the author's knowledge, this study is also the first to carry external balance sheet assessment for developed nations using the signal extraction approach.

2.1. The Real Effective Exchange Rate (REER) as an Ideal Indicator

The vulnerability of to a financial crisis is escalated in an economy with misaligned real exchange rates (Pastor, 1990). Edwards (1989) highlights the detrimental effect of the real exchange rate misalignment on macroeconomic stability. The author notes that exchange rate misalignment generates massive capital flight. Cuddington (1986) refers to capital flight as short-term speculative capital outflows. Dornbusch (1984) associated capital flight with the growth of debt. Macroeconomic instability anticipations causes capital outflows and repatriation induce large and rapid adjustments in both interest and exchange rates. The extent of the situation may lead to depletion of international reserves in defence of the domestic currency, which reduces domestic money supply (Cuddington, 1986). Capital flight also reduces tax base and this increases budget deficit and high costs of foreign borrowing (Cuddington, 1986). The ramifications of high capital flight is that it may not be possible to bring a reflow of capital by altering the domestic policies (Cuddington, 1986). Gouider and Nouira (2014) show that a strong undervaluation may discourage capital flight while a strong overvaluation can stimulate it. The results are similar to previous investigation by Hermes *et al*. (2002). The author noted that overvaluation of the real exchange rate creates expectations of depreciation of the domestic currency thereby increasing capital outflows.

The Smithsonian Agreement formulated in 1971 necessitated that developed nations should peg their currencies to the US dollar. The Nixon shock caused the collapse of the Bretton Woods System of fixed exchange rates among developed nations. The change led many developing countries to avoid their currencies to be determined by the market (Coudert and Couharde, 2009). To stimulate economic growth by stabilizing the REER, developing economies adopted crawling pegs and managed floating. The major concern for trade is to avoid instances of REER misalignment, which has economic growth implications. Misalignment is a common occurrence where the RER deviate substantially from the ideal or the equilibrium exchange rate. Lopez-Villavicencio *et al*. (2012) defines exchange rate misalignment as the gap in percentage between the observed exchange rates and the equilibirum exchange rate.Incidents of misalignment are escalated by globalisation and increasing financial and economic integration. For example, major currency crises in developing nations were instigated by the deviation of

the RER from the equilibrium such as 1994 Mexican Currency Crisis; 1997 Asian Currency Crises; and the 1999 Brazilian devaluation. Asian economies' currencies were significantly misaligned before the currency crisis (Jeong *et al*., 2010; El-Shagi *et al*., 2016).

In developed nations the RER is measured as "the ratio of the foreign to the domestic values of a broad-based price index such as CPI or the deflator for Gross Domestic Product (GDP) expressed in a common currency" (Hinkle and Montiel, 1999). Hinkle and Montiel (1999) define the RER in developing counties as "the relative price of traded goods in terms of non-traded (two good internal real exchange rate), or as the relative prices of exportable and importable goods in terms on non-traded goods (three-good internal real exchange rate) Hinkle and Montiel (1999). The real exchange rate is determined by both internal and external factors (Doroodian *et al*., 2002; Agbola and Kunanopparat, 2005). The equilibrium real exchange rate depends on the supply-side factors within the economy. Hinkle and Montiel (1999) argue that when accounting for the Balassa-Samuelson effect, rising demand of non-traded improves the trade balance, which eventually appreciates the real exchange rate. Government spending has the potential to appreciate the equilibrium exchange rate. For example, marginal spending of tax income on non-traded goods induces demand, which causes the real exchange rate to appreciate (Dumrongrittikul and Anderson, 2016). The effect changes in the case of traded goods as higher spending from tax income the real exchange rate to depreciate. Rising terms of trade improve the trade balance, which necessitate appreciation of the real exchange rate. Comparatively lower world interest rate causes the currency to depreciate. Trade policies such as liberalization create an excess supply in the non-traded-goods markets resulting in real exchange rate depreciation.

According to Kaminsky *et al.* (1998) the deviation of the real exchange rate has the best track record in anticipating an imminent crisis. When applying the Kaminsky *et al.* (1998) approach the variable also provides signals sufficiently in advance. The real exchange rate issues less bad signals and provides a higher percentage of goods signal as a percentage of all possible signals issued.

3. METHODOLOGY

3.1. Review of the Ari (2012) Probit Model

In order to determine the predictive power of capital flight for a forthcoming financial crisis, it is imperative to develop an early warning system. An effective early warning system should incorporate a broad variety of indicators since a financial crisis is usually preceded by multiple economic and political factors (Kaminsky *et al*., 1998). A disadvantage of probit analysis is that it lacks a signalling horizon. Ari (2012) proposed a probit model of the form:

$$Prob(C_t|\boldsymbol{X}_{t-k}\beta) = F(X_{t-k}\beta)$$

The definition of terms is as follows. C_t is the estimated probability of a crisis given a set of explanatory variables, $\boldsymbol{X}_{t-k}$. β is a vector of coefficients and F is the cumulative distribution function (Frankel and Rose, 1996; Ari, 2012). The independent variables include variables from the Public and Real Sector, The External Balance and Capital sector, and the Financial. In order to identify a crisis period, a crisis index ($ISP1$) composed of the real exchange rate, international reserves, and nominal interest rate changes is specified. These variables capture the dynamics of a common financial currency crisis, which is characterized by speculative attack, devaluation of the currency and declining reserves due to selling the domestic currency and raising domestic interest rates (Ari, 2012). The crisis index was specified as:

$$ISP1_t = \frac{1}{\sigma_{RER}}\left(\frac{RER_t - RER_{t-1}}{RER_{t-1}}\right) - \frac{1}{\sigma_{RES}}\left(\frac{RES_t - RES_{t-1}}{RES_{t-1}}\right) + \frac{1}{\sigma_{NIR}}(NIR_t - NIR_{t-1})$$

RER is the real exchange rate, RES is international reserves and NIR is nominal interest rates. The standard deviations of crisis index components are indicated as σ_{RER}, σ_{RER} and σ_{NIR}. The crisis threshold is equal to the crisis index mean (μ) plus three standard deviations of index. The binary crisis variable was expressed as:

$$C_t = \begin{cases} 1 & \text{if } ISP1_t > 3\sigma_{ISP1} + \mu_{ISP1} \\ 0 & \text{otherwise} \end{cases}$$

Due to a large selection of explanatory variables, there is a high chance of collinearity between the financial sector explanatory variables. Ari (2012) proposed a financial fragility index composed measuring credit risk, currency risk and a fall in bank deposits. The financial fragility index was expressed as:

$$IFF_t = \frac{1}{\sigma_{BLOAN}}\left(\frac{BLOAN_t - BLOAN_{t-1}}{BLOAN_{t-1}}\right) - \frac{1}{\sigma_{BDEPO}}\left(\frac{BDEPO_t - BDEPO_{t-1}}{BDEPO_{t-1}}\right) + \frac{1}{\sigma_{BFXLIAB}} \times \left(\frac{BFXLIAB_t - BFXLIAB_{t-1}}{BFXLIAB_{t-1}}\right) + \varepsilon_t$$

$BLOAN$ is the bank loans to the private sector, $BDEPO$ is bank deposits and $BFXLIAB_t$ is bank's foreign liabilities. σ_{BLOAN},$\sigma_{BFXLIAB}$, σ_{BDEPO} are standard deviations of the components of the fragility index.

3.2. The Signal Extraction Model and Data

The study uses annual data from 1980 to 2015 from various sectors of the economy (see Appendix). Developing nations under this analysis are South Africa, China, Russia and Namibia. Advanced economies include Germany, Belgium, Switzerland, United States, United Kingdom and Norway. The signal extraction proposed by Andreou *et al.* (2009) will be followed to predict a forthcoming financial crisis. The signal extraction approach is chosen because the model develops earlier studies proposed by Kaminsky *et al.* (1998); Berg and Patillo (1999); Goldstein *et al.* (2000) and Edison (2003). The paper contributes by evaluating in-depth crisis vulnerability in multiple sectors of selected developing economies. We further examine external balance sheet exposures in developed nations. Kaminsky *et al.* (1998) defines a crisis as a situation characterized by a sharp depreciation of the currency and a large decline in international reserves. Following Andreou *et al.* (2009) the market pressure is observed when the real exchange rate depreciates and there are reserve losses. Thus a crisis is defined is defined as:

$$crisis_t = \begin{cases} 1 & if\ IND_t \geq c \\ 0 & otherwise \end{cases}$$

A crisis occurs when pressures in the exchange rate market and foreign reserves losses are significantly high or below the threshold. IND represents a macroeconomic variable which acts as an indicator for a potential crisis while c represents the threshold parameter. The threshold parameter is thus defined as:

$$c = \overline{IND} + \delta\sigma_{IND}$$

$\overline{IND}$ is the empirical mean of IND and σ_{IND} is the standard deviation. Thus a crisis occurs when the indicator is δ standard deviations above its mean. Following Andreou *et al.* (2009) δ value of 0.75 is viable since it captures most of the pressures examined.

Computing Noise-to Signal Ratio for a Single Indicator

A crisis is predicted based on the performance of macroeconomic variables. A signal S_t is issued by a macroeconomic variable IND_t if its absolute value is greater than the mean.

$$S_t = \begin{cases} 1 & if\ |IND_t| > \overline{IND} \\ 0 & |IND_t| < \overline{IND} \end{cases}$$

A signal horizon of two years is considered in this study due to ease of access of annual data. Andreou *et al.* (2009) defines a signal horizon as the time at which a variable is expected to predict a crisis.The effectiveness of individual indicator's performance would be determined by the performance matrix below (Kaminsky *et al.*, 1998).

Indicator Performance Matrix

	Crisis (within 2 years)	No Crisis (within 2 years)
Signal was issued	A	B
No signal was issued	C	D

Following Kaminsky *et al.* (1998) element A is the number of years where the indicator issued a good signal (signal issued, crisis) while B is the number of years in which the indicator issued a bad signal or noise (signal issued, no crisis). Component C represents the number of years in which the indicator failed to issue a good signal (no signal issued, crisis) and D is the number of months in which the indicator refrained from issuing a signal (no signal issued, no crisis). An ideal indicator would only have elements A and D of the performance matrix. This would mean they are no instances where the indicator issued a false signal (B) and or fails to signal a forthcoming crisis (C).

The first evaluation measures the tendency of individual indicators to issue good signals (A= signal issued, crisis). The performance measure evaluates the number of good signals issued by the indicator as a percentage of the number of years in which good signals could have been issued. The evaluation is depicted as A/(A+C). The frequency of bad indicators produced by a signal is critical for predicting a forthcoming crisis. This will be evaluated by the ratio B/ (B+D), which shows the number of bad signals issued as a percentage of all possible bad signals. The ratio of bad signals to good signals can be expressed as a ratio to evaluate the extent to which an indicator produces false alarms in proportion to good signals. This ratio is B/ (B+D)/A/ (A+C). The unconditional probability of a crisis less the unconditional (A/ (A+B) will be used in the evaluation of the best indicators that predict a crisis (A+C)/ (A+B+C+D). The expression is A/ (A+B)-(A+C)/ (A+B+C+D). The criteria for selecting

the best indicator is that the indicator should have the lowest percentage of bad signals (B/ (B+D)) and noise-to signal ratio B/ (B+D)/A/ (A+C). In addition, the ideal indicator would also have a high conditional probability over unconditional probability. Three sectors are examined in this study, which are external, public and financial.

The External Sector

Following Ahuja *et al.* (2017) this sector aims to detect exchange rate misalignments; external imbalances and external balance sheet exposures in emerging markets. Economic variables to be examined here are current account balance; external debt to exports; reserve coverage.

Public Sector

This sector will examine the solvency of an emerging market economy by evaluating liquidity and expenditure. Variables to be examined in this sector are public debt; average maturity of debt; interest expense and public external debt.

Financial Sector

This sector evaluates the stability of the financial sector. An unstable banking sector raises the probability of a financial breakdown. Indicators to be evaluated are foreign liability capital adequacy ratio; return on assets; loan to deposit ratio and credit to GDP. Each sector's vulnerability index will be constructed as a weighted average of individual indicators, with weights derived from the indicator's signal-noise ratio. The index ranges between zero (low vulnerability) and one (high vulnerability) for each economy.

4. EMPIRICAL RESULTS

The results of the signal extraction postulate that in the external sector the primary indicator for detecting a forthcoming crisis is imports. The indicator has predicted 100% of crisis events registered in 2 years for South Africa and Namibia. In Russia, the indicator correctly predicted 85% of the crises. The adjusted noise to signal ratio ranged between 0.10 and 0.20 for South Africa, Russia and Namibia, which depicts a high intrinsic predictive power. In comparison, China has no ideal indicators to predict an imminent crisis in the external sector.

In the public sector the best indicators for predicting a crisis in South Africa are in the order: maturity of debt; external debt; debt-GDP ratio; interest rate payments; short-term debt and expenditure as a percentage of GDP. In comparison to the external sector, the public sector has more indicators that are viable for crisis prediction in all the economies examined. The average maturity of debt in South Africa is the best indicator with no record of bad signals or noise. The indicator also has a significantly low noise to signal ratio due to a zero record of bad signals. Therefore, the indicator has high predictive capabilities of a crisis.

Comparatively, the best indicators for predicting financial crises in China were in the order external debt; short-term debt and maturity of debt. External debt demonstrated the lowest percentage of bad signals and lowest noise-signal ratio of 0.11534 thus exhibiting strong intrinsic predictive power. In Namibia, the best indicator for predicting crisis was total expenditure and interest rate payments. Comparatively, Russia's crises are better predicted by the following variables: debt ratio; interest rate payments; short-term debt; expenditure and external debt. The two best indicators were debt ratio and interest rate payments.

In the financial sector, the common risk indicator among the economies examined is the lending rate. The key risk indicators for South Africa are the risk premium, lending rate and the real interest rate. The ideal indicator for risks in the financial sector for China was the lending rate followed by the interest rate spread whereas in Russia the refinancing rate was the best indicator. Comparatively, Namibia's interest rate spread is the ideal indicator with the lowest noise-signal ratio. Other significant indicators are the risk premium, real interest rate and the lending rate.

Signal Extraction – Public Sector Results

Table-1. Performance of Indicators Under the Signal Approach South Africa (1980-2015)

	Number of crises for which there are data	Percentage of crises called[a]	Good signals as percentage of possible good signals	Bad signals as percentage of possible bad signals	Noise/ signal (adjusted)[b]	P(crisis /signal)[c]	P(crisis /signal)- P(crisis)[d]
In terms of the matrix in the text			A/(A+C)	B/(B+D)	B/(B+D)/ A/(A+C)	A/(A+B)	A/(A+B)-(A+C)/ (A+B+C+D)
GDP	26	7.69	15.39	100	6.50	28.57	-43.65
Terms of Trade	27	3.70	7.41	100	13.50	18.18	-56.82
Imports	10	100	100	11.54*	0.12*	76.92	49.15*
Exports	25	20	28	100	3.55	38.90	-11.11
Openness	26	26.92	23.08	100	4.33	37.50	-34.72
Reserves	28	28.57	21.43	100	4.70	42.86	-34.92
Current Account	26	96.15	100	100	1	72.22	0
REER	31	38.71	35.48	100	2.82	68.75	-17.36

GDP (A= 4 B=10 C=22 D=0); Terms of Trade (A= 2 B=9 C=25 D=0); Imports (A=26 B=10 C=0 D=0); Exports (A=7 B=11 C=18 D=0); Openness (A=6 B=10 C=20 D=0); Reserves (A=6 B=8 C=22 D=0); REER (A=11 B=5 C=20 D=0). [a]Percentage of crises in which the indicator issued at least one signal in the previous 2 years, out of the total number of crises for which data are available. [b]Ratio of false signals (measured as a proportion of months in which false signals could have been issued) to good signal (measured as a proportion of months in which good signals could have been issued). [c]Percentage of the signals issued by the indicator that were followed by at least one crisis. [d]P(crisis) is the unconditional probability of a crisis, (A+C)/ (A+B+C+D) in terms of the matrix.

Tables-2. Performance of Indicators under the Signal Approach China (1982-2015)

	Number of crises for which there are data	Percentage of crises called[a]	Good signals as percentage of possible good signals	Bad signals as percentage of possible bad signals	Noise /signal (adjusted)[b]	P(crisis /signal)[c]	P(crisis/signal)- P(crisis)[d]
In terms of the matrix in the text			A/(A+C)	B/(B+D)	B/(B+D)/A/ (A+C)	A/(A+B)	A/(A+B)- (A+C)/(A+B+C+D)
Terms of Trade	28	39.29	35.71	100	2.80	62.50	-19.85
GDP	16	0	0	66.70	0	0	-47.06
Current Account	26	7.69	11.54	100	8.67	27.27	-49.20
REER	30	20	20	100	5	60	-28.24
Reserves	26	7.69	11.54	100	8.67	27.27	-49.20
Openness	25	20	28	100	3.57	43.75	-29.78

Terms of Trade: (A=10 B=6 C=18 D=0); GDP (A=0 B=12 C=16 D=6); Current Account (A=3 B=8 C=23 D=0); REER (A=6 B=4 C=24 D=0); Reserves (A=3 B=8 C=23 D=0); Openness (A=7 B=9 C=18 D=0). [a]Percentage of crises in which the indicator issued at least one signal in the previous 2 years, out of the total number of crises for which data are available. [b]Ratio of false signals (measured as a proportion of months in which false signals could have been issued) to good signal (measured as a proportion of months in which good signals could have been issued). [c]Percentage of the signals issued by the indicator that were followed by at least one crisis. [d]P(crisis) is the unconditional probability of a crisis, (A+C)/ (A+B+C+D) in terms of the matrix.

Table-3. Performance of Indicators Under the Signal Approach Russia (1994-2015)

	Number of crises for which there are data	Percentage of crises called[a]	Good signals as percentage of possible good signals	Bad signals as percentage of possible bad signals	Noise/signal (adjusted)[b]	P(crisis /signal)[c]	P(crisis /signal)-P(crisis)[d]
In terms of the matrix in the text			A/(A+C)	B/(B+D)	B/(B+D)/A /(A+C)	A/(A+B)	A/(A+B)-(A+C)/(A+B+C+D)
Imports	7	85.71	100	20*	0.20*	70	38.18*
GDP	15	13.33	26.67	100	3.75	36.36	-31.82
Current Account	17	29.41	35.29	100	2.83	54.55	-22.73
REER	16	18.75	31.25	100	3.20	45.45	-27.27
Reserves	19	36.84	42.11	100	2.38	72.73	-13.64
Openness	17	35.29	29.41	100	3.40	50	-27.27
Exports	14	14.29	28.57	100	3.50	33.33	-30.30

Imports (A=7 B=3 C=0 D=12); GDP(A=4 B=7 C=11 D=0); Current Account (A=6 B=5 C=11 D=0); REER (A=5 B=6 C=11 D=0); Reserves (A=8 B=3 C=11 D=0); Openness (A=5 B=5 C=12 D=0); Exports (A=4 B=8 C=10 D=0). [a]Percentage of crises in which the indicator issued at least one signal in the previous 2 years, out of the total number of crises for which data are available. [b]Ratio of false signals (measured as a proportion of months in which false signals could have been issued) to good signal (measured as a proportion of months in which good signals could have been issued). [c]Percentage of the signals issued by the indicator that were followed by at least one crisis. [d]P(crisis) is the unconditional probability of a crisis, (A+C)/ (A+B+C+D) in terms of the matrix.

Table-4. Performance of Indicators Under the Signal Approach Namibia (1990-2015)

	Number of crises for which there are data	Percentage of crises called[a]	Good signals as percentage of possible good signals	Bad signals as percentage of possible bad signals	Noise /signal (adjusted)[b]	P(crisis /signal)[c]	P(crisis /signal)-P(crisis)[d]
In terms of the matrix in the text			A/(A+C)	B/(B+D)	B/(B+D)/A /(A+C)	A/(A+B)	A/(A+B)-(A+C)/(A+B+C+D)
Openness	21	23.81	23.81	100	4.2	50	-30.77
Terms of Trade	16	0	6.25	100	16	9.09	-52.45
Exports	17	5.88	17.65	100	5.67	25	-40.38
Imports	7	100	100	10.53*	0.11*	77.78	50.85*
GDP	20	20	30	100	3.33	50	-26.92
Current Account	23	91.30	100	100	1	88.42	- 0.05
Reserves	24	91.67	100	100	1	92.31	0

Openness (A=5 B=5 C=16 D=0); Terms of Trade (A=1 B=10 C=15 D=0); Exports (A=3 B=9 C=14 D=0); Imports (A=7 B=2 C=0 D=17); GDP (A=6 B=6 C=14 D=0); Current Account (A=23 B=3 C=0 D=0); Reserves (A=24 B=2 C=0 D=0). [a]Percentage of crises in which the indicator issued at least one signal in the previous 2 years, out of the total number of crises for which data are available. [b]Ratio of false signals (measured as a proportion of months in which false signals could have been issued) to good signal (measured as a proportion of months in which good signals could have been issued). [c]Percentage of the signals issued by the indicator that were followed by at least one crisis. [d]P(crisis) is the unconditional probability of a crisis, (A+C)/ (A+B+C+D) in terms of the matrix.

Signal Extraction – Public Sector Results

Table-1. Performance of Indicators Under the Signal Approach South Africa (1975-2015)

	Number of crises for which there are data	Percentage of crises called[a]	Good signals as percentage of possible good signals	Bad signals as percentage of possible bad signals	Noise/signal (adjusted)[b]	P(crisis/signal)[c]	P(crisis/signal)-P(crisis)[d]
In terms of the matrix in the text			A/(A+C)	B/(B+D)	B/(B+D)/A/(A+C)	A/(A+B)	A/(A+B)-(A+C)/(A+B+C+D)
Debt-GDP	14	78.57	100	14.81*	0.13*	77.78	43.63*
External Debt	9	100	100	12.50*	0.13*	69.23	47.28*
Short-term Debt[1]	12	83.33	100	34.48*	0.34*	54.55	25.28*
Interest Payments[2]	10	100	100	32.26*	0.32*	50	25.61*
Maturity of Debt	10	60	100	0*	0*	100	75.61*
Expenditure[3]	8	87.50	100	48.48*	0.48*	33.33	13.82*
Tax Revenue[4]	30	33.33	36.67	100	2.73	50	-23.17

[1]as % of total external debt; [2] as % of total expenses; [3, 4]as % of GDP; Debt-GDP (A=14 B=4 C=0 D=23); External Debt (A=9 B=4 C=0 D=28); Interest Payments (A=10 B=10 C=0 D=21); Short-term Debt (A=12 B=10 C=0 D=19); Average Maturity (A=10 B=0 C=0 D=31); Expenditure (% GDP) (A=8 B=16 C=0 D=17); Tax Revenue (A=11 B=11 C=10 D=0). [a]Percentage of crises in which the indicator issued at least one signal in the previous 2 years, out of the total number of crises for which data are available. [b]Ratio of false signals (measured as a proportion of months in which false signals could have been issued) to good signal (measured as a proportion of months in which good signals could have been issued). [c]Percentage of the signals issued by the indicator that were followed by at least one crisis. [d]P(crisis) is the unconditional probability of a crisis, (A+C)/ (A+B+C+D) in terms of the matrix.

Table-2. Performance of Indicators Under the Signal Approach China (1984-2015)

	Number of crises for which there are data	Percentage of crises called[a]	Good signals as percentage of possible good signals	Bad signals as percentage of possible bad signals	Noise/signal (adjusted)[b]	P(crisis/signal)[c]	P(crisis/signal)-P(crisis)[d]
In terms of the matrix in the text			A/(A+C)	B/(B+D)	B/(B+D)/A/(A+C)	A/(A+B)	A/(A+B)-(A+C)/(A+B+C+D)
Short-term Debt[1]	9	100	100	26.09*	0.26*	60	31.88*
Debt-GDP	7	100	100	56	0.56*	33.33	11.46*
Maturity of Debt	7	57.14	100	28*	0.28*	50	28.13*
External Debt	6	100	100	11.54*	0.12*	66.67	47.92*

[1]as % of total external debt; Short term Debt (A=9 B=6 C=0 D=17); Debt-GDP (A=7 B=14 C=0 D=11); Average Maturity of Debt (A=7 B=7 C=0 D=18); External Debt (A=6 B=3 C=0 D=23). [a]Percentage of crises in which the indicator issued at least one signal in the previous 2 years, out of the total number of crises for which data are available. [b]Ratio of false signals (measured as a proportion of months in which false signals could have been issued) to good signal (measured as a proportion of months in which good signals could have been issued). [c]Percentage of the signals issued by the indicator that were followed by at least one crisis. [d]P(crisis) is the unconditional probability of a crisis, (A+C)/ (A+B+C+D) in terms of the matrix.

Table-3. Performance of Indicators Under the Signal Approach Russia (1995-2015)

	Number of crises for which there are data	Percentage of crises called[a]	Good signals as percentage of possible good signals	Bad signals as percentage of possible bad signals	Noise/signal (adjusted)[b]	P(crisis /signal)[c]	P(crisis /signal)-P(crisis)[d]
In terms of the matrix in the text			A/(A+C)	B/(B+D)	B/(B+D)/A/(A+C)	A/(A+B)	A/(A+B)-(A+C)/(A+B+C+D)
Debt-GDP	3	33.33	100	14.29*	0.14*	60	42.35*
Maturity of Debt	1	0	100	62.50	0.63	9.91	4.03*
Short-term Debt[1]	3	33.33	100	21.43*	0.21*	50	32.35*
Interest Payments[2]	3	33.33	100	14.29*	0.14*	60	42.35*
External Debt	4	100	100	38.46	0.38*	44.44	20.91*
Expenditure[3]	3	33.33	100	21.43*	0.21	50	32.35*
Tax Revenue[4]	12	25	0	100	0	0	0

[1]as % of total external debt; [2] as % of total expenses; [3, 4]as % of GDP. Debt-GDP (A=3 B=2 C=0 D=12); Average Maturity of Debt (A=1 B=10 C=0 D=6); Short-term Debt (A=3 B=3 C=0 D=11); Interest Payments (A=3 B=2 C=0 D=12); External Debt (A=4 B=5 C=0 D=8); Expenditure (% of GDP) (A=3 B=3 C=0 D=11); Tax Revenue (A=0 B=5 C=12 D=0). [a]Percentage of crises in which the indicator issued at least one signal in the previous 2 years, out of the total number of crises for which data are available. [b]Ratio of false signals (measured as a proportion of months in which false signals could have been issued) to good signal (measured as a proportion of months in which good signals could have been issued). [c]Percentage of the signals issued by the indicator that were followed by at least one crisis. [d]P(crisis) is the unconditional probability of a crisis, (A+C)/ (A+B+C+D) in terms of the matrix

Table-4. Performance of Indicators Under the Signal Approach Namibia (1999-2015)

	Number of crises for which there are data	Percentage of crises called[a]	Good signals as percentage of possible good signals	Bad signals as percentage of possible bad signals	Noise/signal (adjusted)[b]	P(crisis /signal)[c]	P(crisis /signal)-P(crisis)[d]
In terms of the matrix in the text			A/(A+C)	B/(B+D)	B/(B+D)/A/(A+C)	A/(A+B)	A/(A+B)-(A+C)/(A+B+C+D)
Debt-GDP	3	66.67	100	50	0.50	30	12.35
Interest Payments[1]	4	100	100	38.46*	0.38*	44.44	20.91*
Expenditure[2]	4	75	100	30.77*	0.307692*	50	26.47*
Tax Revenue[3]	13	23.08	30.77	100	3.25	50	-26.47

[1] as % of total expenses; [2,3]as % of GDP; Debt-GDP (A=3 B=7 C=0 D=7); Interest Payments (A=4 B=5 C=0 D=8); Expenditure (%GDP) (A=4 B=4 C=0 D=9); Tax Revenue (A=4 B=4 C=9 D=0). [a]Percentage of crises in which the indicator issued at least one signal in the previous 2 years, out of the total number of crises for which data are available. [b]Ratio of false signals (measured as a proportion of months in which false signals could have been issued) to good signal (measured as a proportion of months in which good signals could have been issued). [c]Percentage of the signals issued by the indicator that were followed by at least one crisis. [d]P(crisis) is the unconditional probability of a crisis, (A+C)/ (A+B+C+D) in terms of the matrix.

Signal Extraction – Financial Sector Results

Table-5. Performance of Indicators Under the Signal Approach South Africa (1980-2015)

	Number of crises for which there are data	Percentage of crises called[a]	Good signals as percentage of possible good signals	Bad signals as percentage of possible bad signals	Noise/ signal (adjusted)[b]	P(crisis /signal)[c]	P(crisis /signal)-P(crisis)[d]
In terms of the matrix in the text			A/(A+C)	B/(B+D)	B/(B+D)/A/(A+C)	A/(A+B)	A/(A+B)-(A+C)/(A+B+C+D)
Risk Premium[1]	9	66.67	100	25.93*	0.26*	56.25	31.25*
R. Interest Rate[2]	6	100	100	40*	0.40*	33.33	16.67*
Treasury Bill R[3]	27	37.04	25.93	100	3.86	43.75	-31.25
MMR[4]	27	33.33	22.22	100	4.50	40	-35.00
Lending Rate	10	80	100	30.77*	0.31*	55.56	27.78*

[1]Risk Premium on lending (A=9 B=7 C=0 D=20); [2]Real Interest Rate (A= 6 B=12 C=0 D=18); [3]Treasury Bill Rate (A=7 B=9 C=20 D=0); [4]Money Market Rate (A=6 B=9 C=21 D=0); Lending Rate (A=10 B=8 C=0 D=18). [a]Percentage of crises in which the indicator issued at least one signal in the previous 2 years, out of the total number of crises for which data are available. [b]Ratio of false signals (measured as a proportion of months in which false signals could have been issued) to good signal (measured as a proportion of months in which good signals could have been issued). [c]Percentage of the signals issued by the indicator that were followed by at least one crisis. [d]P(crisis) is the unconditional probability of a crisis, (A+C)/ (A+B+C+D) in terms of the matrix.

Table-6. Performance of Indicators Under the Signal Approach China (1980-2015)

	Number of crises for which there are data	Percentage of crises called[a]	Good signals as percentage of possible good signals	Bad signals as percentage of possible bad signals	Noise/signal (adjusted)[b]	P(crisis/signal)[c]	P(crisis/signal)-P(crisis)[d]
In terms of the matrix in the text			A/(A+C)	B/(B+D)	B/(B+D)/A/(A+C)	A/(A+B)	A/(A+B)-(A+C)/(A+B+C+D)
I.R. Spread[1]	13	100	100	30.43*	0.30*	65	28.89*
R. Interest Rate[2]	8	62.50	100	67.86	0.68	29.63	7.41
Lending Rate	7	100	100	24.14*	0.24*	50	30.56*
Deposit Rate	27	33.33	33.33	100	3	50	-25

[1]Interest Rate Spread (A= 13 B=7 C=0 D=16); [2]Real Interest Rate (A=8 B=19 C=0 D=9); Lending Rate (A=7 B=7 C=0 D=22); Deposit Rate (A=9 B=9 C=18 D=0); [a]Percentage of crises in which the indicator issued at least one signal in the previous 2 years, out of the total number of crises for which data are available. [b]Ratio of false signals (measured as a proportion of months in which false signals could have been issued) to good signal (measured as a proportion of months in which good signals could have been issued). [c]Percentage of the signals issued by the indicator that were followed by at least one crisis. [d]P(crisis) is the unconditional probability of a crisis, (A+C)/ (A+B+C+D) in terms of the matrix.

Table-7. Performance of Indicators under the Signal Approach Russia (1995-2015)

	Number of crises for which there are data	Percentage of crises called[a]	Good signals as percentage of possible good signals	Bad signals as percentage of possible bad signals	Noise/signal (adjusted)[b]	P(crisis /signal)[c]	P(crisis /signal)-P(crisis)[d]
In terms of the matrix in the text			A/(A+C)	B/(B+D)	B/(B+D)/A/(A+C)	A/(A+B)	A/(A+B)-(A+C)/(A+B+C+D)
Deposit Rate	19	21.05	10.53	100	9.50	50	-40.48
Refinancing Rate	3	66.67	100	11.11*	0.11*	60	45.71*
Lending Rate	2	0	100	10.53*	0.11*	50	40.48*
MMR[1]	20	1	1	100	0	0	-95.24

Deposit Rate (A=2 B=2 C=17 D=0); Refinancing Rate (A=3 B=2 C=0 D=16); Lending Rate (A=2 B=2 C=0 D=17); [1]Money Market Rate (A=0 B=1 C=20 D=0). [a]Percentage of crises in which the indicator issued at least one signal in the previous 2 years, out of the total number of crises for which data are available. [b]Ratio of false signals (measured as a proportion of months in which false signals could have been issued) to good signal (measured as a proportion of months in which good signals could have been issued). [c]Percentage of the signals issued by the indicator that were followed by at least one crisis. [d]P(crisis) is the unconditional probability of a crisis, (A+C)/ (A+B+C+D) in terms of the matrix.

Table-8. Performance of Indicators Under the Signal Approach Namibia (1992-2015)

	Number of crises for which there are data	Percentage of crises called[a]	Good signals as percentage of possible good signals	Bad signals as percentage of possible bad signals	Noise/signal (adjusted)[b]	P(crisis /signal)[c]	P(crisis /signal)-P(crisis)[d]
In terms of the matrix in the text			A/(A+C)	B/(B+D)	B/(B+D)/A /(A+C)	A/(A+B)	A/(A+B)-(A+C)/(A+B+C+D)
I.R. Spread[1]	10	60	100	7.69*	0.07*	90	49.09*
R. Interest Rate[2]	6	50	100	25*	0.25*	60	32.73*
Lending Rate	7	71.43	100	26.67*	0.27*	63.64	31.82*
Deposit Rate	16	31.25	25	100	4	40	-32.73
Risk Premium	6	50	100	25*	0.25*	60	32.73*
Treasury Bill Rate	16	37.50	31.25	100	3.20	45.45	-27.27

[1]Interest Rate Spread (A=9 B=1 C=0 D=12); [2]Real Interest Rate (A=6 B=4 C=0 D=12); Lending Rate (A=7 B=4 C=0 D=11); Deposit Rate (A=4 B=6 C=12 D=0); Risk Premium (A=6 B=4 C=0 D=12); Treasury Bill Rate (A=5 B=6 C=11 D=0); [a]Percentage of crises in which the indicator issued at least one signal in the previous 2 years, out of the total number of crises for which data are available. [b]Ratio of false signals (measured as a proportion of months in which false signals could have been issued) to good signal (measured as a proportion of months in which good signals could have been issued). [c]Percentage of the signals issued by the indicator that were followed by at least one crisis. [d]P(crisis) is the unconditional probability of a crisis, (A+C)/ (A+B+C+D) in terms of the matrix.

Following Ahuja *et al.* (2017) for each sector a vulnerability index is constructed as a weighted average of individual indicators from the indicator's signal-to noise ratio. This index ranges between 0 and 1 with 1 depicting high vulnerability. The weights are given by each indicator's signal-to noise ratio. A high aggregate risk index depicts high of a capital account crisis. The countries evaluated here are faced with low capital account risks.

Table-9. Risk Index Aggregation

Country	Sector	Sectoral Index	Aggregate Index
South Africa	External	0.38	0.30
	Public	0.27	
	Financial	0.26	
China	External	0.80	0.43
	Public	0.22	
	Financial	0.28	
Russia	External	0.44	0.25
	Public	0.18	
	Financial	0.12	
Namibia	External	0.40	0.34
	Public	0.24	
	Financial	0.38	

Source: Author's calculations

External Balance Sheet Exposures in Developed Countries

The signal extraction approach is also applied to evaluate vulnerabilities to external and financial crises by examining balance sheet indicators that provide early warning of past crisis in advanced economies. The focus is on financial assets and liabilities from the financial account. According to Ahuja *et al.* (2017) these indicators are significant predictors of a crisis. The variables examined include assets and liabilities of net foreign assets, direct investment; portfolio investment; equity and debt instruments.

The external balance sheet assessment shows that in developed countries predictors of a financial emanate from portfolio investments and direct investments. For UK, the best indicators are in the order: direct investment liabilities; portfolio debt liabilities and direct investments debt instruments. The three indicators registered the lowest noise to signal ratio. Similarly, in Norway, portfolio debt liabilities, direct investment debt instruments liabilities and direct investment equity liabilities were registered significant indicators. In comparison, direct investment debt instrument liabilities were the best predictors of a financial crisis in Germany and Belgium. However, in the US, portfolio debt instrument liabilities and direct investment debt instrument liabilities were the best risk indicators. Ideal indicators for risk assessment in Switzerland were direct investment equity liabilities and total direct investment liabilities. However, in the US, portfolio debt instrument liabilities and direct investment debt instrument liabilities were the best risk indicators.

Signal Extraction: External Balance Sheet Exposure

Table-10. External Balance Sheet Exposure Assessment-Germany (1980-2015)

	Number of crises for which there are data	Percentage of crises called	Good signals as percentage of possible good signals	Bad signals as percentage of possible bad signals	Noise/signal (adjusted)	P(crisis /signal)	P(crisis /signal)-P(crisis)
In terms of the matrix in the text			A/(A+C)	B/(B+D)	B/(B+D)/A/(A+C)	A/(A+B)	A/(A+B)-(A+C)/(A+B+C+D)
Portfolio Invest. (PL)	8	75	100	32.14*	0.32*	47.06	24.84*
Equity & Invest. (PL)	5	80	100	35.48*	0.35*	31.25	17.36*
Debt Instrument (PL)	6	83.33	100	43.33*	0.43*	31.58	14.91*
Direct Invest. (DL)	5	20	100	29.03*	0.29*	35.71	21.83*
Equity & Invest. (DL)	6	66.67	100	23.33*	0.23*	46.15	29.49*
Debt Instrument (DL)	9	77.78	100	22.22*	0.22*	60	35*
Portfolio Invest. (PA)	27	29.62	22.22	100	4.5	40	-35
Equity & Invest. (PA)	29	31.03	27.59	100	3.63	53.33	-27.22
Debt Instruments (PA)	28	32.14	21.43	100	4.67	42.86	-34.92
Direct Invest. (DA)	24	12.5	16.67	100	6	25	-41.67
Equity & Invest. (DA)	26	23.08	19.23	100	5.2	33.33	-38.88
Debt Instrument (DA)	27	25.93	29.63	100	3.38	47.06	-27.94
Net foreign Assets	6	0	0	100	0	0	-40
Other Invest. Assets	29	34.48	34.48	100	2.90	58.82	-21.73

PL= Portfolio Investment Liabilities; DL= Direct Investment Liabilities; PA= Portfolio Investment Assets; DA= Direct Investment Assets. Portfolio Invest. (PL) (A=8 B=9 C=0 D=19); Equity & Invest. (PL) (A=5 B=11 C=0 D=20); Debt Instrument (PL) (A=6 B=13 C=0 D=17); Direct Invest. (DL) (A=5 B=9 C=0 D=22); Equity & Invest. (DL) (A=6 B=7 C=0 D=23); Debt Instrument (DL) (A=9 B=6 C=0 D=21); Portfolio Invest. (PA) (A=6 B=9 C=21 D=0); Equity & Invest. (PA) (A=8 B=7 C=21 D=0); Debt Instruments (PA) (A=4 B=12 C=20 D=0); Direct Invest. (DA) (A=4 B=12 C=20 D=0); Equity & Invest. (DA) (A=5 B=10 C=21 D=0); Debt Instrument (DA) (A=8 B=9 C=19 D=0); Net foreign Assets (A=0 B=9 C=6 D=0); Other Invest. Assets (A=10 B=7 C=19 D=0).

Table-11. External Balance Sheet Exposure Assessment-Belgium (2002-2015)

	Number of crises for which there are data	Percentage of crises called	Good signals as percentage of possible good signals	Bad signals as percentage of possible bad signals	Noise /signal (adjusted)	P(crisis /signal)	P(crisis /signal)- P(crisis)
In terms of the matrix in the text			A/(A+C)	B/(B+D)	B/(B+D)/A/(A+C)	A/(A+B)	A/(A+B)-(A+C)/(A+B+C+D)
Portfolio Invest. (PL)	4	75	100	70	0.70	36.36	7.79
Equity & Invest. (PL)	4	100	100	80	0.80	33.33	4.76
Debt Instrument (PL)	4	50	100	60	0.60	40	11.43
Direct Invest. (DL)	3	100	100	37.50*	0.38*	50	28.57*
Equity & Invest. (DL)	3	66.67	100	45.45*	0.45*	37.50	16.07*
Debt Instrument (DL)	2	50	100	33.33*	0.33*	33.33	19.05*
Portfolio Invest. (PA)	11	45.45	36.36	100	2.75	57.14	-21.57
Equity & Invest. (PA)	10	40	50	100	2	55.56	-15.87
Debt Instruments (PA)	10	70	63.63	100	1.57	70	-8.57
Direct Invest. (DA)	12	33.33	25	100	4	60	-25.71
Equity & Invest. (DA)	11	18.18	0	100	0	0	0
Debt Instrument (DA)	11	45.45	54.54	100	1.83	66.67	-11.90
Net foreign Assets	11	36.36	54.54	100	1.83	54.54	-24.02
Other Invest. Assets	11	63.64	63.64	100	1.57	70	-8.57

PL= Portfolio Investment Liabilities; DL= Direct Investment Liabilities; PA= Portfolio Investment Assets; DA= Direct Investment Assets. Portfolio Invest. (PL) (A=4 B=7 C=0 D=3); Equity & Invest. (PL) (A=4 B=8 C=0 D=2); Debt Instrument (PL) (A=4 B=6 C=0 D=4); Direct Invest. (DL) (A=3 B=3 C=0 D=8); Equity & Invest. (DL) (A=3 B=5 C=0 D=6); Debt Instrument (DL) (A=2 B=4 C=0 D=8); Portfolio Invest. (PA) (A=4 B=3 C=7 D=0); Equity & Invest. (PA) (A=5 B=5 C=5 D=0); Debt Instruments (PA) (A=7 B=3 C=4 D=0); Direct Invest. (DA) (A=3 B=2 C=9 D=0); Equity & Invest. (DA) (A=0 B=3 C=11 D=0); Debt Instrument (DA) (A=6 B=3 C=5 D=0); Net foreign Assets (A=6 B=3 C=5 D=0); Other Invest. Assets (A=7 B=3 C=4 D=0).

Table-12. External Balance Sheet Exposure Assessment- Switzerland (1985-2015)

	Number of crises for which there are data	Percentage of crises called	Good signals as percentage of possible good signals	Bad signals as percentage of possible bad signals	Noise/ signal (adjusted)	P(crisis /signal)	P(crisis /signal) -P(crisis)
In terms of the matrix in the text			A/(A+C)	B/(B+D)	B/(B+D)/A/(A+C)	A/(A+B)	A/(A+B)-(A+C)/(A+B+C+D)
Portfolio Invest. (PL)	5	60	100	53.84	0.54	26.32	10.19
Equity & Invest. (PL)	4	25	100	51.85	0.52	22.22	9.10
Debt Instrument (PL)	1	0	100	100	1	4.35	1.11
Direct Invest. (DL)	5	60	100	23.08*	0.23*	45.45	29.36*
Equity & Invest. (DL)	4	25	100	18.52*	0.19*	44.44	31.54*
Debt Instrument (DL)	3	66.67	100	42.86*	0.43*	20	10.32*
Portfolio Invest. (PA)	24	33.33	29.17	100	3.42	50	-27.42
Equity & Invest. (PA)	22	27.27	18.18	100	5.50	30.77	-40.20
Debt Instruments (PA)	23	21.74	17.39	100	5.75	33.33	-40.86
Direct Invest. (DA)	25	28	24	100	4.17	50	-30.65
Equity & Invest. (DA)	24	25	12.5	100	8	30	-37.42
Debt Instrument (DA)	27	22	18.52	100	5.40	55.56	-31.54
Net foreign Assets	26	34.62	32.26	100	3.1	66.67	-33.33
Other Invest. Assets	2	100	100	74.07	0.74	22.22	15.77

PL= Portfolio Investment Liabilities; DL= Direct Investment Liabilities; PA= Portfolio Investment Assets; DA= Direct Investment Assets. Portfolio Invest. (PL) (A=5 B=14 C=0 D=12); Equity & Invest. (PL) (A=4 B=14 C=0 D=13); Debt Instrument (PL) (A=1 B=22 C=0 D=8); Direct Invest. (DL) (A=5 B=6 C=0 D=20); Equity & Invest. (DL) (A=4 B=5 C=0 D=22); Debt Instrument (DL) (A=3 B=12 C=0 D=16); Portfolio Invest. (PA) (A=7 B=7 C=17 D=0); Equity & Invest. (PA) (A=4 B=9 C=18 D=0); Debt Instruments (PA) (A=4 B=8 C=19 D=0); Direct Invest. (DA) (A=6 B=6 C=19 D=0); Equity & Invest. (DA) (A=3 B=7 C=21 D=0); Debt Instrument (DA) (A=5 B=4 C=22 D=0); Net foreign Assets (A=10 B=5 C=16 D=0); Other Invest. Assets (A=2 B=20 C=0 D=7).

Table-13. External Balance Sheet Exposure Assessment- US (1980-2015)

	Number of crises for which there are data	Percentage of crises called[a]	Good signals as percentage of possible good signals	Bad signals as percentage of possible bad signals	Noise /signal (adjusted)[b]	P(crisis /signal)[c]	P(crisis /signal)-P(crisis)[d]
In terms of the matrix in the text			A/(A+C)	B/(B+D)	B/(B+D)/A/(A+C)	A/(A+B)	A/(A+B)-(A+C)/(A+B+C+D)
Portfolio Invest. (PL)	7	100	100	24.14*	0.24*	50	30.56*
Equity & Invest. (PL)	7	85.71	100	31.03*	0.31*	43.75	24.31*
Debt Instrument (PL)	9	88.89	100	15.38*	0.15*	71.43	43.65*
Direct Invest. (DL)	10	70	100	19.23*	0.19*	66.67	38.89*
Equity & Invest. (DL)	10	90	100	23.08*	0.23*	62.50	34.72*
Debt Instrument (DL)	8	62.5	100	17.86*	0.18*	61.54	39.31*
Portfolio Invest. (PA)	30	30	31	100	3.22	56.25	-24.31
Equity & Invest. (PA)	31	29.03	32.26	100	3.1	66.67	-19.44
Debt Instruments (PA)	30	26.67	30	100	3.33	60	-23.33
Direct Invest. (DA)	25	16	20	100	5	31.25	-38.19
Equity & Invest. (DA)	25	12	12	100	8.33	21.43	-48.01
Debt Instrument (DA)	28	35.71	17.86	100	5.6	38.46	-39.32
Net foreign Assets	28	96.42	100	100	1	77.78	0
Other Invest. Assets	30	56.67	56.67	100	1.76	73.91	-9.42

PL= Portfolio Investment Liabilities; DL= Direct Investment Liabilities; PA= Portfolio Investment Assets; DA= Direct Investment Assets. Portfolio Invest. (PL) (A=7 B=7 C=0 D=22); Equity & Invest. (PL) (A=7 B=9 C=0 D=20); Debt Instrument (PL) (A=10 B=4 C=0 D=22); Direct Invest. (DL) (A=10 B=5 C=0 D=21); Equity & Invest. (DL) (A=10 B=6 C=0 D=20); Debt Instrument (DL) (A=8 B=5 C=0 D=23); Portfolio Invest. (PA) (A=9 B=7 C=20 D=0); Equity & Invest. (PA) (A=10 B=5 C=21 D=0); Debt Instruments (PA) (A=9 B=6 C=21 D=0); Direct Invest. (DA) (A=5 B=11 C=20 D=0); Equity & Invest. (DA) (A=3 B=11 C=22 D=0); Debt Instrument (DA) (A=5 B=8 C=23 D=0); Net foreign Assets (A=28 B=8 C=0 D=0); Other Invest. Assets (A=17 B=6 C=13 D=0).

Table-14. External Balance Sheet Exposure Assessment- UK (1980-2015)

	Number of crises for which there are data	Percentage of crises called[a]	Good signals as percentage of possible good signals	Bad signals as percentage of possible bad signals	Noise /signal (adjusted)[b]	P(crisis /signal)[c]	P(crisis /signal)-P(crisis)[d]
In terms of the matrix in the text			A/(A+C)	B/(B+D)	B/(B+D)/A/(A+C)	A/(A+B)	A/(A+B)-(A+C)/(A+B+C+D)
Portfolio Invest. (PL)	8	62.5	100	21.43*	0.21*	57.14	34.92*
Equity & Invest. (PL)	6	50	100	23.33*	0.23*	46.15	29.49*
Debt Instrument (PL)	6	85.71	100	13.79*	0.14*	63.64	44.19*
Direct Invest. (DL)	6	66.67	100	13.33*	0.13*	60	43.33*
Equity & Invest. (DL)	6	66.67	100	23.33*	0.23*	46.15	29.49*
Debt Instrument (DL)	7	71.43	100	17.24*	0.17*	58.33	38.89*
Portfolio Invest. (PA)	31	48.39	45.16	100	2.21	73.68	-12.43
Equity & Invest. (PA)	24	25	16.67	100	6	25	-41.67
Debt Instruments (PA)	31	51.61	48.39	100	2.07	75	-11.11
Direct Invest. (DA)	30	26.67	26.67	100	3.75	57.14	-26.19
Equity & Invest. (DA)	30	26.67	25	100	4	46.67	-31.11
Debt Instrument (DA)	33	42.42	42.42	100	2.36	82.35	-9.31
Net foreign Assets	30	50	56.67	100	1.76	73.91	-9.42
Other Invest. Assets	31	35.48	38.71	100	2.58	70.58	-15.52

PL= Portfolio Investment Liabilities; DL= Direct Investment Liabilities; PA= Portfolio Investment Assets; DA= Direct Investment Assets. Portfolio Invest. (PL) (A=8 B=6 C=0 D=22); Equity & Invest. (PL) (A=6 B=7 C=0 D=23); Debt Instrument (PL) (A=7 B=4 C=0 D=25); Direct Invest. (DL) (A=6 B=4 C=0 D=26); Equity & Invest. (DL) (A=6 B=7 C=0 D=23); Debt Instrument (DL) (A=7 B=5 C=0 D=24); Portfolio Invest. (PA) (A=14 B=5 C=17 D=0); Equity & Invest. (PA) (A=4 B=12 C=20 D=0); Debt Instruments (PA) (A=15 B=5 C=16 D=0); Direct Invest. (DA) (A=8 B=6 C=22 D=0); Equity & Invest. (DA) (A=7 B=8 C=21 D=0); Debt Instrument (DA) (A=14 B=3 C=19 D=0); Net foreign Assets (A=17 B=6 C=13 D=0); Other Invest. Assets (A=12 B=5 C=19 D=0).

Table-15. External Balance Sheet Exposure Assessment- Norway (1980-2015)

	Number of crises for which there are data	Percentage of crises called[a]	Good signals as percentage of possible good signals	Bad signals as percentage of possible bad signals	Noise /signal (adjusted)	P(crisis /signal)	P(crisis /signal) -P(crisis)
In terms of the matrix in the text			A/(A+C)	B/(B+D)	B/(B+D)/A/(A+C)	A/(A+B)	A/(A+B)-(A+C)/(A+B+C+D)
Portfolio Invest. (PL)	8	75	100	10.71*	0.11*	72.73	50.51*
Equity & Invest. (PL)	5	80	100	29.03*	0.29*	35.71	21.83*
Debt Instrument (PL)	8	75	100	10.71*	0.11*	72.72	50.51*
Direct Invest. (DL)	5	80	100	22.58*	0.23*	41.67	27.78*
Equity & Invest. (DL)	7	42.86	100	20.69*	0.21*	53.85	34.40*
Debt Instrument (DL)	5	100	100	19.35*	0.19*	45.45	31.57*
Portfolio Invest. (PA)	36	30.56	36.11	0	0	100	0
Equity & Invest. (PA)	31	9.68	12.90	100	7.75	44.44	-41.67
Debt Instruments (PA)	30	23.33	30	100	3.33	60	-23.33
Direct Invest. (DA)	28	14.29	14.29	100	7	33.33	-44.44
Equity & Invest. (DA)	28	14.29	14.29	100	7	33.33	-44.44
Debt Instrument (DA)	32	34.75	31.25	100	3.2	71.43	-17.46
Net foreign Assets	30	60	100	100	1	83.33	0
Other Invest. Assets	24	25	16.67	100	6	25	-41.67

PL= Portfolio Investment Liabilities; DL= Direct Investment Liabilities; PA= Portfolio Investment Assets; DA= Direct Investment Assets. Portfolio Invest. (PL) (A=8 B=3 C=0 D=25); Equity & Invest. (PL) (A=5 B=9 C=0 D=22); Debt Instrument (PL) (A=8 B=3 C=0 D=25); Direct Invest. (DL) (A=5 B=7 C=0 D=24); Equity & Invest. (DL) (A=7 B=6 C=0 D=23); Debt Instrument (DL) (A=5 B=6 C=0 D=25); Portfolio Invest. (PA) (A=13 B=0 C=23 D=0); Equity & Invest. (PA) (A=4 B=5 C=27 D=0); Debt Instruments (PA) (A=9 B=6 C=21 D=0); Direct Invest. (DA) (A=4 B=8 C=24 D=0); Equity & Invest. (DA) (A=4 B=8 C=24 D=0); Debt Instrument (DA) (A=10 B=4 C=22 D=0); Net foreign Assets (A=30 B=6 C=0 D=0); Other Invest. Assets (A=4 B=12 C=20 D=0).

5. DISCUSSION AND CONCLUSION

This study applied the signal extraction approach to evaluate leading indicators for a financial crisis over the period 1980-2015. The results of the signal extraction postulate that in the external sector the primary indicator for detecting a forthcoming crisis is imports. The indicator has predicted 100% of crisis events registered in 2 years for South Africa and Namibia. In Russia, the indicator correctly predicted 85% of the crises. This suggests that even though developing nations need imports for economic growth, a high level of imports is incompatible with sustainable economic growth. Unsustainable level of imports is related to high external debt in the public sector, which signals a crisis. Developing nations such as China, South Africa and Russia depend on exports for economic growth and internal and external balance. In comparison, China has no ideal indicators to predict an imminent crisis in the external sector. The average maturity of debt in South Africa is the best indicator with no record of bad signals or noise. The indicator also has a significantly low noise to signal ratio due to a zero record of bad signals. Therefore, the indicator has high predictive capabilities of a crisis. Comparatively, the best indicators for predicting financial crises in China were in the order external debt; short-term debt and maturity of debt. Comparatively, Russia's crises are better predicted by the following variables: debt ratio; interest rate payments; short-term debt; expenditure and external debt. The two best indicators were debt ratio and interest rate payments. Debt is a concern in developing due to capital flight. A high external debt causes high budget deficits and need inflationary financing. The government will be inclined to impose strict tax obligations on income, profits and capital gains. As a result, investors returns will be drastically reduced leading to capital flight to low-tax rate economies.

In the financial sector, the common risk indicator among the economies examined is the lending rate. The key risk indicators for South Africa are the risk premium, lending rate and the real interest rate. The ideal indicator for risks in the financial sector for China was the lending rate followed by the interest rate spread whereas in Russia the refinancing rate was the best indicator. Comparatively, Namibia's interest rate spread is the ideal indicator with the lowest noise-signal ratio. Low lending rates allows consumers to borrow more money resulting in high consumption expenditure. Investment spending relies on low lending rates. If the lending rate is too high, economic agents have no incentive to borrow funds, which will eventually diminish economic growth.

The external balance sheet assessment shows that in developed countries predictors of a financial emanate from portfolio investments and direct investments. For UK, the best indicators are in the order: direct investment liabilities; portfolio debt liabilities and direct investments debt instruments. The three indicators registered the lowest noise to signal ratio. Similarly, in Norway, portfolio debt liabilities, direct investment debt instruments liabilities and direct investment equity liabilities were registered significant indicators. In comparison, direct investment debt instrument liabilities were the best predictors of a financial crisis in Germany and Belgium. However, in the US, portfolio debt instrument liabilities and direct investment debt instrument liabilities were the best risk indicators. Ideal indicators for risk assessment in Switzerland were direct investment equity liabilities and total direct investment liabilities. The results suggest that developed countries should guard against asset bubbles. Asset bubbles occur when asset prices rise substantially without the underlying economic fundamentals. When the bubble bursts, a recession follows causing internal and external imbalance. While the results are essential for crisis prediction, there are some limitations in early warning systems. For example there are other factors that may increase vulnerability to a crisis that are not captured by the early warning system such as the change of government regime, the level of development of financial instructions, and capital controls (Kaminsky *et al.*, 1998). Research on early warning should also evaluate qualitative factors that may increase exposure to a financial crisis.

Funding: This study received no specific financial support.
Competing Interests: The author declares that there are no conflicts of interests regarding the publication of this paper.

REFERENCES

Abiad, A., 2003. Early-warning systems: A survey and a regime-switching approach. IMF Working Paper, No. 03/32.

Abiad, A.G., 1999. Early warning systems for currency crises: A Markov-switching approach to South Asia. Mimeo, Philadelphia, PA: University of Pennsylvania.

Agbola, F.W. and C. Kunanopparat, 2005. Determinants of exchange rate practices: Some empirical evidence from Thailand. Applied Economics, 37(7): 807-816. Available at: https://doi.org/10.1080/00036840500061061.

Agenor, P., J.P. Bhandari and R. Flood, 1991. Speculative attacks and models of balance of payments crises. National Bureau of Economic Research, Working Paper, No. 3919.

Ahuja, A., K. Wiseman and M.H. Syed, 2017. Assessing country risk; Selected approaches (No. 17/08). International Monetary Fund.

Andreou, I., G. Dufrénot, A. Sand-Zantman and A. Zdzienicka-Durand, 2009. A forewarning indicator system for financial crises: The case of six central and Eastern European countries. Journal of Economic Integration, 24(1): 87-115. Available at: https://doi.org/10.11130/jei.2009.24.1.87.

Ari, A., 2012. Early warning systems for currency crises: The Turkish case. Economic Systems, 36(3): 391-410. Available at: https://doi.org/10.1016/j.ecosys.2012.07.001.

Berg, A. and C. Patillo, 1999. Are currency crises predictable? A test. IMF Staff Papers, 46(2): 107-138.

Blanchard, O., H. Faruqee and V. Klyuev, 2009. Did foreign reserves help weather the crisis [Web log post]. Available from https://www.imf.org/en/News/Articles/2015/09/28/04/53/sonum100809a.

Borio, C. and M. Drehmann, 2009. Assessing the risk of banking crises-revisited. BIS Quarterly Review, March: 29-46.

Borio, C. and P. Lowe, 2002a. Asset prices, financial and monetray stability: Exploring the nexus. Working Paper No, 114. Bank for International Settlements.

Borio, C. and P. Lowe, 2002b. Assessing the risk of banking crises. BIS Quarterly Review, December: 43-54.

Borio, C. and P. Lowe, 2004. Securing sustainable price stability: Should credit come from the wilderness? Working Paper, No.157. Bank for International Settlements.

Coudert, V. and C. Couharde, 2009. Currency misalignments and exchange rate regimes in emerging and developing countries. Review of International Economics, 17(1): 121-136. Available at: https://doi.org/10.1111/j.1467-9396.2008.00782.x.

Coudert, V. and J. Idier, 2017. Reducing model risk in early warning systems for banking crises in the Euro area. International Economics, 156(12): 98-116.

Cuddington, J.T., 1986. Capital flight: Estimates, issues and explanations. Princeton Studies in International Finance, 58(12): 1-39.

Dabrowski, J.J., C. Beyers and J.P. de Villiers, 2016. Systemic banking crisis early warning systems using dynamic bayesian networks. Expert Systems with Applications: An International Journal, 62(C): 225-242. Available at: https://doi.org/10.1016/j.eswa.2016.06.024.

Davis, E.P. and D. Karim, 2008. Comparing early warning systems for banking crises. Journal of Financial Stability, 4(2): 89-120. Available at: https://doi.org/10.1016/j.jfs.2007.12.004.

Dawood, M., N. Horsewood and F. Strobel, 2017. Predicting sovereign debt crises: An early warning system approach. Journal of Financial Stability, 28(C): 16-28. Available at: https://doi.org/10.1016/j.jfs.2016.11.008.

Demirgüç-Kunt, A. and E. Detragiache, 1998. The determinants of banking crises in developing and developed countries. Staff Papers, 45(1): 81-109. Available at: https://doi.org/10.2307/3867330.

Demirgüç-Kunt, A. and E. Detragiache, 2000. Monitoring banking sector fragility: A multivariate logit approach. The World Bank Economic Review, 14(2): 287-307.Available at: https://doi.org/10.1093/wber/14.2.287.

Dornbusch, R., 1984. External debt, budget deficits and disequilibrium exchange rates. NBER Working Paper, Working Paper, No. 1336.

Doroodian, K., C. Jung and A. Yucel, 2002. Estimating the equilibrium real exchange rate: The case of Turkey. Applied Economics, 34(14): 1807-1812. Available at: https://doi.org/10.1080/00036840210125503.

Dumrongrittikul, T. and H.M. Anderson, 2016. How do shocks to domestic factors affect real exchange rates of Asian developing countries? Journal of Development Economics, 119(C): 67-85. Available at: https://doi.org/10.1016/j.jdeveco.2015.10.004.

Edison, H.J., 2003. Do indicators of financial crises work? An evaluation of an early warning system. International Journal of Finance and Economics, 8(1): 11-53. Available at: https://doi.org/10.1002/ijfe.197.

Edwards, S., 1989. Exchange rate misalignment in developing countries. The World Bank Research Observer, 4(1): 3-21. Available at: https://doi.org/10.1093/wbro/4.1.3.

Eichengreen, B., A.K. Rose and C. Wyplosz, 1995. Exchange market mayhem: The antecedents and aftermath of speculative attacks. Economic Policy, 10(21): 249-312. Available at: https://doi.org/10.2307/1344591.

El-Shagi, M., A. Lindner and G. von Schweinitz, 2016. Real effective exchange rate misalignment in the Euro Area: A counterfactual analysis. Review of International Economics, 24(1): 37-66. Available at: https://doi.org/10.1111/roie.12207.

Frankel, J. and G. Saravelos, 2012. Can leading indicators assess country vulnerability? Evidence from the 2008–09 global financial crisis. Journal of International Economics, 87(2): 216-231. Available at: https://doi.org/10.1016/j.jinteco.2011.12.009.

Frankel, J.A. and A.K. Rose, 1996. Currency crashes in emerging markets: An empirical treatment. Journal of International Economics, 41(3-4): 351-366. Available at: https://doi.org/10.1016/s0022-1996(96)01441-9.

Frost, J. and A. Saiki, 2014. Early warning for currency crises: What is the role of financial openness? Review of International Economics, 22(4): 722-743. Available at: https://doi.org/10.1111/roie.12124.

Ghosh, S.R. and A.R. Ghosh, 2003. Structural vulnerabilities and currency crises. IMF Staff Papers, 50(3): 481-506.

Goldstein, M., G.L. Kaminsky and C. Reinhart, 2000. Assessing financial vulnerability: An early warning system for emerging markets. Washington: Institute for International Economics.

Gouider, A. and R. Nouira, 2014. Relationship between the misalignment of the real exchange rate and capital flight. Theoretical and Applied Economics, 11(600): 121-140.

Gramlich, D. and M. Oet, 2011. The structural fragility of financial systems: Analyis and modeling implications for early warning systems. Journal of Risk Finance, 12(4): 270-290. Available at: https://doi.org/10.1108/15265941111158460.

Gulcin, O.F. and A. Sutherland, 1995. Policy measures to avoid a currency crisis. Economic Journal, 105(429): 510-519. Available at: https://doi.org/10.2307/2235508.

Guru, A., 2016. Early warning system of finance stress for India. International Review of Applied Economics, 30(3): 273-300. Available at: https://doi.org/10.1080/02692171.2015.1102206.

Hermes, N., R. Lensink and V. Murinde, 2002. Flight capital and its reversal for development financing. Discussion Paper, No. 2002/99.

Hinkle, L. and E. Montiel, 1999. Exchange rate misalignmnent: Concenpts and measurement for developing countries. A World Bank Research Publication. Washington, D.C: World Bank.

Ionela, S.A., 2014. Early warning systems–anticipation's factors of banking crises. Procedia Economics and Finance, 10: 158-166. Available at: https://doi.org/10.1016/s2212-5671(14)00289-5.

Jeong, S.-E., J. Mazier and J. Saadaoui, 2010. Exchange rate misalignments at world and European levels: A FEER approach. International Economics, 121: 25-57. Available at: https://doi.org/10.1016/s2110-7017(13)60007-4.

Kaminsky, G., S. Lizondo and C.M. Reinhart, 1998. Leading indicators of currency crises. Staff Papers, 45(1): 1-48. Available at: https://doi.org/10.2307/3867328.

Kaminsky, G.L., 1999. Currency and banking crises: The early warning of distress. IMF Working Paper, No. 99-178, Washington, D.C.

Kaminsky, G.L. and C.M. Reinhart, 1999. The twin crises: The causes of banking and balance-of-payments problems. American Economic Review, 89(3): 473-500. Available at: https://doi.org/10.1257/aer.89.3.473.

Kim, D.H., S.J. Lee, K.J. Oh and T.Y. Kim, 2009. An early warning system for financial crisis using a stock market instability index. Expert Systems, 26(3): 260-273. Available at: https://doi.org/10.1111/j.1468-0394.2009.00485.x.

Kimmel, R.K., J.H. Thornton and S.E. Bennett, 2016. Can statistics-based early warning systems detect problem banks before markets? The North American Journal of Economics and Finance, 37(C): 190-216. Available at: https://doi.org/10.1016/j.najef.2016.04.004.

Krugman, P., 1979. A model of balance of payments crises. Journal of Money, Credit and Banking, 11(3): 311-325.

Lainà, P., J. Nyholm and P. Sarlin, 2015. Leading indicators of systemic banking crises: Finland in a panel of EU countries. Review of Financial Economics, 24(1): 18-35. Available at: https://doi.org/10.1016/j.rfe.2014.12.002.

Lopez-Villavicencio, A., J. Mazier and J. Saadoui, 2012. Temporal dimension and equilibrium exchange rate: A FEER/BEER comparison. Emerging Markets Review, 13(1): 58-77. Available at: https://doi.org/10.1016/j.ememar.2011.10.001.

Martinez-Peria, M.S., 2002. A regime-switching approach to the study of speculative attacks: A focus on EMS crises. Empirical Economics, 27(2): 299-334. Available at: https://doi.org/10.1007/s001810100102.

Obstfeld, M., 1994. The logic of currency crises. NBER Working Paper, No.4640.

Obstfeld, M., J. Shambaugh and A. Taylor, 2009a. Financial instability, reserves and central bank swap lines in the panic of 2008. American Economic Review, 99(2): 480-486.

Obstfeld, M., J. Shambaugh and A. Taylor, 2009b. Financial stability, the trilemma, and international reserves. American Economic Journal of Macroeconomics, 2(2): 57-94.

Oet, M.V., T. Bianco, D. Gramlich and S.J. Ong, 2013. Safe: An early warning system for systemic banking risk. Journal of Banking & Finance, 37(11): 4510-4533. Available at: https://doi.org/10.1016/j.jbankfin.2013.02.016.

Oka, C., 2003. Anticipating arrears to the IMF: Early warning systems. IMF Working Paper, No. WP/03/18.

Pastor, M., 1990. Capital flight from Latin America. World Development, 18(1): 1-18. Available at: https://doi.org/10.1016/0305-750x(90)90099-j.

Ponomarenko, A., 2013. Early warning indicators of asset price boom/bust cycles in emerging markets. Emerging Markets Review, 15(C): 92-106. Available at: https://doi.org/10.1016/j.ememar.2013.02.006.

Rose, A. and A. Spiegel, 2009. Cross-country causes and consequences of the 2008 crisis: Early warning. Federal Reserve Bank of San Francisco, 2009-17.

Rose, A.K. and M.M. Spiegel, 2010. Cross-country causes and consequences of the 2008 crisis: International linkages and American exposure. Pacific Economic Review, 15(3): 340-363.Available at: https://doi.org/10.1111/j.1468-0106.2010.00507.x.

Rose, A.K. and M.M. Spiegel, 2011. Cross-country causes and consequences of the crisis: An update. European Economic Review, 55(3): 309-324.Available at: https://doi.org/10.1016/j.euroecorev.2010.12.006.

Tsai, B., 2013. An early warning system of financial distress using multinomial logit models and a bootstrapping approach. Emerging Markets Finance and Trade, 49(2): 43-69. Available at: https://doi.org/10.2753/ree1540-496x4902s203.

Velasco, A., 1987. Financial crises and balance of payments crises: A simple model of the Southern cone experience. Journal of Development Economics, 27(1-2): 263-283. Available at: https://doi.org/10.1016/0304-3878(87)90018-6.

Zigraiova, D. and P. Jakubik, 2015. Systemic event prediction by an aggregate early warning system: An application to the Czech Republic. Economic Systems, 39(4): 553-576. Available at: https://doi.org/10.1016/j.ecosys.2015.04.004.

APPENDIX

List of Variables

External Sector

Variable	Description	Source
Terms of Trade	Net barter terms of trade index (2000-100)	WDI
Imports	Imports of goods and services (constant 2010 U$)	WDI
Exports	Exports of goods and services (constant 2010 U$)	WDI
Openness	Trade (% GDP)	WDI
Reserves	Balance of Payments (BOP) reserves and related items	WDI
Current Account	Balance of Payments current account balance	WDI
REER	Real Effective Exchange Rate (Consumer Price Index)	IFS
GDP	Gross Domestic Product (constant 2010 U$ prices)	WDI

Signal Extraction Indicators (Public Sector)

Variable	Description	Source
Debt-GDP	Debt to GDP ratio	WDI
External Debt	Total external debt stocks	WDI
Short-term debt	Short-term debt as a percentage of total external debt	WDI
Interest Payments	Interest payments as a percentage of total expenditure	WDI
Maturity of Debt	Average maturity on new external debt commitment (official years)	WDI
Expenditure	Expenditure as a percentage of GDP	WDI
Tax Revenue	Tax revenue as a percentage of GDP	WDI

Financial Sector

Variable	Description	Source
Real Interest Rate	Lending rate adjusted for inflation as measured by the GDP deflator	WDI
Risk Premium	Risk premium on lending	WDI
Interest Rate Spread	Lending rate minus deposit rate	WDI
Deposit Rate		IFS
Lending Rate		IFS
Treasury Bill Rate		IFS
Refinancing Rate		IFS
Money Market Rate		IFS

External Balance Sheet

Variable	Description	Source
Direct Investment	Direct Investment Assets	IFS
Equity and Investment Fund Share	Direct Investment Assets	IFS
Debt Instrument	Direct Investment Assets	IFS
Direct Investment	Direct Investment Liabilities	IFS
Equity and Investment Fund Shares	Direct Investment Liabilities	IFS
Debt Instrument	Direct Investment Liabilities	IFS
Portfolio Investment	Portfolio Investment Assets	IFS
Equity and Investment Fund Shares	Portfolio Investment Assets	IFS
Debt Instrument	Portfolio Investment Assets	IFS
Portfolio Investment	Portfolio Investment Liabilities	IFS
Equity and Investment Fund Shares	Portfolio Investment Liabilities	IFS
Debt Instrument	Portfolio Investment Liabilities	IFS
Other Investment	Assets	IFS
Net Foreign Assets	Assets	WDI