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Predicting Financial Crises and Signal Indicators in G7 Countries

Hilal Alpdoğan[*+]
Mustafa Akal[**]
Ali Kabasakal[**]
Şakir Görmüş[***]

Abstract: *This study aims to detect financial crises and their signal indicators in G7 countries from 1990 to 2016. For this purpose, fourteen leading economic indicators supported by the economic literature were examined for signaling and the 24-month crisis window before the beginning of a crisis. Among them, successful crisis estimators were determined by the noise signal ratio. The identified crisis estimators provide essential information about the dynamics of economies and the channels of the crisis affecting them. Our findings may help policymakers determine adverse policies against crisis, avoid significant losses, and stabilize the world economy and national economies.*

Keywords: Financial Crises; Signal Approach; KLR Approach; G7 Countries

JEL Classification: G01, G17, O57

Introduction

G7 countries (Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States) are the largest and most stable leading economies globally. It is crucial whether the most prominent variables to predict financial crises determined in the literature can forecast financial crises in those countries. A successful prediction may help avoid economic losses and stabilize national and world economies by applying appropriate policies during or before crises based on the indicators considered in this study.

[*] Sakarya University of Applied Science, Sakarya, Turkey.
[+] Hilal Alpdoğan is corresponding author. E-mail: halpdogan@subu.edu.tr
[**] Sakarya University, Sakarya, Turkey.
[***] Marmara University, İstanbul, Turkey.

Empirical studies on the prediction of financial crises with the help of leading indicators have taken place in the literature since the mid-1990s. Eichengreen et al. (1995) used the graphical technique and multi-term logit analysis to analyze the attacks in the foreign exchange market. Eichengreen et al. (1995) formed a money market index by taking the weighted average of the changes in the exchange rate, interest rate, and international reserves, and they examined 16 variables in foreign exchange market crises in 20 OECD countries with quarterly data for the period of 1959-1993. Sachs, Tornell, and Velazco (1996) investigated the effects of the 1994 Mexican crisis on 20 developing countries and examined the impact of global economic variables on different countries. It is found that the overvalued exchange rate has been shown to have significant effects in countries with low foreign exchange reserves.

Kaminsky, Lizondo, and Reinhart (1998) developed the signal approach - the KLR model – that has an important place in the literature. Edison (2003) has tried to develop the KLR model to predict crises in advance. In addition, Edison (2003) attempted to calculate the probability of crisis according to the variable's value and determined an optimal threshold for the critical value of the variable indicating the crisis. Edison (2003) made estimates for each country separately and emphasized that a standard model could be developed for each country over time.

Berg and Pattillo (1999a) measured the success of the three approaches for predicting the 1997 Asian crisis. The signal approach developed by Kaminsky, Lizondo, and Reinhart (1998) overperformed the probit model applied by Frankel and Rose (1996) and the inter-country regression model used by Sachs, Tornell, and Velasco (1996) in predicting the 1997 Asian crisis. The other two are found unsuccessful in predicting the crisis. In another study, Berg and Pattillo (1999b) examined the ratio of the current account to GDP and the M2 money stock to reserves as leading indicators and the variables discussed in Kaminsky et al. (1998). This study examined the 1997 Asian crisis with 17 leading indicators in 20 countries. As a result, real exchange rate, M2/reserves, exports, reserves, M1 account balance, domestic loans/GDP, terms of trade, current account/GDP, and M2/reserves ratio are determined as successful leading indicators according to the success rate predicting the crisis. Peng and Bajona (2008) analyzed the crises experienced in the Chinese economy during the 1991-2004 period with the signal approach. They predicted the July 1992-July 1993 and the August 1998-May 1999 as possible crisis periods. The devaluation of the Chinese economy in 1994 and the devaluation that was not officially announced in the second period, but the existence of the devaluation, gives the result that the method was successful. Büyükakın and Aydın (2018) estimated the financial crisis for Turkey by KLR Signal Approach developed by Kaminsky and Reinhart Lizondo in 1998. They examined 7 macroeconomic variables for the period of 1990:01 and 2018:9 by introducing new crisis variables such as BIST, cpi, bank deposits, the ratio of export to the import. They found that the selected variables were successful in catching the crisis signal. Karmarkar and Vani (2014) analyzed the 6 major crisis periods experienced

in the USA, India and EU countries during the 1991-2011 period with 17 macroeconomic indicators and concluded that 13 variables are successful leading indicators.

With the utilization KLR signal approach, in this study, at first, dates of financial crises were determined by the calculations of financial pressure indexes (FPI) for the G7 countries. Then, successful crisis estimators were determined by calculating the noise-to-signal ratios (NSR) with conditional and unconditional crisis probabilities of the 14 most important economic indicators that are the most prominent variables to predict financial crises in the literature. Considering the development levels, financial structures, socio-economic status, economic relations and economic history of the countries, the crises and the predictability of crisis indicators were researched fort the G7 countries. However, the differences might exist as a result of the examination of the countries one by one, are pointed out by determining the crisis forecasters specific to the country groups formed and a signaling system that enables the prediction of financial crises in further.

Methodology

KLR, the Signal Approach model, is applied to detect the country's economic crisis and its pre indicators. Firstly, the crisis must be defined in the KLR model. Then, potential leading indicators are detected to provide an estimate of crisis dates. After that, the indicator's behavior by the noise-to-signal ratio (NSR) criterion is classified as an abnormal or normal signal before the crisis. Finally, if the indicator gives a signal, whether the crisis occurred within a reasonable time or whether the signal is a false alarm is determined (Kaminsky and Reinhart, 1999).

In the study conducted by Kaminsky and Reinhart (1999), to determine the financial crises in advance, the 76 crisis period between the years 1970 and 1995 in 15 developed and five developing countries where the simultaneous money and banking crises occurred, the twin crisis, are examined. In this approach, the selected economic indicators are examined before, during, and after the financial crisis.

In this study, the most predominant fifteen leading indicators in the literature were considered for the monthly period 1990-2016. All the data are obtained from the IMF International Financial Statistics' monthly publication and data source. First of all, financial crisis periods are determined using FPI, which consists of the sum of percentage changes in the nominal exchange rate and percentage changes in interest rate minus the percentage change in net international reserves. When the index value's increase exceeds the threshold value, the financial crisis's existence is noted. After determining the crisis months, each indicator's status was observed, and threshold values were determined. Any change in percentage above the threshold value is considered a future financial crisis signal and is expected to occur within 24 months. If a crisis occurs, this indicator is regarded as a good signal. If the crisis does not occur

after a certain time, it is called a false signal or noise. Therefore, when determining the threshold value, the balance between the risk of a false crisis signal and the risk of missing the existing crisis should be appropriately established (Reinhart et al., 1998).

The series is divided into percentiles according to the number of observations to determine the indicators' threshold values. While the percentiles used as the reference range are the same for each country, the threshold values may vary from country to country (Reinhart et al., 1998). The NSR is calculated for each percentile within the upper and lower 10 and 25 percent indicators. The percentile that will minimize NSR is selected as the optimal threshold for that indicator.

Table 1 shows the theoretical calculation of matrix-crisis probabilities and indicator performances of variables. Suppose the threshold value is set too high to ignore false signals. In that case, the crisis may be overlooked (Type I Error), or a critical value close to the normal value may cause false crisis signals that may be a messenger to the crisis that may never occur (Type II Error). To eliminate these errors, the NSR is calculated, indicating the ratio of false signals to the correct signals. The signal-to-noise ratio of the indicator gives information about the variable's ability to provide good signals and prevent bad signals. For this reason, it becomes an indicator that performs well as it gets smaller and approaches zero. To examine the effectiveness of the individual indicators, the performance matrix, which considers each indicator's performance and enables the calculation of the NSR, is needed.

Table 1: Indicator Performance Matrix-Crisis Probabilities

	Crisis in 24 Months	**No Crisis in 24 Months**	**Accuracy Rates**
Signal	A	B (Type II Error)	A/(A+B)
No Signal	C (Type I Error)	D	D/(C+D)
Accuracy Rates	A/(A+C)	B/(B+D)	(A+D)/(A+B+C+D)

Source: Kaminsky, G. & S. Lizondo & C.M. Reinhart (1998:18).

The statistical information in the variable evaluation table, which is formed by using the variables' performance matrices, is explained in Table 2.

Table 2: Crisis Probabilities from Performance Matrix

A/(A+C)	**B/(B+D)**	**[B/(B+D)]/ [A/(A+C)]**	**A/(A+B)**	**D/(C+D)**	**[A/(A+B)]- [(A+D) / (A+B+C+D)]**	**(A+D) / (A+B+C+D)**
Likelihood of signaling in case of a crisis	Likelihood of signaling in the absence of a crisis	Noise signal ratio	Likelihood of crisis in case of signaling	Likelihood of crisis in the absence of signaling	Likelihood of crisis in case of signaling - the likelihood of accurate signaling	Likelihood of accurate signaling

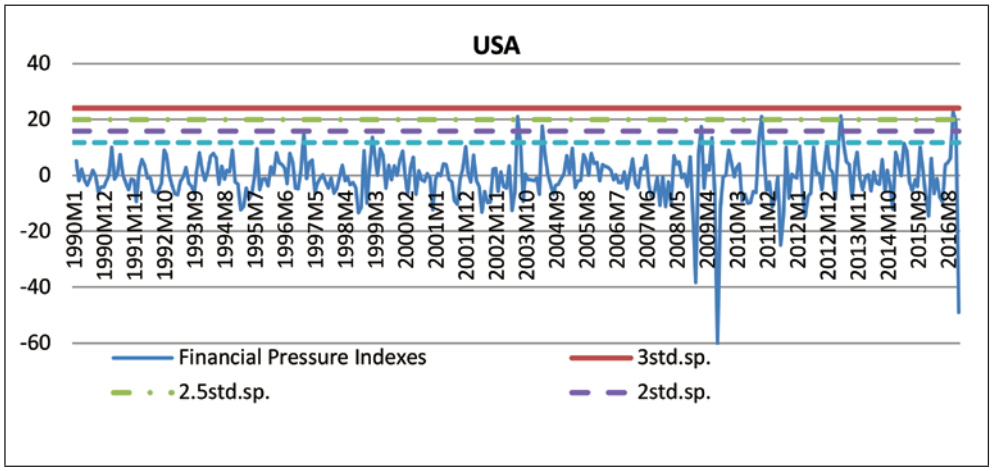
Determination of Crisis Dates of Each Country

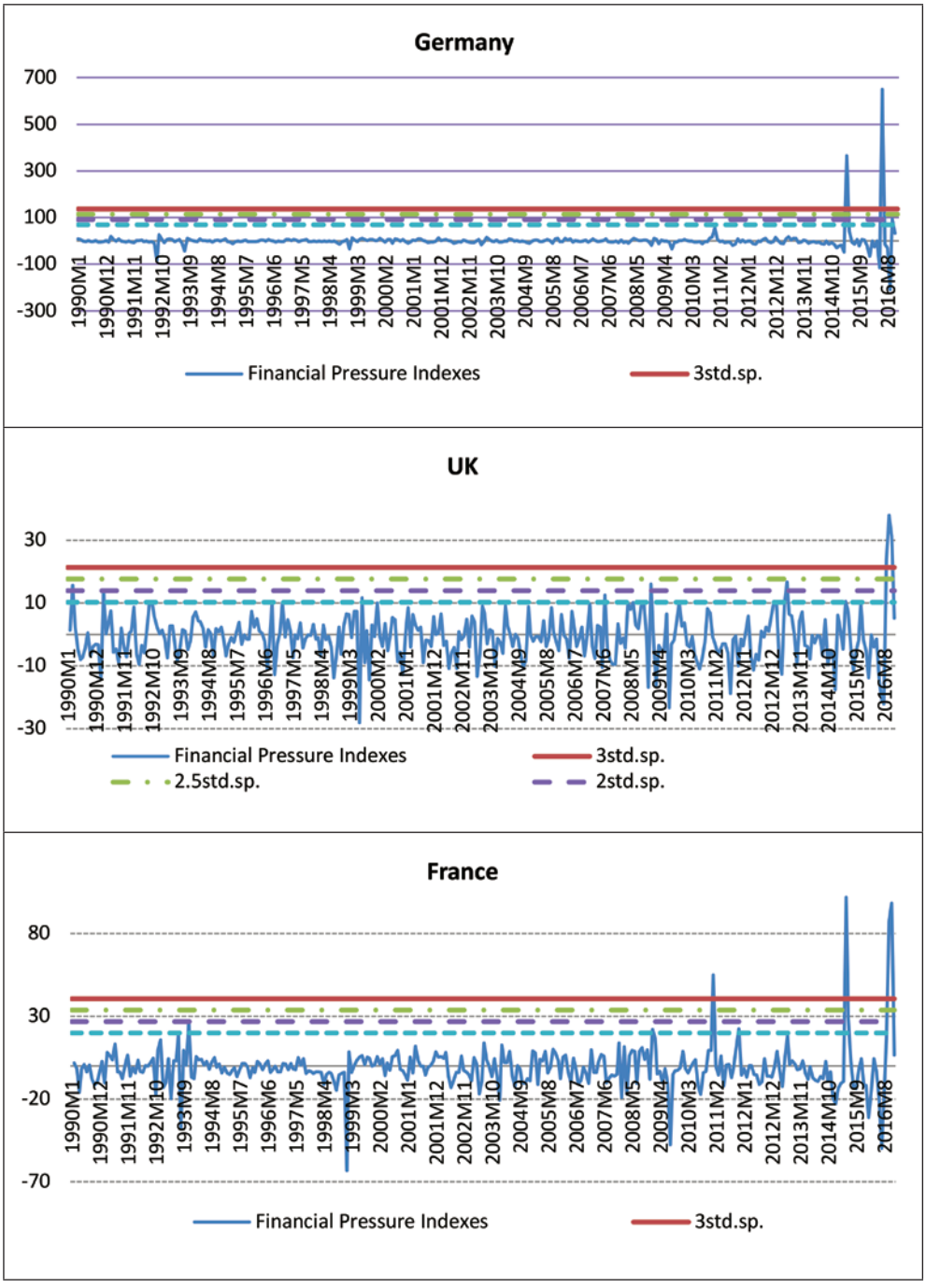
The crisis dates of G7 countries determined by FPI from 1990 through 2016, at least 3σ threshold values are shown in Table 3. Also, Figure 1 shows the course of the FPI, which we use to determine the countries' crisis dates out 1.5 to 3 standard deviations or separation threshold values.

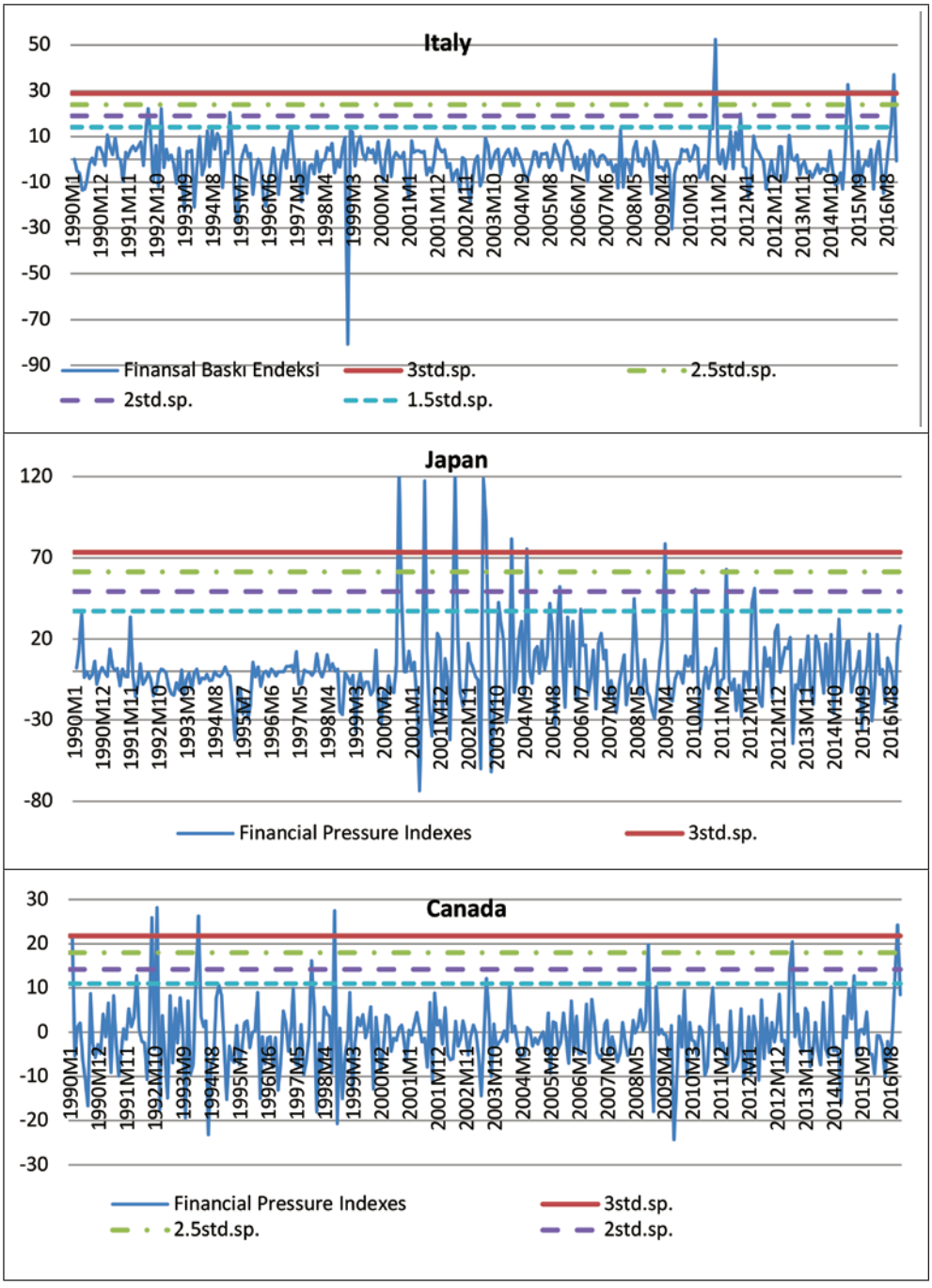
Table 3: Dates of Crises for the G7 Countries

Country	Threshold; 3σ	Months of Crises
United States Of America (USA)*	**19.98**	July 2003, December 2010, May 2013, October 2016
Germany	**136.68**	May 2015, July 2016
United Kingdom (UK)	**21.38**	September 2016
France	**40.63**	January 2011, October 2016
Italy	**28.8**	January 2011, November 2016
Japan	**73,36**	June 2001, April 2004, April 2009
Canada	**21.76**	September 1992, Mach 1994, August 1998, October 2016
*2.5 σ was taken into consideration for the evaluation of the USA.		

Figure 1: FPI and Threshold Values of Each Country




Germany
700
500
300
100
-100
-300
1990M1
1990M12
1991M11
1992M10
1993M9
1994M8
1995M7
1996M6
1997M5
1998M4
1999M3
2000M2
2001M1
2001M12
2002M11
2003M10
2004M9
2005M8
2006M7
2007M6
2008M5
2009M4
2010M3
2011M2
2012M1
2012M12
2013M11
2014M10
2015M9
2016M8
Financial Pressure Indexes
3std.sp.
UK
30
10
-10
-30
Financial Pressure Indexes
3std.sp.
2.5std.sp.
2std.sp.
France
80
30
-20
-70
Financial Pressure Indexes
3std.sp.


Italy
50
30
10
-10
-30
-50
-70
-90
1990M1
1990M12
1991M11
1992M10
1993M9
1994M8
1995M7
1996M6
1997M5
1998M4
1999M3
2000M2
2001M1
2001M12
2002M11
2003M10
2004M9
2005M8
2006M7
2007M6
2008M5
2009M4
2010M3
2011M2
2012M1
2012M12
2013M11
2014M10
2015M9
2016M8
Finansal Baskı Endeksi
3std.sp.
2.5std.sp.
2std.sp.
1.5std.sp.
Japan
120
70
20
-30
-80
Financial Pressure Indexes
3std.sp.
Canada
30
20
10
0
-10
-20
-30
Financial Pressure Indexes
3std.sp.
2.5std.sp.
2std.sp.

Determination of Leading Indicators of Each Country

The KLR Signal Approach model, described in the previous section, determined leading indicators for a crisis in countries and performance probabilities.

USA

The USA's crisis dates were determined with the help of FPI. Crisis dates have been calculated in the literature by considering various standard deviations. Crisis dates for the USA are shown in Table 3 as of July 2003, December 2010, May 2013, and October 2016, according to the 19.98 threshold value calculated by taking 2.5 standard deviations into account. The course of the US FPI and threshold values are shown in Figure 1.

Table 4 shows the direction of change of the USA's leading indicators, the threshold value, the number of signals in crisis windows, and the percentage explaining the crisis. International reserves, M2 money stock/ International reserves, inflation, industrial production index, GNP change, and M2 money stock variables did not change the direction of change in the determining crisis windows by 10-25 percent. Besides, since the net indebt, current account balance, and the number of unemployed variables are more than one NSR, it is considered unsuccessful in predicting the crisis according to the KLR model.

Successful crisis estimators with a signal-to-noise ratio of 0 to 1 are found as net portfolio investments, stock index, exports, and imports. The stock market index decreased by 12 percent and over in the crisis window and signaled twice before the 2010 crisis. The percentage explaining the crisis by signaling in only one of the four crisis periods is 25 percent. The crisis estimator is found as net portfolio investments and interest rates, showing a percentage explaining the crisis by giving a signal at least once in all crisis windows identified. And the exports indicator signaled in two of the four crises, and the percentage explaining the crisis was 50 percent.

Table 4: Threshold Values of Leading Indicators of USA and Number of Signals in Crisis Window

Variables	Threshold		Number of Signals in a Crisis Window				A/Number of Crisis
	Change Direction	Percent Level	2003	2010	2013	2016	
Reserves	-	**NA**	0	0	0	0	0
M2/ Reserves	+	**NA**	0	0	0	0	0
Net Portfolio Investments	-	**24**	8	8	6	8	100
Stock Index	-	**12**	0	2	0	0	25
Exports	-	**11**	1	2	0	0	50
Interest Rates	+	**14**	1	1	1	1	100
Imports	-	**10**	1	2	0	0	50

Variables	Threshold		Number of Signals in a Crisis Window				A/Number of Crisis
	Change Direction	Percent Level	2003	2010	2013	2016	
Inflation	+	**NA**	0	0	0	0	0
Industrial Production Index	-	**NA**	0	0	0	0	0
Change of GNP	-	**NA**	0	0	0	0	0
M2	+	**NA**	0	0	0	0	0
Net Indebt	+	**Unsuccessful**	7	3	7	4	100
Current Account Balance	-	**Unsuccessful**	2	3	2	2	100
Number of Unemployed	+	**Unsuccessful**	3	1	0	2	75

NA: It indicates that the pioneering indicator examined did not signal in the 24 months before the crisis date. **Unsuccessful:** The signal-to-noise ratio of the indicator is greater than 1. **Percent Level:** The determined threshold values represent the percentage change.

In Table 5, successful leading indicators according to the US KLR model are listed in order of success by taking into account the NSRs. The USA's most successful crisis estimator is the interest rate of 0.1058 NSR. The interest rate gave the crisis window four times a good signal and a false signal outside the crisis window. The probability of a crisis depending on the condition that the interest rate exceeds the threshold value is 80 percent, and the probability of an unconditional crisis is 50.27 percent. The second successful crisis estimator in the US is the stock market index. The stock index has an NSR of 0.2127, giving two good signals and one false signal in the crisis window. The probability of a crisis based on the condition that the stock index gives a signal is 50 percent, and the probability of an unconditional crisis is 20.18 percent. It is possible to make the same comments for other crisis forecasters.

The number of unemployed, current account balances, and net indebt variables are unsuccessful because their NSR is greater than one. The USA's successful crisis forecasters are interest rate, stock exchange index, export, net portfolio investments, and imports.

Table 5: USA's Leading Indicators According to KLR Model

Variables	A	B	C	D	A/(A+C)	B/(B+D)	[B/(B+D)] / [A/(A+C)]	A/(A+B)	A/(A+B)-[(A+C)/(A+B+C+D)]
Interest Rates	4	1	92	226	0.0416	0.0044	**0.1058**	0.80	0.5027
Stock Index	2	1	94	225	0.0208	0.0044	**0.2127**	0.66	0.3619
Exports	3	2	93	225	0.0312	0.008	**0.256**	0.60	0.3027
Net Portfolio Investments	30	28	66	199	0.3125	0.1233	**0.3947**	0.51	0.2197
Imports	3	4	93	223	0.0312	0.0176	**0.5647**	0.42	0.1313
Number of Unemployed	5	13	91	214	0.0520	0.0572	**1.1013**	0.27	-0.0272
Current Account Balance	9	31	87	196	0.0937	0.1365	**1.4574**	0.22	-0.0722
Net Indebt	22	52	74	84	0.2291	0.3823	**1.6689**	0.29	-0.0001

Germany

The FPI of Germany was calculated by considering three standard deviations, and the crisis dates were determined by considering the 136.68 threshold value. Germany's crisis dates are detected as May 2015 and July 2016 in Table 3. Figure 1 shows the course of the threshold values calculated by taking into account Germany's FPI and various standard deviations, such as the USA and other countries.

Table 6 shows the direction of change of the leading indicators in Germany, the threshold value, the number of signals in the crisis window, and the percentage of explaining the crisis. International reserves, stock exchange index, exchange rate, inflation, short-term debt-to-reserves ratio, GNP change, and net indebt variables did not change in the crisis windows and did not signal. Furthermore, since the NSR of the current account balance was greater than one, it was deemed unsuccessful in predicting the crisis.

The number of unemployed, interest rate, import, export, net portfolio investments, and industrial production index variables were 10-25 percent change in the direction of the shift in crisis windows. NSRs were successful crisis estimators with a range of 0 to 1. Since there is only one crisis window, the percentage of all crisis estimators explaining the crisis is 100 percent.

Table 6: Threshold Values of Leading Indicators of Germany and Number of Signals in Crisis Window

Variables	Threshold		Number of Signals in a Crisis Window	A/Number of Crisis
	Change Direction	Percent Level		
Reserves	-	**NS**	0	0
Number of Unemployed	+	**12**	1	100
Stock Index	-	**NS**	0	0
Current Account Balance	+	**11**	3	100
Interest Rates	+	**Unsuccessful**	2	100
Exchange Rates	+	**NS**	0	0
Inflation	+	**NS**	0	0
Short Term Debt / Reserves	+	**NS**	0	0
Change of GNP	-	**NS**	0	0
Net Indebt	+	**NS**	0	0
Imports	+	**10**	3	100
Exports	-	**18**	1	100
Net Portfolio Investments	-	**25**	17	100
Industrial Production Index	-	**17**	1	100
M2	+	**13**	1	100

NS: Indicates that the pioneering indicator examined has not given any signal 24 months before the crisis date. **Unsuccessful:** The signal-to-noise ratio of the indicator is greater than 1. **Percent Level:** The determined threshold values represent the percentage change.

Table 7 lists GNSRs. Germany's most successful crisis estimator is the current account balance with an NSR of 0, not giving false signals outside the crisis window. While the probability of a crisis due to the current account balance signaling is 100 percent, the likelihood of an unconditional crisis is 92 percent. Later, the exports became the crisis estimator with an NSR of 0.2027. Exports were the second most successful crisis estimator by giving the proper signal twice in the crisis window and five times the wrong signal outside the crisis window. The probability of a crisis due to the signaling of exports is 28 percent, and the likelihood of an unconditional crisis is 21 percent. Similar comments can be made for other crisis forecasters. Since the NSR of interest rates is greater than one, it is an unsuccessful crisis estimator for Germany under the KLR model. Germany's successful crisis forecasters are the changes in the current account balance, exports, imports, net portfolio investments, industrial production index, and the number of unemployed, respectively.

Table 7: Leading indicators of Germany with KLR

Variable	A	B	C	D	A/(A+C)	B/(B+D)	(B/B+D))/ (A/(A+C)) GSO	A/(A+B) P(Crisis/ Signal)	A/(A+B)-((A+C)/ (A+B+C+D)) P(Crisis/ Signal)- P(Crisis)
Current Account Balance	1	0	23	299	0.0416	0	**0**	1	0.9257
Exports	2	5	22	291	0.0833	0.0168	**0.2027**	0.2857	0.2107
Imports	1	3	23	296	0.0416	0.0100	**0.2408**	0.25	0.1757
Net Portfolio Investments	17	94	7	205	0.7083	0.3143	**0.4438**	0.1531	0.0788
Industrial Production Index	1	5	23	258	0.0416	0.0190	**0.4563**	0.1666	0.0830
M2	1	8	23	291	0,0416	0,02675	**0,64214**	0,111111	0,036808
Number of Unemployed	3	32	21	267	0.125	0.1070	**0.8562**	0.0857	0.0114
Interest Rate	3	72	21	227	0.125	0.2408	**1.9264**	0.04	-0.0343

United Kingdom

The UK's financial crisis dates are detected based on three standard deviations percentage changes of FPI, with a threshold value of 21.38 at three standard deviation levels. The UK signaled a crisis in September-November 2016, as seen in Table 3 and Figure 1.

Table 8: Threshold Values of Leading Indicators of UK and Number of Signals in Crisis Window

Variable	Threshold		Number of Signals in a Crisis Window	A/Number of Crisis
	Change Direction	Percent Level	2016	
Reserves	-	**13**	1	100
Exchange Rates	+	**NS**	0	0
M2/ Reserves	+	**14**	1	100
Exports	-	**NS**	0	0
Imports	-	**NS**	0	0
Current Account Balance	-	**Unsuccessful**	4	100
Short Term Debt / Reserves	+	**25**	6	100
M2	+	**NS**	0	0
Interest Rate	+	**10**	2	100
Net Indebt	+	**Unsuccessful**	4	100
Inflation	+	**NS**	0	0
GDP Change	-	**NS**	0	0
Number of Unemployed	+	**NS**	0	0
Industrial Production Index	-	**NS**	0	0
Stock Index	-	**NS**	0	0
PSBR/GNP	-	**NS**	0	0
Net Portfolio Investments	-	**16**	12	100

NS: Indicates that the pioneering indicator examined has not given any signal 24 months before the crisis date. **Unsuccessful:** The signal-to-noise ratio of the indicator is greater than 1. **Percent Level:** The determined threshold values represent the percentage change.

As shown in Table 8, the leading indicators' change direction of the crisis window, the number of signals in the crisis window, and the percentage explaining the crisis are shown. Of the 17 macroeconomic indicators examined, five signaled in the crisis window, and the NSR was identified as a successful crisis estimator with a value between 0 and 1. International reserves, M2-to-reserves ratio, Short-term debt-to-reserves ratio, interest rate, and net portfolio investments are successful crisis estimators according to the UK's KLR model. Current account balance and net indebt variables are considered to be unsuccessful according to the KLR signaling approach. Exchange rate, export, import, M2, inflation, GNP change, change in the number of unemployed, industrial production index, stock exchange index, and the ratio of Public Sector Borrowing Requirement (PSBR)/GNP did not show any change in the direction of the shift determined in the crisis window within the range of 10-25 percent.

Table 9 lists the UK's leading pioneering indicators according to the KLR model. International reserves with the smallest NSR are the UK's most successful crisis forecaster. When there is a signal in international reserves, the probability of a crisis is 50 percent. The probability of an unconditional crisis is 42.56 percent. Then, the UK's

successful crisis estimators are the interest rates, M2-to-reserves ratio, net portfolio investments, and the short-term debt to reserves ratio. Current account balance and net indebt variables have more than one NSR and failed according to the KLR model.

Table 9: UK Leading Indicators, Thresholds, and Signal Numbers

Variables	A	B	C	D	A/(A+C)	B/(B+D)	(B/B+D))/ (A/(A+C)) GSO	A/(A+B) P(Crisis/ Signal))	A/(A+B)-((A+C)/ (A+B+C+D)) P(Crisis/Signal))- P(Crisis)
Reserves	1	1	23	298	0.0416	0.0033	**0.0803**	0.5	0.4257
Interest Rate	2	3	22	296	0.0833	0.0100	**0.1204**	0.4	0.3257
M2/ Reserves	1	2	23	297	0.0416	0.0067	**0.1605**	0.3333	0.2590
Net Portfolio Investments	12	110	12	188	0.5	0.3691	**0.7383**	0.0984	0.0238
Short-Term Debt/ Reserves	6	74	18	225	0.25	0.2475	**0.9899**	0.07500	0.0007
Current Account Balance	4	66	20	233	0.1666	0.2207	**1.3244**	0.0571	-0.0171
Net Indebt	4	71	20	228	0.1666	0.2375	**1.4247**	0.05333	-0.0209

France

France's financial crisis dates are estimated as January 2011, May 2015, and October 2016, considering the threshold value of 3 standard deviations (see Table 3). According to Table 10, the change in the number of unemployed, stock exchange index, exchange rate, inflation, and GNP in France did not signal the determined crisis window. International reserves, current account balance, interest rate, net indebt, imports, exports, net portfolio investments, and industrial production index were the leading indicators with an NSR of 0 to 1 and signal in the crisis window. Among the successful leading indicators, only international reserves signaled during a crisis. The percentage of explaining the crisis was 50 percent; others showed a signal in both crisis windows and a 100 percent explanation for the crisis.

Table 10: Threshold Values of Leading French Indicators and Number of Signals in Crisis Window

Variables	Threshold		Number of Signals in a Crisis Window		A/Number of Crisis
	Change Direction	Percent Level	2011	2016	
Reserves	-	**17**	1	0	50
M2/ Reserves	+	**Unsuccesfull**	1	0	50
Number of Unemployed	+	**NS**	0	0	0
Stock Index	+	**NS**	0	0	0
Current Account Balance	+	**23**	9	5	100
Interest Rate	+	**10**	2	1	100
Exchange Rate	+	**NS**	0	0	0
Inflation	+	**NS**	0	0	0
GDP Change	-	**NS**	0	0	0
Net Indebt	+	**25**	9	4	100
Imports	+	**25**	1	1	100
Exports	-	**23**	2	2	100
Net Portfolio Investments	-	**24**	9	11	100
Industrial Production Index	-	**23**	2	2	100
M2	+	**NS**	0	0	0

NS: Indicates that the pioneering indicator examined has not given any signal 24 months before the crisis date. **Unsuccessful:** The signal-to-noise ratio of the indicator is greater than 1. **Percent Level:** The determined threshold values represent the percentage change.

Table 11 lists France's successful leading indicators, estimated by the KLR model, considering their NSRs. France's successful crisis estimators are; exports, international reserves, imports, net portfolio investments, interest rates, industrial production index, net indebt, and current account balance changes. France's most successful crisis estimator is the exports variable, with an NSR of 0.1047. A total of 20 good signals (A) and 12 false signals (B) were given in the exports crisis window. The probability of a crisis depending on exports' signaling condition is 62.5 percent, and the probability of an unconditional crisis is 47.63 percent. Similar comments can be made for other indicators.

Table 11: France's Leading Indicators by KLR

Variables	A	B	C	D	A/(A+C)	B/(B+D)	(B/B+D))/ (A/(A+C)) GSO	A/(A+B) P((Crisis/ Signal)	A/(A+B)-((A+C)/ (A+B+C+D)) P(Crisis/Signal))- P(Crisis)
Exports	20	12	28	263	0.4166	0.0436	**0.1047**	0.625	0.4763
Reserves	1	1	47	274	0.0208	0.0036	**0.1745**	0.5	0.3514
Imports	4	6	44	269	0.0833	0.0218	**0.2618**	0.4	0.2514
Net Portfolio Investments	2	4	46	271	0.0416	0.0145	**0.3491**	0.3333	0.1847

Interest Rate	3	8	45	267	0.0625	0.0290	**0.4655**	0.2727	0.1241
Industrial Production Index	4	11	44	264	0.0833	0.04	**0.48**	0.2666	0.1180
Net Indebt	13	49	35	226	0.2708	0.1781	**0.6579**	0.2096	0.0610
Current Account Balance	14	54	34	221	0.2916	0.1963	**0.6732**	0.2058	0.0573
M2/ Reserves	1	7	47	208	0,02083	0,03255	**1,5628**	0,125	-0,0575

Italy

According to the threshold value calculated by taking three standard deviations into account, Italy's crisis dates are January 2011, May 2015, and November 2016 in Table 3. According to Table 12, successful leading indicators for Italy that signal in crisis windows and whose NSR is between 0 and 1; the change in the number of unemployed, the stock market index, the change in the current account balance, interest rate, net indebt, imports, exports, net portfolio investments and changes in the industrial production index.

The variables of international reserves, exchange rate, inflation, and GNP did not signal crisis windows. One of the successful leading indicators is the number of unemployed. The stock market index is only 50 percent of the crisis explanation by giving signals in the crisis window of 2011; The percentage of explaining the crisis was 100 percent, while other indicators signaled both crisis windows.

Table 12: Leading Indicators, Threshold Values, and Signal Numbers in Italy

Variables	**Threshold**		**Number of Signals in a Crisis Window**		**A/Number of Crisis**
	Change Direction	**Percent Level**	**2011**	**2015**	
Reserves	-	**NS**	0	0	0
M2/ Reserves	+	**NS**	0	0	0
Number of Unemployed	+	**23**	2	0	50
Stock Index	-	**14**	1	0	50
Current Account Balance	+	**13**	6	12	100
Interest Rate	+	**10**	1	1	100
Exchange Rates	+	**NS**	0	0	0
Inflation	+	**NS**	0	0	0
GDP Change	-	**NS**	0	0	0
Net Indebt	+	**Unsuccessful**	4	11	100
Imports	-	**23**	2	2	100
Exports	-	**17**	4	3	100
Net Portfolio Investments	+	**10**	10	10	100
Industrial Production Index	-	**25**	2	2	100
M2	+	**NS**	0	0	0

NS: Indicates that the pioneering indicator examined has not given any signal 24 months before the crisis date. **Unsuccessful:** The signal-to-noise ratio of the indicator is greater than 1. **Percent Level:** The determined threshold values represent the percentage change.

Table 13 lists Italy's crisis forecasters estimated by the KLR model, taking into account their NSRs. Italy's leading indicators are; the stock exchange index, change in the number of unemployed, interest rate, imports, net portfolio investments, current account balance, exports, and industrial production index. The stock market index did not give a good signal (A) in the crisis window and no faulty signals except for the crisis windows. It became Italy's most successful crisis estimator, as NSR is zero. In this case, the probability of a crisis depending on the condition that the stock market index gives a signal is 100 percent. The probability of an unconditional crisis is 71.42 percent. The second most successful crisis estimator is the change in the number of unemployed. It has a good signal (A) twice in the crisis window and a defective signal (B) in the crisis window and has an NSR of 0.1745. The probability of a crisis due to signaling by the number of unemployed is 50 percent, and the probability of an unconditional crisis is 35.13 percent. Similar comments can be made for other crisis forecasters.

A crisis estimator whose NSR is greater than one and fails according to the KLR model is net indebt. The net indebt indicator gave a good signal (A) 15 times in the crisis window and 86 bad signals (B) outside the crisis window.

Table 13: Italy's Leading Indicators by KLR

Variables	A	B	C	D	A/(A+C)	B/(B+D)	(B/B+D))/ (A/(A+C)) GSO	A/(A+B) P((Crisis/ Signal))	A/(A+B)-((A+C)/ (A+B+C+D)) P((Crisis/Signal))- P(Crisis)
Stock Index	1	0	47	120	0.0208	0	**0**	100	0.7142
Number of Unemployed	2	2	46	273	0.0416	0.0072	**0.1745**	0.5	0.3513
Interest Rate	2	4	46	271	0.0416	0.0145	**0.3491**	0.3333	0.1847
Imports	4	14	44	261	0.0833	0.0509	**0.6109**	0.2222	0.0736
Net Portfolio Investments	20	87	28	188	0.4166	0.3163	**0.7592**	0.1869	0.0383
Current Account Balance	18	84	30	191	0.375	0.3054	**0.8145**	0.1765	0.0278
Exports	7	33	41	242	0.1458	0.12	**0.8228**	0.175	0.0264
Industrial Production Index	4	21	44	254	0.0833	0.0763	**0.9164**	0.16	0.0114
Net Indebt	15	86	33	189	0.3125	0.3127	**1.0007**	0.1485	-9.2E-05

Japan

Japan's crisis dates are estimated as of June 2001, April 2004, and April 2009 by considering three standard deviation thresholds (See Table 3). Since the crisis dates determined in the first half of the 2000s are very close, June 2001, April 2004, and

April 2009 are used as crisis periods in analyzing crisis estimators to separate the crisis windows.

Table 14 shows the direction of change of the leading indicators in Japan, the number of signals in crisis windows (A), and the percentage of explaining the crisis. International reserves, M2-to-reserves ratio, exchange rate, inflation, GNP change, and M2 change did not change in the direction of shift in the determining crisis windows within 10-25 percent. The current account balance and net indebt are not a successful crisis estimator according to the KLR model, as they have more than one NSR despite the signal.

Table 14: Leading Indicators, Threshold Values , and Signal Numbers in Japan

Variables	Threshold		Number of Signals in a Crisis Window			A/Number of Crisis
	Change Direction	Percent Level	2001	2004	2009	
Reserves	-	**NS**	0	0	0	0
M2/ Reserves	+	**NS**	0	0	0	0
Number of Unemployed	+	**11**	0	0	1	33
Stock Index	-	**10**	1	0	3	66
Current Account Balance	+	**Unsuccessful**	3	4	5	100
Interest Rate	+	**24**	2	8	1	100
Exchange Rates	+	**NS**	0	0	0	0
Inflation	+	**NS**	0	0	0	0
GDP Change	-	**NS**	0	0	0	0
Net Indebt	+	**Unsuccessful**	0	3	5	66
Imports	-	**16**	0	0	2	33
Exports	-	**25**	1	0	1	66
Net Portfolio Investments	+	**16**	10	7	10	100
Industrial Production Index	-	**14**	1	0	1	66
M2	+	**NS**	0	0	0	0

NS: Indicates that the pioneering indicator examined has not given any signal 24 months before the crisis date. **Unsuccessful:** The signal-to-noise ratio of the indicator is greater than 1. **Percent Level:** The determined threshold values represent the percentage change.

The change in the interest rate, net portfolio investments, imports, industrial production index, export, stock exchange index, and the number of unemployed signaled the change in the range of 10 to 25 percent in the direction of the determined change. Also, they had a successful crisis because they had an NSR ranging between 0 and 1 as predictors. The interest rate and net portfolio investments signaled the crisis explanation by 100 percent. The industrial production index, export, stock market index, and the number of unemployed signal the crisis by 66 percent; The percentage of imports explaining the crisis by giving signals only in the 2009 crisis window was 33 percent.

Table 15 ranks the successful crisis estimators in order of success by considering their NSRs. Japan's most successful crisis forecasters are; change in the number of unemployed, import, export, industrial production index, stock exchange index, interest rate, and net portfolio investments. The change in the number of unemployed variables signaled a total of 1 in crisis windows. It zeroed outside the crisis windows, making it the most successful crisis estimator with an NSR of 0. In comparison, the probability of an impending crisis is 100 percent. Similar comments can be made for other crisis forecasters. The NSR of the current account balance and net indebt variables is considered unsuccessful because they are greater than one. When the current account balance is analyzed, it gives 12 good signals in crisis windows; the window gave 40 faulty signals out of the crisis. In this case, the number of bad signals to the total number of signals is 1.34. Similarly, the ratio of the net indebt variable to the total number of false signals is 1.25.

Table 15: Japan's Leading Indicators by KLR

Variables	A	B	C	D	A/(A+C)	B/(B+D)	(B/B+D))/ (A/(A+C)) GSO	A/(A+B) P((Crisis/ Signal))	A/(A+B)-((A+C)/ (A+B+C+D)) P((Crisis/Signal))- P(Crisis)
Number of Unemployed	1	0	71	215	0,013889	0	**0**	1	0,749129
Imports	2	1	70	250	0,02777	0,00398	**0,1434**	0,6666	0,4437
Exports	2	2	70	249	0,02777	0,00796	**0,2868**	0,5	0,2770
Industrial Production Index	2	3	70	248	0,02777	0,01195	**0,4302**	0,4	0,1770
Stock Index	4	7	69	244	0,05479	0,02788	**0,5089**	0,3636	0,1383
Interest Rate	11	20	61	231	0,15277	0,07968	**0,5215**	0,3548	0,1319
Net Portfolio Investments	27	48	45	131	0,375	0,26815	**0,7150**	0,36	0,0731
Net Indebt	8	25	64	155	0,11111	0,13888	**1,25**	0,2424	-0,0432
Current Account Balance	12	40	60	138	0,16666	0,22471	**1,3483**	0,2307	-0,0572

Canada

Canada's crisis dates are determined according to 21.76, the threshold value calculated based on three standard deviations; September 1992, August 1998, and October 2016. Figure 1 shows the course of the threshold values calculated by considering the FPI of Canada and different standard deviations.

Table 16 shows the change direction of leading indicators, the number of signals in crisis windows, and the percentage explaining the crisis in Canada. The stock market index, exchange rate, inflation, GNP change, industrial production index, and M2 variables did not show any change in the direction of change in crisis windows

in the range of 10 to 25 percent and did not give any crisis signal in the Canadian economy. M2/reserves ratio, current account balance, and net indebt variables are considered unsuccessful according to the KLR model because their NSR is greater than one. International reserves, the interest rate is only one of the three crisis periods, giving a signal to the crisis, the percentage of explaining the crisis is 33 percent. Since the number of unemployed data did not cover the 1992 crisis period, only the movements in the two crisis windows could be examined. The percentage explaining the crisis by giving a signal in the 1998 crisis window was 50 percent. Likewise, since the data of the 1998 crisis window could not be reached in the data set of the imports variable, only the changes in the 1992 and 2016 crisis windows were examined, and the percentage of explaining the crisis by giving a signal in the 1992 crisis window was 50 percent. On the other hand, the exports variable is signaled in two of the three crises examined, and the percentage of explaining the crisis is 66 percent. Since net portfolio investments signal in every crisis window, the rate of explaining the crisis is 100 percent.

Table 16: Leading Canadian Indicators, Thresholds, and Signal Numbers

Variables	Threshold		Number of Signals in a Crisis Window			A/Number of Crisis
	Change Direction	Percent Level	1992	1998	2016	
Reserves	-	**14**	0	1	0	33
M2/ Reserves	+	**Unsuccessful**	0	1	0	33
Number of Unemployed	+	**18**	NA	1	0	50
Stock Index	-	**NS**	0	0	0	0
Current Account Balance	+	**Unsuccessful**	6	6	3	100
Interest Rate	+	**10**	0	0	3	33
Exchange Rates	+	**NS**	0	0	0	0
Inflation	+	**NS**	0	0	0	0
GDP Change	-	**NS**	0	0	0	0
Net Indebt	+	**Unsuccessful**	6	6	3	100
Imports	-	**12**	3	NA	0	50
Exports	-	**12**	1	1	0	66
Net Portfolio Investments	+	**16**	9	6	5	100
Industrial Production Index	-	**NS**	0	0	0	0
M2	+	**NS**	0	0	0	0

NA: Data not available. **NS:** Indicates that the pioneering indicator examined has not given any signal 24 months before the crisis date. **Unsuccessful:** The signal-to-noise ratio of the indicator is greater than 1. **Percent Level:** The determined threshold values represent the percentage change.

Table 17 lists Canada's successful crisis forecasters by the KLR model by taking into account their NSRs. Canada's most successful crisis estimator is the imported variable, with an NSR of 0.2105. The probability of a crisis due to imports signals in crisis windows is 60 percent. The probability of an unconditional crisis is 36 percent.

The successful crisis estimators were then the interest rate, number of unemployed, international reserves, exports, and net portfolio investments. The current account balance, net indebt, and M2-to-reserves ratio whose NSR is greater than one is considered unsuccessful according to the KLR model.

Table 17: Canada's Leading Indicators for KLR

Variables	A	B	C	D	A/(A+C)	B/(B+D)	(B/B+D))/ (A/(A+C)) GSO	A/(A+B) P((Crisis/ Signal))	A/(A+B)-((A+C)/ (A+B+C+D)) P((Crisis/Signal))- P(Crisis)
Imports	3	2	45	150	0.0625	0.0131	**0.2105**	0.6	0.36
Interest Rate	3	5	69	246	0.0416	0.0199	**0.4781**	0.375	0.1520
Number of Unemployed	1	2	71	249	0.0138	0.0079	**0.5737**	0.3333	0.1104
Reserves	1	3	71	248	0.0138	0.0119	**0.8605**	0.25	0.0271
Exports	2	6	70	245	0.0277	0.0239	**0.8605**	0.25	0.0271
Net Portfolio Investments	20	63	52	187	0.2777	0.252	**0.9072**	0.2409	0.0173
Current Account Balance	15	55	57	196	0.2083	0.2191	**1.0518**	0.2142	-0.0086
Net Indebt	15	59	57	191	0.2083	0.236	**1.1328**	0.2027	-0.0209
M2/Reserves	1	4	71	247	0.0138	0.0159	**1.1474**	0.2	-0.0229

Crisis Dates for the G7 and the Leading Common Indicators

At the time of the crisis, the leading indicators of each country were determined separately. Leading indicators identified by the KLR model are summarized in Table 18, covering all G7 countries. In Table 19, where G7 countries are evaluated cumulatively, crisis estimators are listed in order of success by considering the NSRs. The crisis forecasters of G7 nations in order of success; international reserves, exports, imports, stock exchange index, M2-to-international reserves ratio, industrial production index, net portfolio investments, interest rate, current account balance, short-term debt to reserve ratio.

When G7 countries are evaluated cumulatively, variables that do not change within the range of 10-25 percent in the direction of change determined in the crisis window in any G7 country are found as M2, inflation, exchange rate, and GNP change. Since these variables did not signal the crisis window, they could not be evaluated as crisis estimators. Moreover, since the NSR values of the M2-to-international reserves ratio, Net debt stock, and Net Debt and M2 money stock indicators are greater than one, NSR indicators are more than one. As seen in Table 19, they are not successful crisis predictors for G7 countries.

Table 18: Leading Indicators of G7 Countries

USA	Germany	UK	France	Italy	Japan	Canada	G7
- Interest Rate - Stock Index - Exports - Net Portfolio Investments - Imports	- Current Account Balance - Exports - Imports - Net Portfolio Investments - Industrial Production Index - Number of Unemployed	- Reserves - Interest Rate - M2/Reserves - Net Portfolio Investments - Short-Term Debt/Reserves	- Exports - Reserves - Imports - Net Portfolio Investments - Interest Rate - Industrial Production Index - Net Indebt - Current Account Balance	- Stock Index - Number of Unemployed - Interest Rate - Imports - Net Portfolio Investments - Current Account Balance - Exports - Industrial Production Index	- Imports - Exports - Number of Unemployed - Industrial Production Index - Stock Index - Interest Rate - Net Portfolio Investments	- Imports - Interest Rate - Number of Unemployed - Reserves - Exports - Net Portfolio Investments	- Exports - Reserves - Imports - Stock Index - M2/ Reserves - Industrial Production Index - Net Portfolio Investments - Interest Rate - Current Account Balance - Short-Term Debt/ Reserves
Net Portfolio Investments							

The exports indicator gave 34 good signals in the crisis windows of the G7 countries and 54 times false signals outside the crisis window. The exports with an NSR of 0.3053 has been the most successful crisis estimator in G7 countries. When G7 countries are analyzed separately, it is seen that international reserves signal in England, France, and Canada. On the other hand, the exports indicator signals all G7 countries except the UK. Similarly, the imports indicator signaled all G7 countries except the UK and became a successful crisis estimator.

Then, considering the NSR in G7 countries, the successful crisis estimator is the stock market index. When the G7 countries are evaluated separately, it is seen that the stock index gives signals in USA, Italy, and Japan. Another successful crisis estimator that signals all G7 countries is net portfolio investments. On the other hand, the interest rate has been a successful crisis estimator, signaling in all G7 countries except Germany.

Table 19: Estimation of Leading Indicators by KLR Model in G7 Countries

Variables	A	B Type I Error	C Type II Error	D	A/ (A+C)	B/ (B+D)	(B/(B+D))/ (A/(A+C))	A/ (A+B)	(A/(A+B))- ((A+C)/ (A+B+C+D))
Exports	34	54	278	1569	0.108	0.033	**0.305**	0.386	0.225
Reserves	3	5	381	1872	0.007	0.002	**0.340**	0.375	0.205
Imports	17	30	343	1748	0.047	0.016	**0.357**	0.361	0.193
Stock Index	34	54	354	981	0.087	0.052	**0.595**	0.386	0.113
Industrial Production Index	11	40	301	1753	0.035	0.022	**0.632**	0.215	0.067
Net Portfolio Investments	128	434	256	1469	0.333	0.228	**0.684**	0.227	0.059
Interest Rate	28	113	356	1764	0.072	0.060	**0.825**	0.198	0.028
Number of Unemployed	12	49	396	1676	0,029	0,028	**0,965**	0,196	0,005
Current Account Balance	73	330	311	1474	0.190	0.182	**0.962**	0.181	0.005
M2/ Reserves	3	13	357	1465	0,008	0,008	**1,055**	0,187	-0,008
Net Indebt	77	342	307	1144	0.200	0.230	**1.147**	0.183	-0.021
M2	1	8	383	1750	0.002	0.004	**1.747**	0.111	-0.068
Total	**340**	**1109**	**2976**	**14242**	**0,102**	**0,072**	**0,704**	**0,234**	**0,057**

On the other hand, the crisis estimators determined according to the internal dynamics provide essential information about the country's economy. This opportunity may disappear when the nations are evaluated cumulatively.

Results

In the study by Kaminsky et al. (1998) and developed by Edison (2003) using the KLR model, financial crisis dates in G7 countries were determined by calculating the FPI. Afterward, 14 leading economic indicators that could be predictors of crises in the countries were examined, and successful crisis estimators were determined by considering the NSR, conditional and unconditional crisis probabilities. In the continuation of the study, the number of times the leading indicators signaled by exceeding the threshold value in the 24-month crisis window before the crisis dates and the percentage of explaining the crises were included. The leading indicators identified for each country are then evaluated within the scope of G7, and common leading indicators are listed. Important information has been obtained about the nations' successful crisis forecasters, the countries' internal dynamics, and the variables in which the deterioration of the leading economic indicators experienced during the crisis periods.

It has been shown whether the indicators whose changes were examined in the crisis window (24 months before the determined crisis date) determined by considering

the threshold value with 3 standard deviations in the G7 countries, showed a change in the range of 10-25 percent in the direction of the determined change compared to the previous month. The crisis forecasters variable for the G7 countries, in order of success; were found as the exports, international reserves, imports, stock market indexes, industrial production indexes, net portfolio investments, interest rates, change in the number of unemployed, current account balances. Variables that do not show a change in the range of 10-25 percent in the direction of change determined in the crisis window of the G7 country; are found as the exchange rates, inflation rates, GNP changes. Since these variables did not give a signal in the crisis window, they could not be evaluated as crisis predictors. In addition, since NSRs of the indicators of change in net indebtedness, M2/International reserves and the number of unemployed were found greater than one, they can not be successful leading indicators for G7 countries. The common set of leading indicators obtained by evaluating the G7 countries separately; net portfolio investments are in the form of interest rates and current account deficit. Successful crisis forecasters that signal all of the G7 countries, both individually and cumulatively; were found as net portfolio investments and current account balances. The interest rate, on the other hand, has been a successful crisis forecaster, signaling in all of the G7 countries except Germany.

As Edison (2003) mentioned in his study, it is possible to create crisis prediction models consisting of crisis estimators that reveal countries' internal dynamics using the KLR model. However, crisis estimators may vary from country to country, and as the country's crisis period changes, successful crisis estimators may change. However, the performance of a crisis estimator that is successful for each country in predicting the crisis also changes. Although crisis forecasters vary by period and nation, it is possible to identify common crisis estimators for country groups. In the last part of our study, it was observed that the crisis estimators that emerged in the cumulative assessment created by ignoring the internal dynamics of the countries and the estimators that arose when the nations were evaluated separately were consistent.

The G7 group covers the seven most developed countries in the world economy. The most important common feature of G7 countries is that they have stable monetary indicators. The main reason for this is that three of the countries in the group (Germany, France, and Italy) are in the Euro monetary union, and the other currencies (US Dollar, Japanese Yen, and British Pound) in the group are strong and stable. Exchange rate, inflation, and GNP indicators did not give any signal in G7 countries. This situation shows the existence of monetary stability in 7 developed countries.

The leading indicators of the G7 country group may show differences from the leading indicators of developing or less developed countries. Three G7 countries are in the Eurozone and since the presence of solid currencies such as US Dollars in G7 does not let the exchange rate exit the trend, the exchange rate is not considered a successful crisis estimator. In the literature, Kaminsky and Reinhart (1999), Eichengreen et al. (1995), Edin and Vredin (1993), and Goldstein (2000), we can conclude that we

have encountered such a result that there is no monetary union in these studies and that it is not a member of this group in the country group examined. In addition, G7 countries are generally digitalized, have completed the industrialization process, have high efficiency in the services sector, and have extensive and stable financial markets. There are areas in which they have superiorities. These and similar structures create resistance against crises. It is even possible that the leading indicators show insensitivity or that the theory shows otherwise. For example, in the Mundell-Fleming model, countries may be differentiated in determining interest rates and direction of capital flow depending on whether they are large countries (developed countries) or small countries (developing countries). Each of the G7 countries has more than 1% foreign trade volume, high levels of GDP, and monetary assets to influence international markets and economies. Therefore, predicting financial crisis indicators may help governments stabilize both individual and world economies.

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Conflicts of interest/Competing interests

There is no conflict of interest/Competing interests

Availability of data and material

The data that support the findings of this study are openly available in the website of World Bank (www.worldbank.org).

Code Availability

The computer program results are shared through the tables in the manuscript.

Authors' Contributions

Hilal Alpdoğan: Conceptualization, Software, Formal analysis, Writing – Original Draft, Review and Editing, Visualization, Supervision.
Mustafa Akal: Conceptualization, Formal analysis, Writing – Original Draft, Review and Editing.

Ali Kabasakal: Writing – Original Draft, Review and Editing.
Şakir Görmüş: Review and Editing.

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