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Leading indicators of sovereign debt and currency crises: Comparative analysis of 2001 and 2018 shocks in Argentina

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Abstract

Aim/purpose – This paper investigates the accuracy of leading indicators in the case of the 2001 sovereign default crisis and the 2018 currency turmoil in Argentina.

Design/methodology/approach – In this paper, we conducted early warning signals analysis based on a-priori selected variables. For each of the macroeconomic variables, we computed yearly changes and selected the threshold to minimise the noise-to-signal ratio, i.e. the ratio of percentage of false signals in ‘normal’ times to percentage of good signals in a two-year period preceding each of the crises.

Findings – The predictive power of indicators differs significantly in various crisis episodes. For the 2001 crisis, the decline in value of bank deposits was the best leading indicator based on the noise-to-signal ratio. For the 2018 currency crisis, the lowest noise-to-signal ratio was observed for the lending-deposit rate ratio.

Research implications/limitations – The survey is limited mostly by the data availability and their quality.

Originality/value/contribution – This paper gives a complex review of the major early warning indicators in the context of the most recent history of Argentina’s economy. It applies a set of classical leading indicators to two modern cases of financial crises. The paper proposes an original ‘knocking the window’ approach to the presentation of traditional warning concepts in the context of current economic events.

Keywords: Argentina, currency crisis, early warning signals, sovereign debt crisis.

JEL Classification: E44, F37, H12.

1. Introduction

Argentina is an example of a country with a long history of financial crises and therefore an interesting case study. After several cases of crises in the 20th century the next age began encumbered with considerable macroeconomic problems. Investments and consumption were falling while the public debt was increasing rapidly. In spite of this, the government was still able to encourage foreign investors to buy Argentinian bonds by offering higher yields. In 2000 and 2001, Argentina needed assistance from the International Monetary Fund for an amount over \$22bn. At the same time, the macroeconomic outlook and social indicators kept worsening. In December 2001, Argentina defaulted and financial controls to prevent abroad fund transfer transactions were introduced. The default led to severe bank runs, economic slowdown, mass layoffs, political disturbances and increased poverty. The authorities managed to stabilise the exchange rate around mid-2002. The recovery plan consisted of a competitive real exchange rate policy and establishment of new social programmes (Stanley, 2018).

The global financial crisis of 2007-2009 had a limited impact on Argentina. The authorities drew conclusions from the previous crisis and introduced important institutional solutions and political changes. Relative isolation of Argentina's financial markets also weakened the impact of crisis transmission via financial channel.

On the one hand, as stated in OECD report (2019), between 2007 and 2015, public expenditure increased from 28% of GDP to 40%, inflation rose to 25% and net currency reserves dropped significantly. To overcome these problems, substantial reforms were undertaken since 2015. The main improvements included social protection programmes and reinstatement of access to international capital markets. On the other, despite this effort, significant vulnerabilities had been mounting up, leading finally to another currency crisis that started early 2018. The main factors which contributed to this crisis were large fiscal deficits and high interest rates due to a tight monetary policy. Furthermore, the severe drought and the resulting decline in agricultural exports contributed to lower demand for the Argentinian peso. As public debt was largely denominated in the U.S. dollars, the peso depreciation raised the debt by about 30% of GDP, pushing it above levels observed in other emerging market economies (OECD report, 2019). Because the liquidity had dried up, the crisis ended with \$57 bn total bailout program from IMF. To receive this loan, Argentina had to agree to amend its budget and cut spending. The economy was expected to recover shortly,

reaching a primary surplus of 1% of GDP in 2020 (OECD report, 2019). However, in 2020, Argentina like other countries faced unprecedented COVID-19 pandemic and the following global recession. The long-term consequences of this crisis are still unknown and are out of scope of this paper.

The economic literature provides a wide spectrum of tools which can be used to find the most relevant factors or early warning signals (EWS) to build an effective early warning system. The latest literature is influenced by non-parametric or machine learning techniques. Many authors argue that this approach has greater predictive power than less sophisticated econometric techniques (e.g. Papadopoulos et al., 2017). Nevertheless, there is a large body of evidence that less complex models can still exhibit high accuracy in predicting banking and currency crises (e.g. Musdholifah & Hartono, 2017).

The aim of this paper is to develop EWS framework based on macroeconomic and financial data in the case of 2001 and 2018 breakdowns in Argentina. The hypothesis of this paper is that key indicators proposed by the literature still work well in the case of Argentina and the crises had been foreseeable and ‘visible’ in the changes of macroeconomic and financial data. Therefore, the conclusions from this paper are important for policy makers because careful monitoring of particular indicators might help avoid or at least mitigate the impact of potential upcoming financial turmoil.

This paper is organised as follows. Section 2 reviews the literature of early warning signals. Section 3 summarises the methodology used in the survey. Section 4 describes the empirical results in the case of Argentina. Section 5 provides conclusions.

2. Literature review

Currency crises gained economists’ interest at the turn of the 1970s and 1980s due to large currency depreciations in Argentina, Brazil and Mexico. One of the most influential papers in this context was prepared by Krugman (1979). His pioneering work belongs to the so-called ‘first generation’ of models of currency crises, which explains the currency crises in Latin America in the 1970s. The theory states that crises are caused by poor ‘economic fundamentals,’ for example, expansionary monetary and fiscal policies, which lead to depletion of international reserves and as a result the governments are no longer able to keep exchange rates parities. According to this model, the international reserves are decreasing and the ratio of domestic credit to the demand for money is growing

rapidly in the period preceding the currency crisis. Moreover, fiscal imbalances themselves (e.g. budget deficit, credit to the public sector) are indicated as a premise of a currency crisis.

The 'second generation' of models of currency crises was developed by Obstfeld (1986). The theory applies to countries where a prudent macroeconomic policy is conducted, in accordance with the regime of a fixed exchange rate. The cause of the crisis, no matter how positive the macroeconomic indicators are, is a speculative attack which occurs when investors suspect that the authorities will stop defending the peg. A textbook example is the 1992-1993 ERM crisis.

The 'third generation' of models of currency crises was influenced by the Asian Crisis of 1997-1998. This sort of models links currency crises to banking problems, structural weaknesses, institutional factors and investigates their impact on real economy (Chang & Velasco, 2001).

The more recent literature focuses on many factors which may be the causes of crises or which may play the role of early warning signals. If such a variable reaches a certain threshold, the currency crisis is likely to occur within a certain forecast period (typically 24 months). Below we present some important findings from the existing literature on the potentially useful EWS in the context of Argentina.

Kaminsky & Reinhart (1999) searched for linkages between banking and currency crises. Their investigation provides evidence that these crises are highly correlated with each other when financial markets are vastly deregulated and the currency crisis is often preceded by the problems in the banking sector. The authors analysed 16 financial and macroeconomic indicators as potential EWS in case of both banking and balance of payment crises, divided into six sections: financial liberalisation (M2 multiplier, domestic credit/GDP, real interest rate, lending-deposit rate ratio), other financial indicators (excess M1 balances, M2/reserves, bank deposits), current account (exports, terms of trade, real exchange rate, imports), capital account (reserves, real interest-rate differential), real sector (output, stock prices) and fiscal sector (deficit to GDP ratio). The indicator predicts the crisis if the threshold value is reached within 18 months before the crisis starts (different thresholds are chosen for banking and currency crises, the thresholds are computed to minimise the noise-to-signal ratio). Capital account indicators captured the highest proportion of correctly predicted crises – both in the case of balance of payments and banking crises (around 80% in both cases). The fiscal sector variables turned out to be the least predictive – 28% and 44% in the case of balance of payments and banking crises, respectively.

Kaminsky, Lizondo, & Reinhart (1997) investigated over one hundred potential EWS. They defined a currency crisis as a state in which an attack on the domestic currency takes place, as a result of which sharp depreciation of the currency or large deterioration of international reserves occurs (sometimes both). Based on 79 crises in various parts of the world, they concluded that the most efficient variables in forecasting currency crises are international reserves, output, equity prices, the ratio of broad money to gross international reserves, deviations of the real exchange rate from trend, domestic credit, credit to the public sector and domestic inflation. Export performance, money growth, real GDP growth and fiscal deficit turned out to be less predictive. However, the authors found no evidence for some other important EWS stressed by the literature, such as imports, differential between foreign and domestic interest rates and bank deposits. The authors concluded their survey that the signalling approach represents a solid framework for EWS system for currency crises.

Bruggemann & Linne (1999) applied the above methodology and indicators to a sample of selected Eastern European countries in the 1990s, reaching inconclusive results. They considered the government deficit/GDP and real exchange rate to be the only relevant indicators. This can be explained by the low openness of the economy at the time, problems with the economic transition and the small credit expansion.

Eichengreen & Areta (2000) examined the sensitivity of the results of indicator models, coming to the opinion that if empirical results are strong, the indicators are statistically significant for all regression models. They obtained inconclusive results for the deposit insurance system and insufficient system regulation. Nevertheless, rapid growth of domestic credit, large liabilities of banks to reserves and financial liberalisation in the country turned out to be significant factors.

In turn, the IMF pointed to macroeconomic variables related to economic growth, interest and exchange rates, balance of payments, contagion effects (a contagion is a situation when problems in one economy cause turmoil in one or more neighbouring/other countries), inflation and lending booms as potential threats to the stability of the financial system (Evans, Leone, Gill, & Hilbers, 2000). A crucial factor of crisis warning system is the current health of the financial sector. It can be derived by aggregating indicators of the health of individual financial institutions. The *CAMELS* framework is a commonly used methodology, which involves the analysis of six groups of indicators reflecting the health of financial institutions: Capital adequacy, Asset quality, Management soundness, Earnings, Liquidity, and Sensitivity to market risk (Evans et al., 2000).

Hutchison & McDill (1999) also pointed to similar factors: high interest rates, weak GDP growth, fast growth of domestic debt, deterioration of the current account balance and increase of the real exchange rate. An increase in domestic interest rates is one of the most frequently considered potential EWS. First, under the fixed exchange rate regime, higher interest rates mean for the authorities higher financing costs. Thus, the decision to abandon the parity may be dependent on a volume of the public debt. Second, as stated in Obstfeld (1995), rapid growth of interest rates may have devastating impact on the banking system. Consequently, it may be optimal for the government to float the exchange rate rather than to bear the costs of potential bailouts. Therefore, some authors (e.g. Calvo, 1995) try to find the links between banking problems (relative stock prices, non-performing loans, central bank credit to the banking sector, decline in deposits) and balance of payments crises. Calvo (1995) presented the view that all countries are responsible, to some extent, for public debt in a form of bank deposits and, therefore, it is sometimes more preferable for governments to devalue the currency rather than to bail out the insolvent banking sector. Furthermore, foreign interest rates are an important potential indicator of an upcoming crisis. Frankel & Rose (1996) used annual data from 1971 through 1992 for over one hundred emerging countries to investigate the variables predicting the currency crashes. Foreign interest rates turned out to be one of the best leading indicators of crises (among output growth, rate of change of credit, and the total debt burden).

Macroeconomic fundamentals and contagion effects are also considered as potential EWS. For example, Gerlach & Smets (1994) developed a model in which the devaluation conducted by one country forces its trading partners (or competitors) to react in the same way to maintain competitiveness. Calvo & Reinhart (1996) examined weekly returns from equity and Brady bonds for developing countries in Latin America after the Mexican peso crisis at the turn of 1994 and 1995. They concluded that there was evidence of co-movement among these returns after the Mexican crisis, which can be explained by herding behaviour among investors.

Some models suggest that a crisis may erupt without any substantial change in economic fundamentals. In such a case, a crisis is a consequence of pessimistic expectations of market participants – i.e. the investors may expect the currency to depreciate, which leads to the political decisions that validate agents' expectations (self-fulfilling crisis or second generation crisis). Calvo (1995) argued that countries were highly dependent on the confidence of financial markets – if

investors find the country not credible, no funds are invested and the country will become insolvent. Finally, political variables (e.g. a dummy variable for elections year) can also be considered as potential EWS. The most recent papers often use non-parametric techniques which can be summarised as machine learning (i.e. k-nearest neighbours, neural networks, random forests) to predict banking and currency crises. For example, Papadopoulos, Stavroulias, Sager, & Baranoff (2017) developed an EWS framework for forecasting a financial crisis of the magnitude of the Global Financial Crisis for the European Union countries using multinomial logistic regression, discriminant analysis and neural networks. The authors concluded that the machine learning models exhibit high accuracy. The evidence from the majority of the recent works show that the machine learning models mostly outperform benchmark logistic regression methods in out of sample predictions and forecasting (e.g. Bluwstein, Buckmann, Joseph, Kang, Kapadia, & Simsek, 2020; Bräuning, Malikkidou, Scricco, & Scalone, 2019; Casabianca, Catalano, Forni, Giarda, & Passeri, 2016; Holopainen & Sarlin, 2016; Jarmulska, 2020; Peltonen, Sarlin, & Piloju, 2016; Tölö, 2019). However, Beutel, List, & von Schweinitz (2019) investigated financial crises over the past 45 years in 15 advanced countries (including the US and Japan) and stated that machine learning methods are not superior to conventional models in predicting financial crises. Other often used techniques for EWS modelling in recent papers include vector autoregression (VAR) framework (Inske, 2016), logistic regressions (Łupiński, 2019; Marjanović & Marković, 2019; Minguez & Carrascal, 2019; Sondermann & Zorell, 2019), panel logit/probit models (Antunes, Bonfim, Monteiro, & Rodrigues, 2016; Danieli & Jakubik, 2018), time series models with switching regimes (Wang, Zong, & Ma, 2019) and Bayesian approach (Sigmund & Stein, 2017). Lastly, the signalling approach proposed by Kaminsky, Lizondo & Reinhart (1997) is still in use (Hermansen & Röhn, 2015; Musdholifah & Hartono, 2017).

3. Research methodology

This research is based on the analysis of selected variables that can be regarded as early warning indicators in the case of Argentina's last two most severe crises – the 2001 sovereign debt crisis and the 2018 currency crisis. The list of indicators consists of the most important macroeconomic variables selected on the basis of the literature discussed in the previous part. The macroeconomic data were retrieved from the following databases: Central Bank of the Argentine

Republic (2019), Federal Reserve Economic Data (2019), Investing.com (2020) and The World Bank (2019).

After the preliminary set of macroeconomic variables was established, we calculated yearly changes for all the variables except for the exchange market pressure index, which is used directly. The changes have been defined as percentage changes between the value of the variable in the current month and the value of the variable a year earlier. This transformation ensures that the variables are stationary, seasonally adjusted and have definite moments. The final set of macroeconomic variables, on which we constructed the indicators, is presented in Table 1. Additionally, in Appendix 2, we present sources and units of measure of the macroeconomic variables used in the study.

Table 1. The final set of macroeconomic variables for Argentina

No.	Variable	Frequency	First data point	Last data point
1	M2 multiplier	Monthly data	1998-01	2018-07
2	Bank deposits		1999-12	2019-11
3	Exports		1991-01	2019-10
4	Imports		1991-02	2016-12
5	Real exchange rate		1994-01	2019-11
6	Exchange market pressure index		1996-01	2019-11
7	Lending deposit rates ratio		2010-07	2019-11
8	Terms of trade		1991-01	2019-09
9	Unemployment		2002-01	2019-06
10	Inflation		1992-06	2019-10
11	M2 to reserves ratio		1998-01	2018-07
12	Domestic credit	Quarterly data	1996-06	2019-09
13	Domestic credit to GDP ratio		1996-06	2019-06
14	Total foreign debt		1995-03	2018-12
15	Short term foreign debt		1993-12	2014-09
16	Commercial bank loans to enterprises		1992-12	2018-12
17	Commercial bank loans to household		1994-03	2018-12

Source: Authors' own research.

Next, we defined the months when the crises started (shown in data as the last day of the month). In December 2001, Argentina defaulted and experienced massive bank runs and deposit withdrawals, which match the classic definition of the banking crisis. Hence, we assumed **31 December 2001** as the starting date for the first crisis. Identifying the currency crisis is quite more difficult. Kaminsky, Lizondo, & Reinhart (1997) argued that currency turmoil means losses of international reserves and currency depreciation. They used a formal definition

of the exchange market pressure index to define the crisis breakout event. The index was a weighted average of monthly percentage changes in international reserves and monthly percentage changes in the exchange rate (defined as units of domestic currency per U.S. dollar). However, for the purpose of this study, we took a simplified approach and assumed that the starting date of the currency crisis was **30 April 2018** (the moment of the peso collapse).

The periods of two years before each of these two dates have been considered as signalling horizons. We expected that a good indicator sends signals within this pre-crisis period more often than in other, tranquil periods. The indicator sends the signal if the value of the indicator in the particular month is above the threshold (for variables that are expected to rise before the crisis) or below the threshold (for variables that are expected to fall before the crisis, therefore we had to take into account the negative sign of the changes). Thus, if the indicator sends a signal within the period of 24 months before the crisis it is called a good signal while the signal sent outside this period is called a false signal or noise. The performances of indicators for given thresholds are summarised in Table 2.

Table 2. Signal classification matrix

Specification	Crisis occurs	No crisis occurs
Signal issued	A	B
Signal not issued	C	D

Source: Kaminsky & Reinhart (1999).

In this matrix, A is the number of months (quarters) in which the indicator issued true signals for the upcoming crisis, B is the number of months (quarters) with false signals, or noise, C is the number of months (quarters) without a signal issued before the crisis and D is the number of months (quarters) without a signal issued but also with no crisis following. Based on this matrix for the given threshold, we first calculated the share of good signals to total signals, expressed as $A/(A+C)$. In the next step, we computed the ratio of bad signals (noise) sent by an indicator to the number of months (quarters) in which false signals could have been sent ($B/(B+D)$). Finally, we computed the noise-to-signal ratio, i.e. ratio of false signals to good signals, as $(B/(B+D))/(A/(A+C))$. The prediction rule states that the lower this ratio is, the more successful is the indicator in predicting currency or banking crisis (Kaminsky & Reinhart, 1999).

The thresholds have been chosen to balance between too many false signals and missing too many crises. For each variable, the thresholds were chosen to minimise the noise-to-signal ratio for that variable. The threshold for each of the indicators was defined in terms of percentile of the distribution of the values of the indicator in the whole time span. For example, by choosing the threshold of 90 percentile, 10% of the total observations would be above the threshold and would be classified as 'signals.' To select the threshold for a particular indicator, we considered one of the two sets of percentiles depending on whether the variable is expected to rise or decline before the date of the crisis. If the variable is expected to rise in the period preceding the crisis, the indicator is expected to be above the threshold and the thresholds are set from 75 to 95 percentiles of the distribution. If the variable is expected to decline before the upcoming crisis, the thresholds are ranging from 5 to 25 percentile and the indicator is expected to be below the threshold. Finally, for each percentile from the chosen set of percentiles, we computed the noise-to-signal ratios for 2001 and 2018 crises separately. The percentile that minimises the noise-to-signal ratio was chosen as a final threshold for that variable and particular crisis (2001 or 2018). The corresponding noise-to-signal ratio is the final characteristic that is used for the evaluation of the predictive power of the indicator.

In the closing step, we ranked the variables based on the final noise-to-signal ratios, for 2001 and 2018 crises independently. In the next section, we present the indicators that best predict at least one of the analysed crises.

4. Research findings and discussion

This section describes the outcomes of the analysis of potential early warning indicators constructed for Argentina in the context of the 2001 and 2018 crises.

4.1. Empirical results

As already stated, the noise-to-signal ratio is a key measure to rank the indicators. In Table 3, we present the variables ordered according to this measure in the case of the 2001 sovereign debt crisis in Argentina (the table excludes the variables for which no signals were issued in the 24-month window before the crisis). The fourth column of the table shows the theoretical presumptions if the variable should go up or down in the period preceding the crisis. The fifth column presents the minimum noise-to-signal ratio computed as described in section 3. The sixth column of the table presents the percentage of correctly

issued signals in the 24-month period before the crisis and the last column presents the percentage of incorrectly issued signals in the tranquil periods (i.e. in the periods outside the two 24-month windows preceding the 2001 and 2018 crises and for which the data are available).

Table 3. The most successful indicators of 2001 crisis in Argentina

No.	Variable	Frequency	Presumptions	min noise-to-signal	% good	% bad
1	Bank deposits	M.	Down	0.08	100.0%	7.9%
2	Imports	M	Up	0.18	20.8%	3.7%
3	Short term foreign debt	Q	Up	0.19	37.5%	6.9%
4	Exchange market pressure index	M	Up	0.32	41.7%	13.4%
5	Terms of trade	M	Up	0.49	41.7%	20.4%
6	M2 multiplier	M	Up	1.41	4.2%	5.9%
7	M2 to reserves ratio	M	Up	1.41	4.2%	5.9%
8	Exports	M	Down	1.93	4.2%	8.0%
9	Real exchange rate	M	Up	3.06	8.3%	25.5%

Source: Authors' own research.

The most successful indicators in the case of the 2001 crisis (i.e. the ones with the noise-to-signal ratio lower than 1.0) turned out to be bank deposits, imports, short term foreign debt, exchange market pressure index and terms of trade.

The same methodology to rank the indicators was applied to the noise-to-signal ratios computed in the case of the 2018 currency crisis in Argentina. The results are presented in Table 4.

Table 4. The most successful indicators of 2018 crisis in Argentina

No.	Variable	Frequency	Presumptions	min noise-to-signal	% good	% bad
1	Lending-deposit rate ratio	M	Up	0.00	20.8%	0.0%
2	Domestic credit	Q	Up	0.08	50.0%	4.1%
3	Commercial bank loans to enterprises	Q	Up	0.13	100.0%	12.9%
4	Unemployment	M	Up	0.14	20.8%	2.9%
5	Total foreign debt	Q	Up	0.15	87.5%	13.2%
6	Commercial bank loans to household	Q	Up	0.15	25.0%	3.8%
7	Inflation	M	Up	0.20	100.0%	19.8%
8	M2 multiplier	M	Up	0.28	41.7%	11.8%
9	Domestic credit to GDP ratio	Q	Up	0.29	37.5%	11.0%
10	Terms of trade	M	Up/ Down	0.67	20.8%	14.0%
11	Exchange market pressure index	M	Up	0.68	16.7%	11.3%
12	Real exchange rate	M	Up	0.96	12.5%	12.0%
13	Exports	M	Down	1.12	20.8%	23.4%
14	M2 to reserves ratio	M	Up	2.31	12.5%	28.9%

Source: Authors' own research.

The list of indicators sending true signals in the period preceding the crisis contains more variables than in the case of the 2001 crisis, but the order of indicators and their corresponding predictive powers differ considerably comparing to the 2001 crisis. This is due to two main reasons: first, the nature of the two crises is clearly different (the 2001 crisis can be identified as a sovereign debt crisis while the 2018 crisis as a currency crisis) and second, more technical, the time series of some variables are not long enough to cover both periods preceding the 2001 and 2018 crises. In the case of the 2018 crisis, the indicators with the noise-to-signal ratios lower than 1.0 are lending-deposit rate ratio, domestic credit, commercial bank loans to enterprises, unemployment, total foreign debt, commercial bank loans to household, inflation, M2 multiplier, domestic credit to GDP ratio, terms of trade, exchange market pressure index and real exchange rate.

In Appendix 1, we present two figures with the most successful indicators for each of the analysed crises: one figure with indicators based on monthly data and one figure based on quarterly data. For each series, we put markers to highlight the points in time where the signals were sent. In Figure 1, we plotted indicators based on monthly data of bank deposits, imports and exchange market pressure index in the context of the 2001 sovereign debt crisis. All of these variables started to send many true signals about a year before the crisis and the exchange market pressure index was sending some signals even earlier. Imports began to grow rapidly before the crisis outbreak as the assumptions suggest and bank deposits were falling in the time window preceding the crisis, also in line with economic theory. The exchange market pressure index was reaching the highest levels in the 24-month window preceding the crisis due to the outflow of reserves and currency depreciation. Interestingly, all of the described variables also kept sending signals after the crisis had begun for the period of approximately a year and a half and then the signals expired. In Figure 2, we show the plot of the indicator based on a short term foreign debt, which turned out to be the only indicator on quarterly basis with the noise-to-signal ratio lower than 1.0 in the case of the 2001 crisis. For this indicator, we observe a small number of knocks for the entire period investigated, but the adopted approach of the noise-to-signal ratio methodology allows us to set a high threshold value so that we have only a few hits in the entire time span. Three of these knocks are located in the 24-month window preceding the crisis, hence the noise-to-signal ratio for this indicator is low and we can conclude that significant growths in the levels of short term foreign debt can be regarded as a good indicator of sovereign debt crisis in the case of Argentina. Figure 3 presents the most successful indicators

of the 2018 currency crisis in Argentina calculated based on the following monthly data: lending-deposit rate ratio, unemployment and inflation. All of these indicators were generally rising in the 24-month window preceding the crisis as expected, but the patterns differ from each other. While the inflation was rising significantly throughout the whole 24-month window and even before and after the time window, the lending-deposit rate ratio and unemployment sent a few strong signals in the period from two years to a year before the crisis and then the trend of these variables reversed, with no signals sent at all for the rest of the time window. Interestingly, the trend reversed again shortly after the crisis broke out, and in the case of unemployment, the signals were sent yet again. In Figure 4, we present the most effective indicators calculated on quarterly basis in the case of the 2018 crisis: domestic credit, commercial bank loans to enterprises and total foreign debt. All of these variables were also expected to rise in the time window preceding the crisis and such a trend was observed in the data. However, in the case of a total foreign debt and commercial bank loans to enterprises it seems that the 24-month window preceding the crisis was too short to capture the entire period for which the indicators sent the warning signals. It can be observed that the indicators start sending signals about three years before the crisis outbreaks.

It should be noted that even the most effective indicators might also be sending some false signals and, in some periods, might be ‘predicting’ crises that in fact never happened. Among the indicators just discussed, this issue is recognised in the years 2002/2003 in the case of inflation, commercial bank loans to enterprises and foreign debt indicators. However, this period was extraordinary and, in fact, the values of the indicators should be regarded as a consequence of the 2001 default rather than a ‘false alarm’ in tranquil times before another crisis. After the recovery around 2003, the false signals were very rare and single for the selected best indicators (except for the inflation in 2014). Therefore, we conclude that the selected set of indicators is robust and based on historical experience the probability of getting many false-positive signals is low.

To conclude the empirical analysis of early warning signals in the case of the 2001 and 2018 shocks in Argentina, it was possible to select a few macroeconomic variables that followed the pattern described in the economic literature before the crises of 2001 and 2018, and hence the constructed indicators based on these variables sent many good warning signals. However, the most successful indicators were different for both crises. It suggests that each crisis is unique and different sets of indicators should be considered for each economic turmoil. Moreover, using all sets of indicators in real time, we can try to predict the nature of the incoming shock from the number of signals in the particular set.

In the next section, we analyse in detail the most successful indicators again and confront our findings with the existing literature.

4.2. Most successful indicators for Argentina

In this section, we discuss the indicators that have the lowest noise-to-signal ratios for at least one of the analysed crises.

Bank deposits turned out to have the lowest noise-to-signal ratio in the case of the 2001 sovereign default crisis. Kaminsky & Reinhart (1999) found that this variable remains stable in the period preceding the crisis and slightly decreases as the crisis already unfolds. In the case of Argentina, this variable generally experienced sustainable growth for the entire period. In fact, in the case of the 2001 crisis, the indicator behaved exactly as in Kaminsky & Reinhart (1999). From December 2000 to March 2001, the growth of deposits was much lower than the threshold value and then it started to be negative and persisted negative until November 2002. Interestingly, this indicator is useless in the case of the 2018 currency crisis. Bank deposits were steadily growing for the entire period before and after the currency crisis, with no signals issued. At first glance, such a conclusion might look surprising because Argentines are accustomed that economic turmoil often leads to restrictions in the access to bank accounts. Historically, people preferred to withdraw their bank deposits as soon as the crisis appeared on the horizon. The absence of a bank run in 2018 suggests much higher confidence in the resilience of the banking system relative to previous crises. The financial system was in good shape in terms of capitalisation and liquidity (i.e. total liquid assets to deposits were at 46% in 2018 – *Argentina's banks rue the loss of last year's future*, 2018) and extraordinary high interest rates (an average deposit rate over 30% in 2018 and over 40% in 2019) provided a great motivation to keep savings on the bank accounts.

The lending-deposit rate ratio is the best leading indicator in the case of the 2018 currency crisis. Kaminsky & Reinhart (1999) reported that this variable started to grow rapidly from approximately six months prior to the currency crisis. In the case of Argentina, this ratio started to grow much earlier, approximately in August 2016 and reached the highest growth rates around a year before the crisis started, sending many good signals (no signals were issued by this indicator outside the 24-month period for the chosen threshold, hence the noise-to-signal ratio is equal to zero for this variable). Theoretically, in the case of banking crises, this variable plays little role as an early warning signal, as it re-

mains stable in the pre-crisis period and peaks during the crisis (due to the fact that banks do not want to lend money). Unfortunately, it was impossible to compute this ratio for the 2001 crisis in Argentina because of the lack of data.

The literature suggests that exports are below their long run average in the period of a year and a half preceding both balance of payments and banking crises. In the case of Argentina, a decreasing trend of exports in terms of value in U.S. dollars was observable for approximately five years preceding 2018 currency crash, but the declines in the value in the 24-month window preceding the crisis were not large enough to trigger many early warning signals. This indicator also played a little role in predicting the severe crisis of 2001/2002. Exports were falling consistently for two months preceding the crisis (and the decline was not significant) and then started to recover two months after the crisis outbreak.

The theoretical presumptions of the behaviour of imports in the years preceding the crisis are not sufficiently clear. If the exchange rate is overvalued in the pre-crisis period (as it was before the 2001 crisis in Argentina), then it should stimulate imports. However, the appreciated real exchange rate reduces exports and, as a result, weakens economic growth and import demand. In Argentina, imports were growing from March 2001 to January 2002, sending positive signals in the pre-crisis period. No such behaviour of imports was observable before the 2018 currency crisis.

Measures of debt servicing obligations (short term foreign debt and total foreign debt) are statistically significant predictors of upcoming sovereign debt crises. Manasse, Roubini, & Schimmelpfennig (2003) concluded that debt service on external debt to reserves is higher one year before the crisis and falls sharply just after the eruption of a crisis due to conversion of short-term debt into long-term debt and debt restructuring programmes. In the case of Argentina, a short term foreign debt (in the U.S. dollar) was slightly growing since the mid-nineties and started to climb rapidly around a year before the 2001 default, thus sending positive signals of the crisis approaching. Unfortunately, due to the lack of data, we were not able to conclude whether this indicator was sending any signals before the 2018 crisis. Conversely, the total foreign debt was growing rapidly before the 2018 currency turmoil and this indicator turned out to be a quite good predictor of this crisis (low noise-to-signal ratio).

Kaminsky & Reinhart (1999) stated that domestic credit (financial institutions' loans to the private sector) as a percentage of GDP is expected to rise in the period preceding the crisis and then the trend sharply reverses. It seems that

it was exactly the case of the 2018 currency crisis (low noise-to-signal ratio), but in the case of the 2001 crisis, the trend reversed around a year before the crisis, hence the indicator sent no signals in the case of this crisis. It should also be noted that the absolute values of domestic credit, commercial bank loans to enterprises and commercial bank loans to household were considerably lower and quite stable in the period preceding the 2001 crisis compared to the 2018 crisis. In the case of the latter crisis, the rapid growth in these three variables before the crisis resulted in positive signals sent by all these indicators while, in the case of the former one, no signals were sent at all.

Unemployment is pointed out as a statistically significant indicator of currency crises in many empirical surveys. For example, Tomczyńska (2000) concluded that rising unemployment rates suggest that government may be reluctant to defend an exchange rate regime by economic policies that could further weaken the real sector and the currency finally collapses. In the case of Argentina, the situation seems to be more complicated. The unemployment rates reached the highest values at the beginning of 2002, but there were no monthly data available before this date, therefore, we were not able to evaluate this indicator in the case of the 2001 crisis. Nevertheless, growth in the unemployment rate before 2018 crisis was huge enough to send positive signals warning of the incoming currency turmoil. The conclusions drawn from this indicator should be interpreted with caution as the indicator is very sensitive to the time window chosen.

Inflation is also usually considered as a premise of the impending crisis. Tomczyńska (2000, p. 19) stated that inflation “determines the mean rate at which the economy is moving toward the critical point.” However, in the case of Argentina, the inflation rose sharply just after the crisis broke out in 2001 with no warning signals sent before the crisis. On the contrary, in the case of the 2018 crisis, the inflation growth rates were quite high for more than two years before the crisis, sending 100% of good signals in the observation period before the currency crisis (it should also be noted that figures for inflation in Argentina between 2014 and 2016 are not reliable due to possible data manipulations by the Argentinian authorities).

The exchange market pressure index is defined as a weighted average of monthly percentage changes in the exchange rate (ARS per U.S. dollar) and the negative of monthly percentage changes in gross international reserves in U.S. dollar as proposed by Kaminsky, Lizondo, & Reinhart (1997). The crisis of 2001 in Argentina was preceded by a systematic losses of central bank reserves and

domestic currency depreciation, hence the changes in the index are the most significant in the period preceding this crisis (the minimum noise-to-signal ratio equals to 0.34). Interestingly, in the case of the 2018 crisis, the abrupt currency depreciation was partially balanced by the increase in official international reserves, therefore the changes in the index were low and, in consequence, this indicator has limited predictive power in the case of this crisis (minimum noise-to-signal ratio equal to 0.68).

Kaminsky & Reinhart (1999) found that M2 to reserves ratio exceeds its long-term average in the period preceding both banking and currency crises. In Argentina, such a performance of this variable is hardly observed in periods preceding the 2018 and 2001 crises, hence the ratios of noise-to-signal are quite high for this indicator in both cases.

The pattern of M2 multiplier is different for both crises. In 2001, M2 multiplier rose sharply in the moment of crisis with no signals sent before the crisis. For 2018 currency turmoil, the opposite is true: this variable was growing steadily before the crisis, but it cannot be regarded as a good early warning indicator because it was also sending many false-positive signals, hence the noise-to-signal ratio is greater than 1.0.

The empirical evidence (Dornbusch, Goldfajn, & Valdes, 1995) revealed that the real exchange rate in a year before a banking or currency crisis sharply appreciates and, in the moment of crisis breakdown, the trend reverses and the real exchange rate starts to depreciate significantly. The macroeconomic data show that it is the case of Argentina and the 2001 crisis. The real exchange rate was going up since 1996 and then suddenly plummeted between 2001 and 2002. In the case of the 2018 currency turmoil, the effects described above still seem to take place but to a lesser extent. Interestingly, this indicator has the noise-to-signal ratio lower than 1.0 for the 2018 crisis only. This is because the EWS methodology takes into account only the appreciation period before the crisis (the appreciation rates were not very high before the 2001 crisis), not the sharp depreciation which is an effect of the crisis itself.

5. Conclusions

In this study, we analysed the effectiveness of early warning indicators in the context of the 2001 sovereign default crisis and the 2018 currency shock in Argentina. The main contribution of this study is that classical macroeconomic variables suggested in the literature proved their value predicting these two

crises, i.e. issuing many strong signals in periods preceding crises and exhibited a very low fraction of false signals in tranquil periods. The unique feature of this study is a construction of exclusive sets of early warning indicators, taking into account the specific nature of the approaching crisis (currency or sovereign debt crisis). Moreover, using all sets of indicators in real time, one can try to predict the nature of the incoming crisis from the number of signals in a specific set.

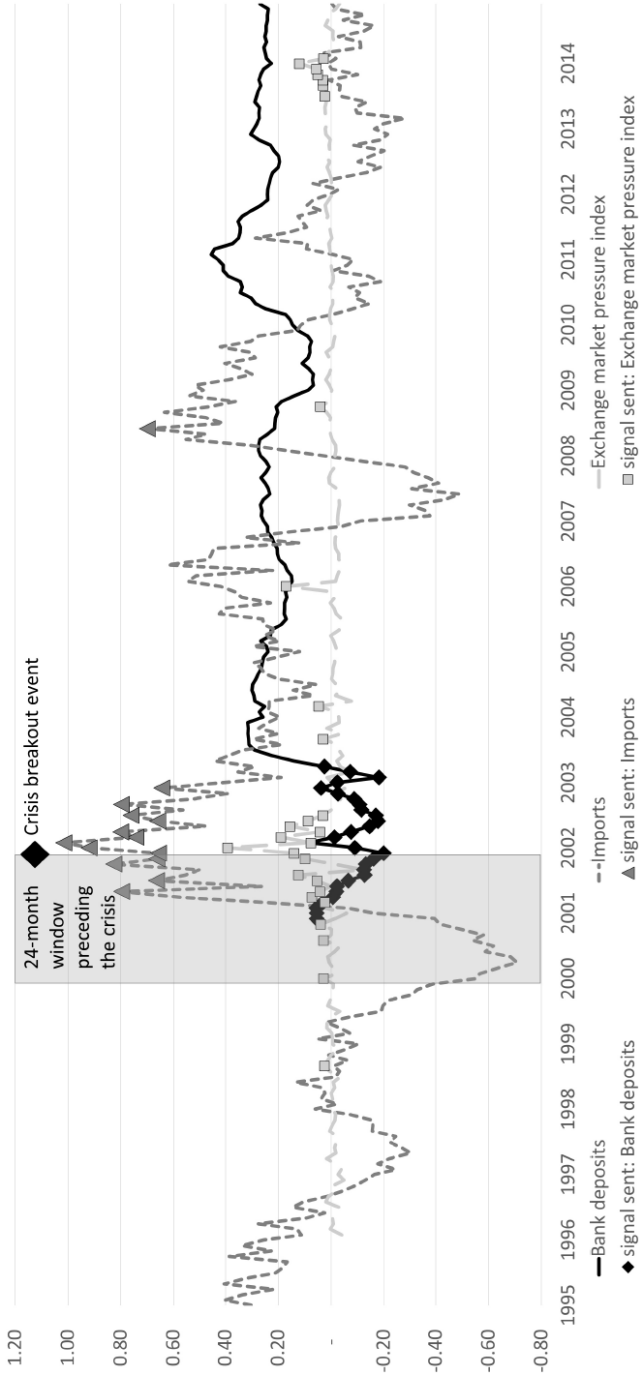
For the 2001 crisis in Argentina, the best predictive power in terms of the noise-to-signal ratio was observed for bank deposits, imports, short term foreign debt and exchange market pressure index. For the 2018 crisis, the best selected indicators were lending-deposit rate ratio, domestic credit, commercial bank loans to enterprises, unemployment, total foreign debt, commercial bank loans to household and inflation.

This study showed that despite different natures of both crises, traditional indicators predicted them quite well. It seems that the most robust and modern framework for early warning signals should take into consideration the type of the possible crisis approaching (sovereign debt crisis or currency crisis) and each type of a crisis should have different weights assigned to particular indicators based on their predictive power for a specific type of a crisis. However, the main limitation of this study is – still – data availability, quality and comparability. The authors were unable to calculate a full set of indicators suggested in the economic literature because of the lack of reliable data for Argentina.

The results of the survey suggest that the approach of both crises was not unexpected from the view of traditional theory of economics, represented by macroeconomic indicators widely discussed in the literature. Therefore, the implications of this study are important for policy makers because the authors believe that careful observers of economic developments could not be unaware of the increasing probability of the crisis occurrence. The conclusions drawn from this paper are also important for other researchers because this framework can also be applied to other countries facing similar problems as Argentina.

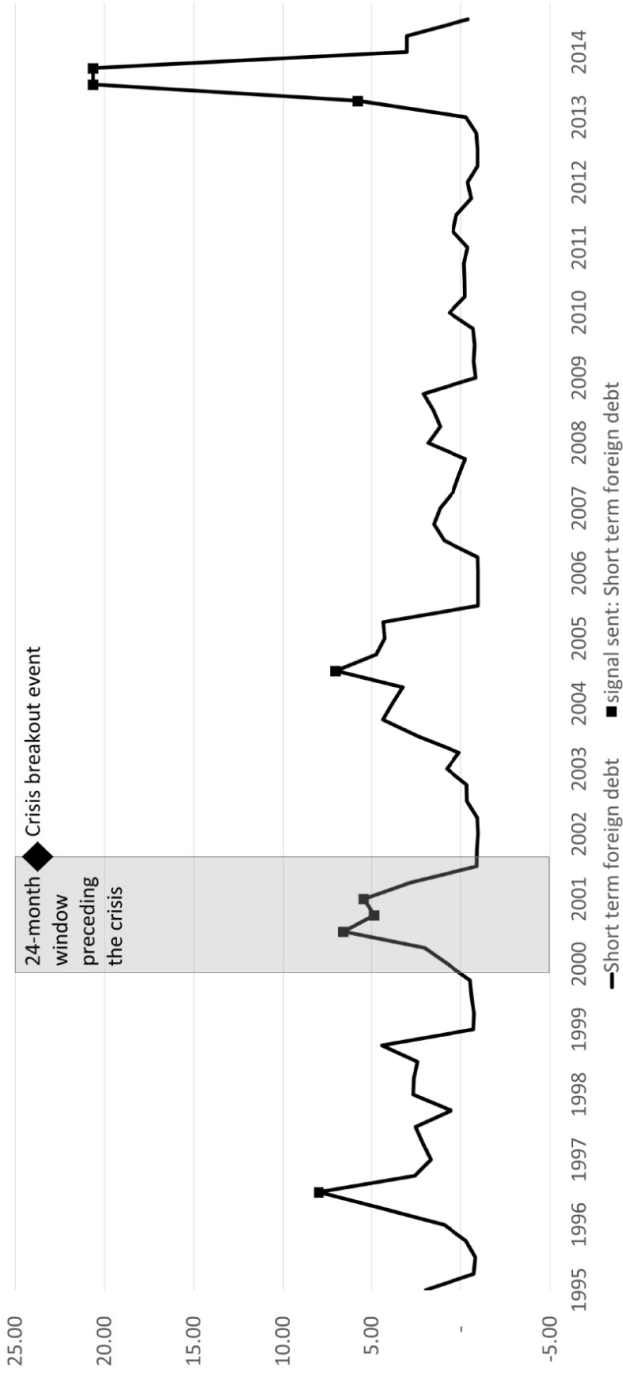
Appendix 1

Figure 1. The most successful indicators of 2001 crisis in Argentina – monthly data



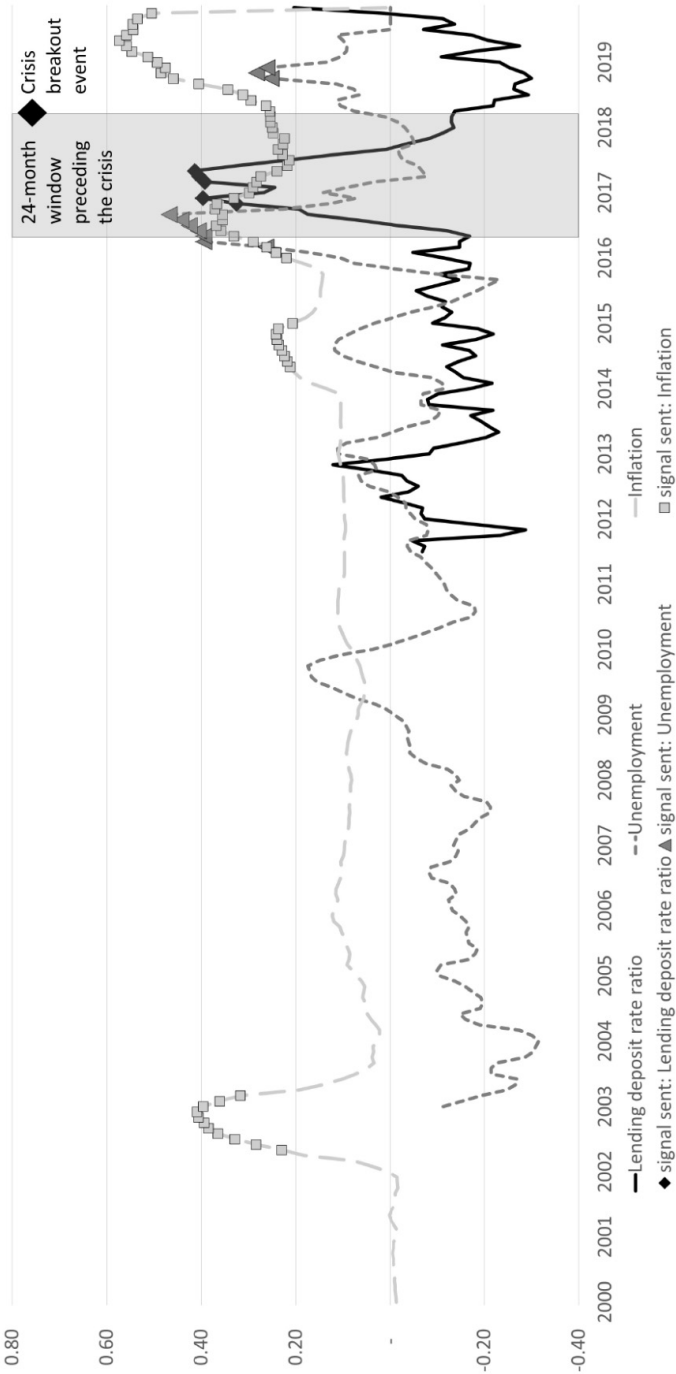
Source: Authors' own research.

Figure 2. The most successful indicators of 2001 crisis in Argentina – quarterly data



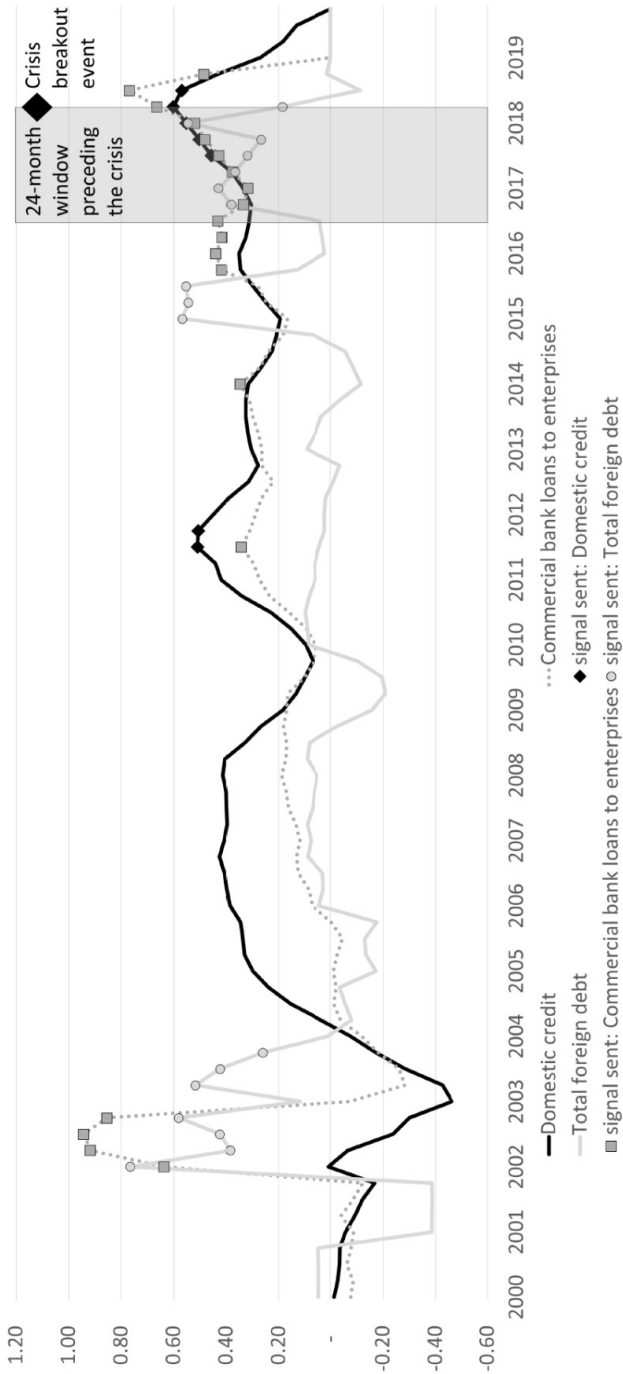
Source: Authors' own research.

Figure 3. The most successful indicators of 2018 crisis in Argentina – monthly data



Source: Authors' own research.

Figure 4. The most successful indicators of 2018 crisis in Argentina – quarterly data



Source: Authors' own research.

Appendix 2

Table 5. Macroeconomic variables used in empirical study

No.	Variable	Frequency	Description	Source
1		3		5
1	M2 multiplier	Monthly data	Calculated as broad money (M2) to monetary base.	Federal Reserve Economic Data / Central Bank of the Argentine Republic
2	Bank deposits		Cash deposits with financial institutions – total amount in pesos.	Central Bank of the Argentine Republic
3	Exports		Value in current U.S. dollars, seasonally adjusted.	The World Bank
4	Imports		Value in current U.S. dollars, seasonally adjusted.	The World Bank
5	Real exchange rate		The weighted average of a country's currency in relation to basket of other major currencies.	The World Bank
6	Exchange market pressure index	Monthly data	The weighted average of monthly percentage changes in the exchange rate (ARS per U.S. dollar) and the negative of monthly percentage changes in gross international reserves (BCRA's stock of international reserves in U.S. dollars). The weights are inversely proportional to the standard deviations of the variables.	Investing.com / Central Bank of the Argentine Republic
7	Lending-deposit rate ratio		Average of loan rate (interest rate on personal loans) to average of deposit rate (interest rate on 30-day deposits with financial institutions).	Central Bank of the Argentine Republic
8	Terms of trade		Ratio of import to export unit value.	The World Bank
9	Unemployment		Unemployment rate, seasonally adjusted.	The World Bank
10	Inflation		Year on year inflation (year on year change).	Central Bank of the Argentine Republic
11	M2 to reserves ratio	Quarterly data	Calculated as broad money (M2) to international reserves (in U.S. dollars).	Federal Reserve Economic Data / Central Bank of the Argentine Republic
12	Domestic credit		Financial institutions' loans to the private sector in pesos.	Central Bank of the Argentine Republic
13	Domestic credit to GDP ratio		Domestic credit in pesos to GDP (GDP in current pesos and seasonally adjusted).	Central Bank of the Argentine Republic / The World Bank
14	Total foreign debt		Amount outstanding of total debt securities in general government sector, all maturities, residence of issuer in Argentina (in U.S. dollars).	Federal Reserve Economic Data

Table 5 cont.

1	2	3	4	5
15	Short term foreign debt		Amount outstanding due within one year of international debt securities for general government sector, nationality of issuer in Argentina (in U.S. dollars).	Federal Reserve Economic Data
16.	Commercial bank loans to enterprises		Total credit to private non-financial sector, adjusted for breaks (in pesos).	Federal Reserve Economic Data
17	Commercial bank loans to household		Total credit to households and non-profit institutions serving households, adjusted for breaks (in pesos).	Federal Reserve Economic Data

Source: Central Bank of the Argentine Republic (2019); Federal Reserve Economic Data (2019); Investing.com (2020); The World Bank (2019).

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