FINANCIAL ECONOMICS

DYNAMIC ANALYSIS OF MACROFUNDAMENTAL VARIABLES AND RISK CASES, COLOMBIA AND LIMA (PERU)

Centro de Investigaciones
Facultad de ciencias
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Prolog

Dedicated to all those who believe in their dreams and sow day by day to achieve them.

This research book is the product of a frank and open debate related to the importance of accurately measuring financial phenomena that turn out to be related to scenarios of economic openness, financial globalization, competitive market environments and their incidence on risk. Thus, the authors of this book have wanted to show in a clear and detailed way methodological approaches that allow future researchers to carry out replications of this work in other contexts or to broaden the theoretical reflection to strengthen the theoretical framework of financial economics.

The analysis contexts in this book have been chosen considering spatial, temporal or historical peculiarities that have aroused intellectual interest in understanding how differentiated impacts are produced on commodity prices, exchange rate and risk or which variables are determinants of these categories of analysis. This work aims to provide investors and researchers with a methodological approach to carry out technical and / or fundamental analyzes for the prediction of the behavior of the main currency pairs worldwide, especially those that can be traded through the Internet, in various platforms that brokers develop to facilitate access and participation in these types of markets. In many cases, the broad panorama of research topics related to the field of financial economics may induce a greater focus on performance analysis to leave out very important elements that should be considered when making investment decisions, such as For example, the most appropriate statistical tools for a certain behavior, the combination of analysis to confirm or deny a prediction, the indicators of more and less risky operations, linearity or non-linearity in quantitative relationships of interest. However, this work does not guarantee success in your investment decisions, due to a large number of factors that will be explained later in the following chapters, however, it intends to considerably reduce your deliberate, irrational and unfounded decisions, regarding amounts, risk analysis, types of currency, duration and times when financial operations are carried out. This requires the application of statistical tools (technical analysis) based on longitudinal data available in secondary information sources and the analysis of the most influential economic indicators in the behavior of the assets mentioned in the document (fundamental analysis). Carlos David Cardona Arenas

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The author Carlos David Cardona Arenas, is interested in quantitative analysis applied to economic analysis, he is an economist from the University of Manizales, a Magister in economics from the same university, Magister in Economic Sciences from the Pontifical Javeriana University and is currently a candidate for Doctor of Economic Sciences from the same university, his areas of interest for research are related to international economics, financial economics, labor market, impact of economic policy and predictive time series models, as well as the use of macroeconometrics tools for economic analysis. He currently works as coordinator of the Department of Administration and Economics of the Autonomous University of Manizales and as coordinator of the Master in Business Administration of the same university.

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Capítulo

1

Chapter 1. The Exchange Rate in Colombia: Criteria for Fundamental Analysis to Estimate a VAR Model

Abstract

The present study seeks to identify the fundamental variables that impacted the COP/USD exchange rate, in Colombia, during the 1995-2020 period. In order to provide relevant information regarding the fundamental determinants of said exchange rate, a Vector Autoregressive (VAR) estimation methodology was employed. Based on time series analysis and the interpretation of impulse-response functions and the variance decomposition process, the present study concludes that the Colombian RMR responds, in the short term, mainly to international variables, such as the Federal Reserve interest rate, fuel energy commodity index, and total exports.

Keywords: VAR, impulse response functions, exchange rate, variance decomposition.

JEL Classification: E30, E32, E47, C3, C51

MSC2010: 00A72, 62J10, 62J86

Tasa de cambio en Colombia: Criterios de análisis fundamental para estimación de un modelo VAR

Resumen

El presente estudio busca identificar las variables fundamentales que impactan el tipo de cambio COP/USD para Colombia para el periodo 1995-2020. Para proporcionar información relevante sobre los determinantes fundamentales de la tasa de cambio, se emplea una metodología de estimación mediante Vectores Autorregresivos (VAR). A partir del análisis de series temporales e interpretación de las funciones impulso-respuesta y el proceso de descomposición de varianza, el estudio permite concluir que la RMR en Colombia responde a corto plazo primordialmente a variables internacionales tales como la tasa de interés de la reserva federal, el índice *commodity* de energía combustible y las exportaciones totales.

Palabras claves: VAR; funciones impulso respuesta; TRM; mercado internacional de divisas; descomposición de varianza.

Clasificación JEL: E30; E32; E47; C3; C51

MSC2010: 00A72; 62J10; 62J86

1. Introduction

In the context of emerging economies, it is essential to identify the determinants of the exchange rate, in order to provide information relevant to economic decision-making for the central government, companies, and individuals (Murcia and Rojas, 2014), given that this cannot be predicted linearly, using exclusively technical analysis (Sierra, Duarte, and Rueda, 2015). Shifts in the exchange rate associated with macro-fundamental factors have been widely debated in the literature, and little consensus has been reached regarding the connections therebetween. However, Rossi (2013) and Bunčák (2016), suggest that exists a robust connection between the rate of change and the macro-fundamental variables if the purpose of measurement is clearly known, and an adequate model specification should be presented. Which may include economic instabilities and probable structural breaks on the series.

In the first part of this investigation, relevant categories for the fundamental analysis of the COP/USD exchange rate, in Colombia, are determined. Monthly data are considered for the period between March of 1995 and January of 2020. The methodology implemented to estimate the dynamic model was the multi-equation Vector Autoregressive system (VAR). This allows for the characterization of the simultaneous interactions between the group of variables under study: From RMR, exports and imports, monetary base, American federal reserve interest rate, interbank interest rates, to global fuel index of commodity good prices .

The present study presents a rigorous VAR model specification and estimation process. To this end, model identification, series stationarity analysis, cointegration analysis, causality and unit root tests, determination of the VAR order with the Akaike information criterion, Breusch-Godfrey - LM serial autocorrelation tests, and post-estimation analysis of the interpretation of impulse response functions was carried out, so as to finally deconstruct RMR variance, as explained by the shocks induced in a system of equations. The results show that slightly more than two thirds of RMR behavior is explained by factors external to the Colombian economy[1], and by itself due to the inertial effect. Thus, the study contains the following sections: i) Literature review, ii) Methodology, iii) Results, and iv) Conclusions.

2. Literature review

The present literature review aims to analyze the fundamental variables that significantly impact the behavior of the COP/USD exchange rate in Colombia. As suggested by Beckmann, Belke, and Kühl (2011), and considering the theoretical basis of the global financing liquidity channel, nominal

[1] Including the RMR itself, due to its inertial effect

exchange rates tend to fluctuate, depending on monetary policy stances (Adrian, Etula, and Shin, 2009). Similarly, it is well known that exchange rate behavior reflects the speculative conditions of the foreign exchange market, and its future changes, in response to short-term shocks to macro-fundamental variables (Bhanja, Dar, and Tiwari, 2015), (Bunčák, 2016) and (Rincón, Rodríguez, and Castro, 2017). For example, it is conceivable that the decisions made by central banks to control exchange rate instability directly affect the path of the exchange rate. (López , Rodríguez., and Ortíz, 2011).

Whether through conventional or unconventional mechanisms, central bank interventions can impact the conditions for direct foreign investment, arbitrage opportunities or profits (Galindo and Salcines, 2004), and external risk behavior. Botero and Rendón Gonzáles (2015), found, through a Dynamic and Stochastic General Equilibrium model (DSGE), that a negative monetary policy shock tended to appreciate the exchange rate in Colombia. On the other hand, the literature highlights the influence that international oil prices and American federal fund interest rates have on the exchange rate in Colombia (Galvis, de Moraes, and Anzoátegui, 2017). Some studies emphasize the usefulness of Vector Autoregressive Models (VAR) for improved RMR forecasting and trajectory change results, which stem from short-term shocks (Fayad, Fortich, and Vélez, 2009). These VAR models permit consideration of the analysis of those simultaneous interactions between oil prices, exchange rates, and stock markets under the effects of volatility, as a measure of market uncertainty.

Considering this analytical framework, Roubaud and Arouri, (2018) demonstrate, by way of a VAR model, that significant non-linear interrelationships exist between the foreign exchange, oil, and equity markets. This is supported by the findings of Bermudez, Bermudez, and Saucedo (2018), which show that oil prices exercise a statistically significant influence on the exchange rate. However, the effects observed tend to disappear over time, which points to a short-term relationship. Thus, the causal relationship between the global commodity price index and the exchange rate supports the assumption that external factors explain RMR behavior, while shocks to internal variables do not have statistically significant effects on their behavior (Murcia and Rojas, 2014).

In the Colombian context, the work of Rincón et al., (2017) is highlighted. Therein, two important effects on the analysis of determinants of the nominal exchange rate are studied. On the one hand, it is expected that oil price innovations will affect the trajectory and volatility of the nominal exchange rate, and on the other, and in accordance with the parity interest rate theory, an increase in the domestic nominal interest rate would tend to increase the expectation of depreciation. Therefore, in the short term, there is an effective appreciation, due speculative causes. In summary, short-term RMR trajectory and volatility in Colombia may be explained, to a greater extent, by international factors (Uribe, Jiménez and Fernández, 2015), given that a disturbance in the price of oil generates a sudden inflow of currency, which appreciates the exchange rate (Rodríguez, 2011).

Recently (Cardona-Arenas and Serna-Gómez, 2020) analyze the effect of COVID-19 (2019-nCoV) and the variations in international oil prices on the Colombian peso-US dollar exchange rate between February 16 and March 14, 2020. The authors select this period because There, the pandemic spread to South America. The methodology implemented by the research consisted of estimating an Autoregressive Vector Model (VAR), without arbitrary restrictions. Among the main results is that the process of depreciation of the Colombian peso against the dollar, during said period, is explained by a mixed effect between COVID-19 and oil prices. This highlights the short-term effect of pandemic media coverage on the Colombian economy and the dependence of the exchange rate on the international oil price. Additionally, decisions on the FED rate and international economic situation are expected to impact the RMR, especially in the short term (Jansen and De Haan, 2005).

3. Methodology

As originally proposed by Sims, (1986), the VAR model permits the valuation of the effect of an innovation or shock to the system of endogenous variables, over time (Melo and Hamann, 1998). These shocks may be sudden and generate deviations or imbalances in the market, with macroeconomic repercussions (Pérez and Trespalacios, 2014). Impulse response functions measure the reaction of each endogenous variable to a shock to one variable, which will transmit the effects to the remaining variables through the multi-equation structure.

The model is appropriate because it allows for the characterization of the simultaneous interactions between the groups of variables under analysis. Thus, it may be assumed that system endogenous variables are functions of lagged values of all endogenous variables. Thus, the VAR model offers a simple and flexible alternative to traditional multi-equation models. Let $Y_t = (x1, x2., x3, \dots, x7)$ be a vector of $(n\ x\ 1)$, a series of stationary variables in which Y_t corresponds to the set of endogenous stationary and seasonally adjusted variables in period (t), obtained previously. The model is represented in the following reduced form:

$$Y_t = \sum_{i=1}^{\rho} \Pi_i Y_{t-\rho} + \epsilon_t \ \ [\mathbf{1}]$$

This representation describes the way in which the estimated shock to each endogenous variable is simulated by the impulse response function, considering that system variables are endogenous (Beaton, Lalonde and Luu, 2009). The reduced form of the vector autoregressive model, in order ρ -VAR(30), is:

$$Y_t = \mathrm{C}_0 + \Pi_1 y_{t-1} + \Pi_2 Y_{t-2} + \cdots + \Pi Y_{t-30} + \epsilon_t \quad [\mathbf{2}]$$

In which the lag operator is generally defined as follows:

$$(I_n - \Pi_1 L - \Pi_2 L^2 - \cdots - \Pi_p L^p) y_t = \mathrm{C}_0 + \epsilon_t \quad [\mathbf{3}]$$

And the polynomial lag is represented thus:

$$\Pi(L) y_t = \mathrm{C}_0 + \epsilon_t \qquad [4]$$

Where Π_i, is the coefficient matrix $(n \ x \ n)$, C_0, is the constant matrix, and ϵ_t is characterized by being a $kx1$ vector of innovations without serial correlation, or white noise, and with zero average and variance matrix $\sigma^2_{\varepsilon i}$ covariances σ_{ij}, which are constant over time. It merits mention that, for Y_t to be a stationary process, polynomial matrix $\Pi(L)$ must be invertible. In general, endogenous system variables are functions of the lagged values of all other endogenous variables. This model representation permits estimation bias problems to be overcome, and reduces potential identification problems. Among the estimation purposes is to calculate the impulse response functions in such a way that both contemporary reactions and the post-shock effects on endogenous variables may be considered, these impulse response functions are generally represented as:

$$FIR_t = \sum_{j=1}^{n} \left[\sum_{i=1}^{m} r_{t,jt-i} \right] \qquad [5]$$

Where $r_{t,jt-i}$ measures the response of the RMR variation in each variable j, endogenous to the system in the previous periods. In other words, in its lags, which correspond to vector $Y_t = (x1, x2., x3, \dots, x7)$, each variable is expressed as a function of the accumulated random disturbances. Thus, for each shock, there are as many accumulated impulse response functions as there are variables. In the present study, the generalized and accumulated impulse response functions are estimated, considering that variable ordering is not required, as the variables of interest are, in any case, endogenous and explanatory in the simultaneous system of equations. Therefore, the identification problem in the present study matches the perspective of Sims (1986), in which no arbitrary restrictions are imposed on the model, considering that none of the variables in the system of equations of the estimated VAR model have sufficient theoretical or empirical support to be considered exogenous.

The monthly values for the following variables were considered: the RMR, commodity fuel energy index, seasonally adjusted Colombian exports, seasonally adjusted Colombian imports, Colombian interbank interest rate, American Federal Fund interest rates, and Colombian monetary base for the period between March of 1995 and January of 2020. The sources of information correspond to the data published by the Banco de la República (BR), the International Monetary Fund (IMF), and Federal Reserve System (FED). The series that exhibited seasonality were de-seasonalized using the CensusX12 method. Below, several descriptive statistics related to the variables analyzed in the article are presented in Table 1. Each variable has 299 observations that correspond to monthly data for the period between March of 1995 and January of 2020. The exchange rate is expressed as the number of pesos per US dollar, total exports and imports are expressed in millions of dollars FOB and CIF, respectively and all of these` are reported by the BR. The commodity fuel index (2016 = 100), calculated by the IMF, will henceforth be called Fuel_index, as it includes oil, natural gas, coal prices, and propane gas. Colombia's interbank interest rate is reported by the BR, and the American federal fund rates are reported by the FED. Table 2 presents the correlation matrix, since, by implication, variables must be strongly correlated for inclusion in the VAR system. Likewise, the unit root tests are presented, as it is understood that the estimation analysis of a VAR model with non-stationary variables can lead to spurious results.

Table 1. Descriptive statistics

	TRM	**Fuel_index**	**EX.**	**i_Col**	**i_FED**	**MB**	**IM.**
Average	2130.208	126.9377	2403.277	9.833910	2.494858	33252.61	2674.950
Median	2117.000	120.0000	2164.780	6.000000	1.750333	25163.00	2489.232
Maximum	3357.000	312.0000	5562.479	50.00000	6.544516	98081.00	5870.623
Minimum	865.0000	30.00000	745.0133	3.000000	0.066429	5028.000	740.5623
Stand. dev.	600.4262	67.68521	1409.235	8.806569	2.270016	26622.73	1531.193
Asymmetry	-0.191168	0.438169	0.529690	1.848375	0.370864	0.711350	0.327643
Kurtosis	2.413099	2.108583	2.034131	5.909922	1.475808	2.154137	1.606049
Jarque-Bera	5.908032	18.81624	24.74787	266.5255	34.59956	32.98886	28.56882
Probability	0.052130	0.000082	0.000004	0.000000	0.000000	0.000000	0.000001
Sum	615630.0	36685.00	694547.0	2842.000	721.0141	9610004.	773060.6
Sum Sq. Dev.	1.04E+08	1319411.	5.72E+08	22336.03	1484.056	2.04E+11	6.75E+08
Observations	299	299	299	299	299	299	299

Source: Prepared by the authors, based on data provided by the IMF for the commodity fuel index (Fuel_index), BR for RMR data, Exports (EX), Imports (IM), Monetary Base (MB) and Colombia Interbank Interest Rate (i_Col), FED for data for federal fund interest rates (i_FED).

Table 2. Correlation matrix

	TRM	**Fuel_index**	**EX**	**i_Col**	**i_FED**	**BM**	**IM.**
TRM	1.000	0.098*	0.156***	-0.653***	-0.486***	0.565***	0.256***
Fuel_Index	0.098*	1.000	0.899***	-0.624***	-0.575***	0.513***	0.799***
EX	0.156***	0.899***	1.000	-0.604***	-0.706***	0.733***	0.951***
i_Col	-0.653***	-0.624***	-0.604***	1.000	0.697***	-0.560***	-0.57***
i-FED	-0.486***	-0.575***	-0.706***	0.697***	1.000	-0.662***	-0.714***
MB	0.565***	0.513***	0.733***	-0.560***	-0.662***	1.000	0.860***
IM	0.256***	0.799***	0.951***	-0.575***	-0.714***	0.860***	1.000

Source: Prepared by the authors, based on data provided by the IMF for the commodity fuel index (Fuel_Index), BR for RMR data, Exports (EX), Imports (IM), Monetary Base (MB), and Colombia Interbank Interest Rate (i_Col), FED for data for federal fund interest rates (i_FED). Note: the symbols *, **, and *** correspond to the level of statistical significance: 10%, 5%, and 1%, respectively.

Table 3. Unit root tests: Augmented Dickey-Fuller and Phillip-Perron test

Variable	**Augmented Dickey-Fuller test static**				**Phillip-Perron test statistic**				
	ADF in levels		ADF first differences		PP in levels		PP first differences		
	Trend and Intercept								
	T-Stat.	*Prob.*	*T-Stat.*	*Prob.*	*T-Stat.*	*Prob.*	*T-Stat.*	*Prob.*	*Integration Order*
TRM	-1.853	0.6757	-12.32	0.000	-1.695	0.7509	-12.104	0.000	I(1)
MB	-0.399	0.9872	-3.681	0.025	-1.317	0.8817	-52.367	0.000	I(1)
i_Col	-2.880	0.1704	-10.510	0.000	-3.407	0.052	-26.526	0.000	I(1)
i_FED	-1.474	0.8363	-7.956	0.000	-1.735	0.7328	-7.964	0.000	I(1)
EX	-1.443	0.8462	-24.160	0.000	-1.928	0.6372	-24.186	0.000	I(1)
IM	-1.472	0.8368	-11.376	0.000	-2.519	0.3187	-31.736	0.000	I(1)
Fuel_Index	-2.222	0.4792	-10.943	0.000	-2.003	0.5968	-11.027	0.000	I(1)

Source: Prepared by the authors, based on data provided by the IMF for the commodity fuel index (Fuel_index), BR for RMR data, Exports (EX), Imports (IM), Monetary Base (MB) and Colombia Interbank Interest Rate (i_Col), FED for data for federal fund interest rates (i_FED). Note: (P-value)-Prob based on (MacKinnon, 1996) on-sided p values, null hypothesis: has a unit root (P-value > 0.01), Alternative hypothesis (P-value < 0.01) Lag length: 7 (Automatic – based on SIC, maxlag=11)

From the unit root tests, it was evident that, at level, all the variables had unit roots. However, in the first difference, it was clear that all the variables were stationary, so the variables were integrated of order I (1). If evidence of cointegration were found in the variables, the model would have been estimated by including an integration equation as an additional regressor in the VAR system, and thus take the form of a Vector Error Correction Model (VECM). Table 4 confirms the non-existence of cointegration in the variable system, with a confidence level of 99%, based on the Engle-Granger methodology. Additionally, a VAR system with n variables can have maximum (n-1) cointegration relationships, based on the Johansen methodology. This study identified three cointegration equations, for a total of n = 7 endogenous variables. Therefore the number of cointegration equations was less than the number of variables (see Annex D). As such, it was unlikely that the series would move together in unison in the long term, and the estimation was therefore not required from a VECM model.

Based on the described criteria, the present study estimated an unrestricted VAR model as suggested (Aljandali and Tatahi, 2018, p. 212), and in accordance with Bermúdez, Bermúdez and Saucedo's (2018) methodology, variable I(1) had to be differentiated to carry out the Granger causality test, (see Annex E). The results demonstrate that the RMR is caused, in the Granger sense, by imports, Federal Reserve interest rates, the monetary base, and Fuel_index index, under the null hypothesis of non-causality, at a confidence level of 99%,.The fact that the monetary base turns out to be caused by caused_granger[2], by the RMR at a 99% confidence level, stands out as consistent with the theory. From the analysis, it can be concluded that there is only double directionality in causation with the monetary base and RMR, none of the other variables presents causality in both directions. This is consistent with the results of the cointegration test performed, demonstrating that the behavior of the objective variables of analysis may be explained by the system set of equations, thus it should be considered a general VAR specification, in which all are considered endogenous system variables.

Table 4. Engle-Granger cointegration test

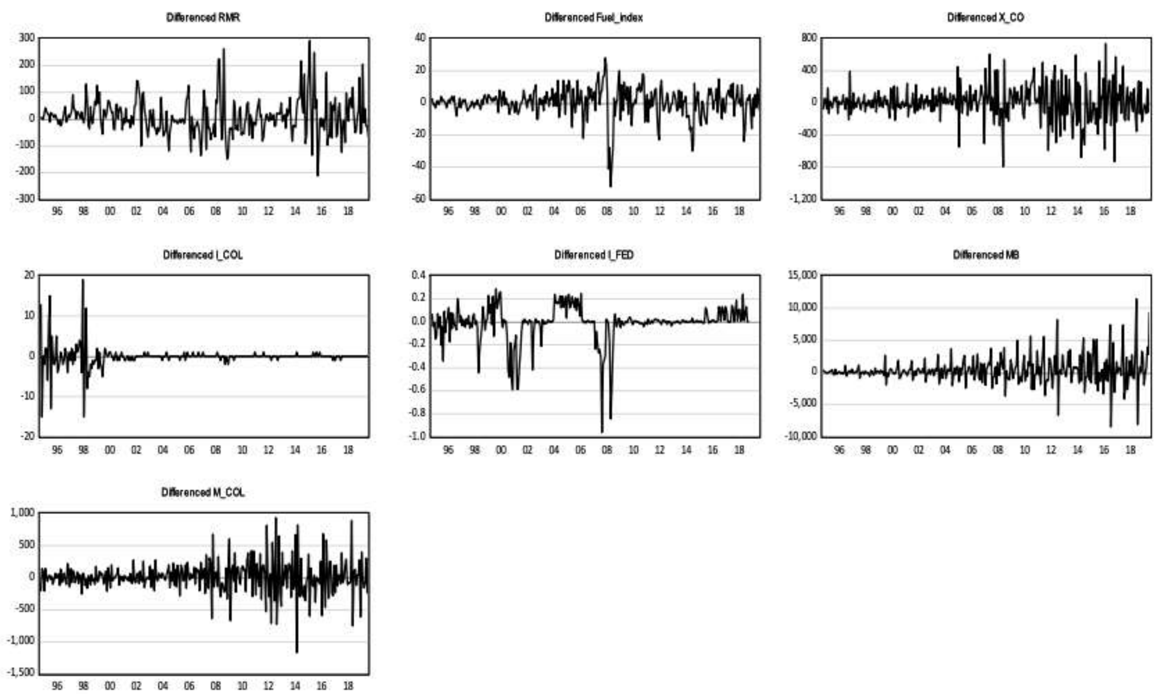
	tau. Statistic	Prob.*	Z-statistic	Prob*
TRM	-4.070743	0.3391	-32.69650	0.2872

[2] This is not evidence of a causal relationship, but of a connection with a predictive nature, that reflects a bidirectional link between the exchange rate and monetary base. This mirrors an endogeneity characteristic between variables.

Fuel_Index	-3.846328	0.4520	-29.72987	0.3869
EX	-4.896886	0.0719	-48.52481	0.0348
i_Col	-4.327155	0.2279	-40.94510	0.1055
I_FED	-2.604725	0.9412	-16.70408	0.8791
MB	-3.538353	0.6145	-27.66895	0.4648
IM	-4.116522	0.3176	-36.58448	0.1847

Source: Prepared by the authors based on data provided by the IMF for the commodity fuel index (Fuel_Index), BR for RMR data, Exports (EX), Imports (IM), Monetary Base (MB) and Colombia Interbank Interest Rate (i_Col), FED for data for federal fund interest rates (i_FED). Note: The null hypothesis is that the series are not cointegrated at a 1% level of significance, MacKinnon, 1996 p-values.

Figure 1. Variables in first difference



Source: Author elaboration based on the information provided by the BR, the IMF, Macrotrends, and the seasonally adjusted series CensusX12 method.

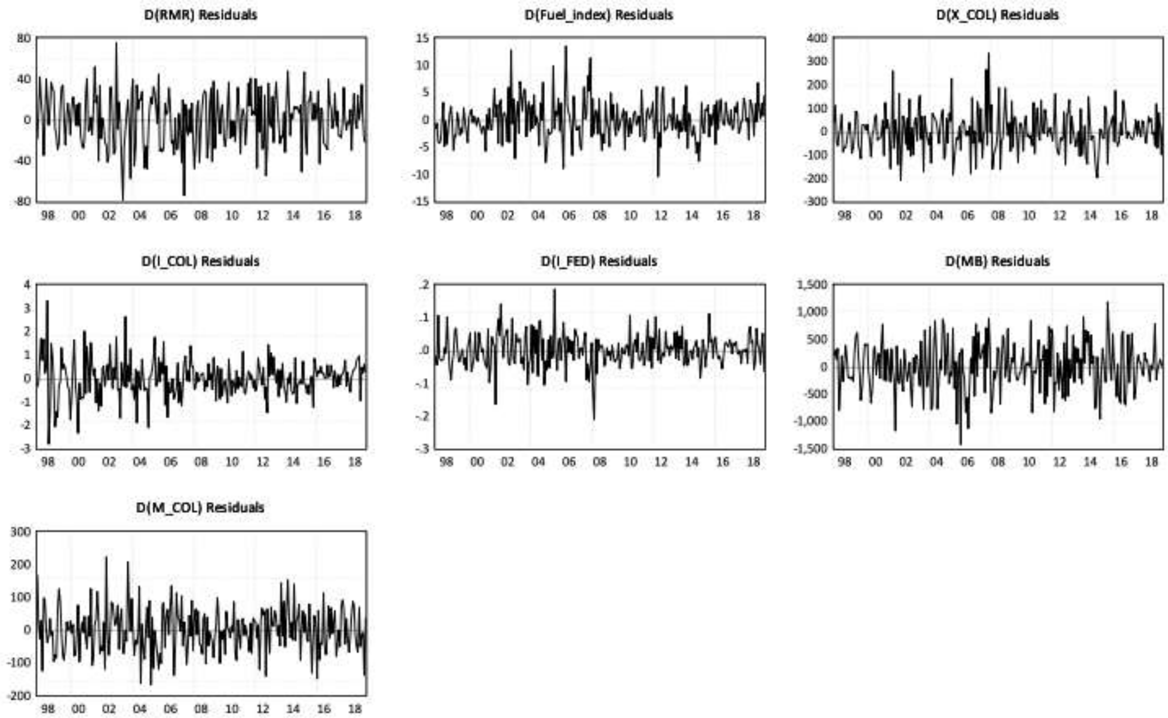
Figure 1 reveals variable movement, differentiated over time, where the fluctuations in the RMR between January of 2003 and June of 2013 stand out, and may be explained by the macroeconomic adjustment derived from the transit of periods of high inflation in the late 1990s towards lower levels, thanks to the adoption of a target inflation scheme. Said economic adjustment process caused repercussions on RMR volatility. In turn, between June of 2008 and February of 2009, RMR fluctuations were considerable, in response to the subprime financial crisis which originated in the United States (Kristjanpoller and Barahona, 2014).

In turn, the decrease in the global international economic dynamics affected the commodity global price index of goods significantly, and in general, in total Colombian exports, forcing the issuer to adjust the interest rate, in order to mitigate the recessive effects of the crisis. Similarly, the interest rate in American federal funds reacted, under expansionary principles, to stimulate the aggregate demand, and affect the trajectory of the exchange rate. International oil prices largely determine the entry into and exit of dollars from Colombia, this is due to the country's dependence on oil revenues. Precisely, during the 2015 – 2017 period, strong RMR variations are evident, due to the fall in oil prices, which in turn impacted the global raw material price index, although not by the same magnitude as that of 2008. It is intuited that the behavior of the exchange rate in Colombia is sensitive to external factors, such as American monetary and the quotation of international oil prices. This dependence suggests that the price of oil causes the behavior of the nominal exchange rate in Colombia, but the RMR does not cause the international price of oil. Causality is unidirectional and independent of pre- and post-crisis behavior.

4. Results

From the VAR model estimation, the residuals in the model are represented in Figure 2. This is so, in order to show that they effectively follow a stationary process, with constant variance and zero hope. Next, the model was specified, including 30 lags, in accordance with the Akaike information criterion, in which a correction was made to the sample size of the likelihood function, for which, $AIC = T.\ln(|\Sigma|) + 2p$. Where T is the sample size, p is the total number of regressors in all estimated equations in the VAR model, and $|\Sigma|$ is the covariance matrix of the residuals. Finally, the serial autocorrelation "Breusch-Godfrey LM-Test" was performed with 30 lags, proving that there are no serial autocorrelation problems of residuals, considering a level of statistical significance of 0.01 (see Annex A). Figure 2 shows that the residuals are distributed white noise, and are identically distributed over time with zero mean and constant variance: $\varepsilon_t \sim N(0, \sigma^2),\ cov(\varepsilon_{ti}, \varepsilon_{tj}) = 0, \forall t_i \neq\ t_j$. For the general statistics of the multi-equation model estimation, see Annex F.

Figure 2. VAR model residuals



Source: Author elaboration, based on VAR model estimation.

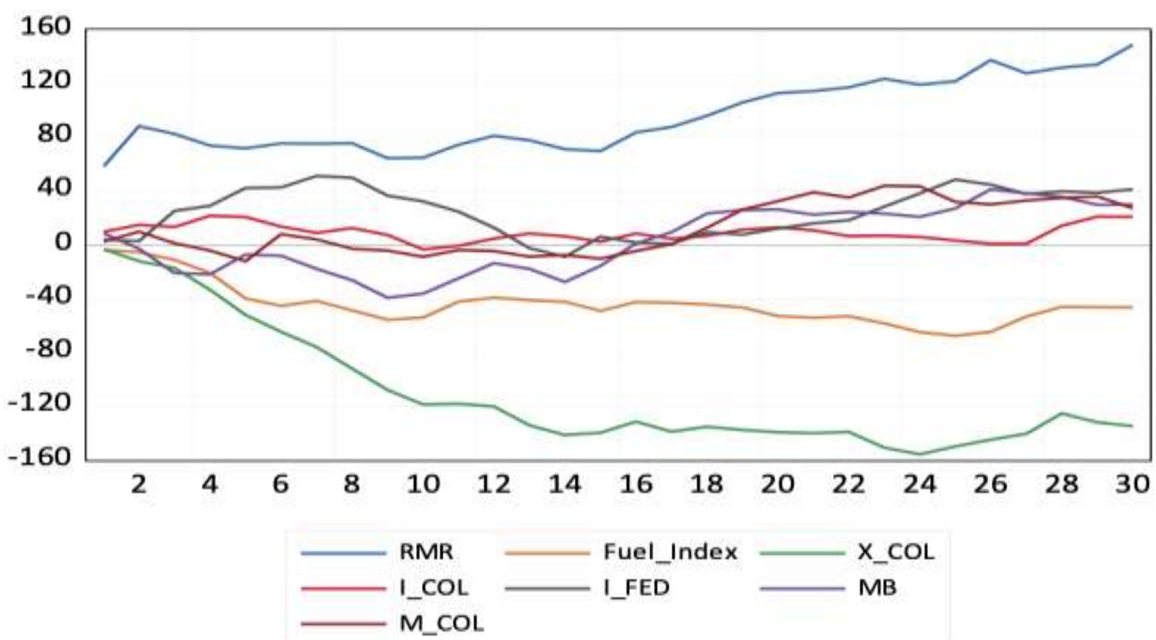
Figure 3 presents the cumulative generalized impulse response (FIR) functions for the difference between RMR and innovations in system endogenous variables. Annex C shows the asymptotic confidence bands and response to innovations of endogenous variables. The results of the VAR estimation demonstrate that the RMR presents an inertial effect during the first 10 months following a shock, which concurs with the results of Mike and Kızılkaya (2019), who emphasize that the behavior of the RMR in Colombia follows a strong unit root process, associated with an order of integration I(1). Thus, it may be inferred that the behavior of the original series has path dependence, or depends on its own path.

It should be noted that an increase in the global commodity price index produces a decrease in RMR, an effect which is significant in the first six to nine periods after the shock. A positive shock generated in the American federal fund interest rate produces a positive and significant RMR response, from the second to the seventh period after the shock. This effect is explained by the inflow of capital into the system American financial institution, for the obtention of higher yields, which tends to depreciate the exchange rate.

It merits note that the objective of the implementation of the free floating exchange rate regime is to stabilize the price of the currency at exceptional times (Lopera, Mesa and Londoño, 2014). However, discretionary interventions of this type, in Colombia, are rare. According to the results obtained, a positive shock in exports causes the RMR to decrease, in response to the entry of currency, and therefore create an appreciation in the exchange rate. The result is statistically significant, and different from zero, between periods six and 18 following the shock. Contrarily, the effect of an increase in imports is not statistically significant, and therefore, it seems that RMR may be primarily explained by foreign demand for goods and its consequent effect on the entry of currency into the country.

The RMR does not respond significantly to the Colombian interbank rate or monetary base. Comparatively, it would be expected that a positive disturbance in the monetary base would raise the peso-dollar ratio, and generate a process of exchange rate depreciation. However, the effect is almost null. Therefore, the result is inconclusive. By way of synthesis, the shocks of the variables determined by internal economic conditions do not affect the other variables since, from the economic point of view, Colombia is a price taker in the world market for goods and capital (Rincón et al., 2017). Thus, the statistical evidence provided supports the main finding of the present study, in the global currency market: the Colombian RMR responds more to external conjunctural elements than to the internal elements of its economy, which is reflected in its exposure to international shocks. The results suggest that it is commodity prices, FED interest rates, and exports, as external demand for national goods, that have the greatest impact on the RMR in Colombia, during the time frame analyzed herein.

Figure 3. Generalized cumulative RMR response to VAR model endogenous variable innovations



Source: Author elaboration, based on VAR model estimation.

Despite not finding statistical significance between innovations in the American federal fund rates and RMR behavior in this document, the significant uncertainty generated by monetary policy announcements by the central banks, regarding interest and exchange rates (Fratzscher, 2008), should be considered. From the process of decomposition of the variance of the RMR forecast error, it may be observed that the variables that most affect exchange rate variability are external to the Colombian economy. This statement is consistent with the findings of Gavíria and Sierra (2003). All this led to the performance a variance decomposition analysis.

During period one, the RMR depended entirely on itself, but as it progressed to different periods, it reduced its independence and began to be explained by other factors, such as total exports and the index of the prices of commodity goods. Variability percentages may be seen in Table 5. Results reveal that, as of Period 55, the model stabilizes, and about 9.13% of RMR variance may be explained by the global index of commodity good prices, 16.48% by exports, and 9.31% by the American federal fund interest rate. Thus, a total of 36.15% of RMR variability, or more than a third, may be explained by these variables, and more than 30% by itself (long-term inertia of the variable) and only about a third, may be explained by other variables, including: the interbank interest rate, imports, and monetary base. As these do not present statistical significance, they are not considered to be determining factors in the behavior of the exchange rate. In summary, it may be affirmed that none of the variables behaves as totally exogenous, with respect to the other variables incorporated into the analysis, as they did not explain 100% of the variance of their error during the considered time frame.

Table 5. RMR variance decomposition, using generalized weights

	TRM	**Fuel_Index**	**i_COL**	**i_FED**	**IM**	**EX**	**MB**
***t* =1**	100%	0%	0%	0%	0%	0%	0%
***T*=55**	29.38%	9.13%	4.03%	12.46%	14.28%	14.67%	16.28%
***t* =60**	29.23%	9.81%	4.69%	12.04%	14.24%	14.14%	15.82%

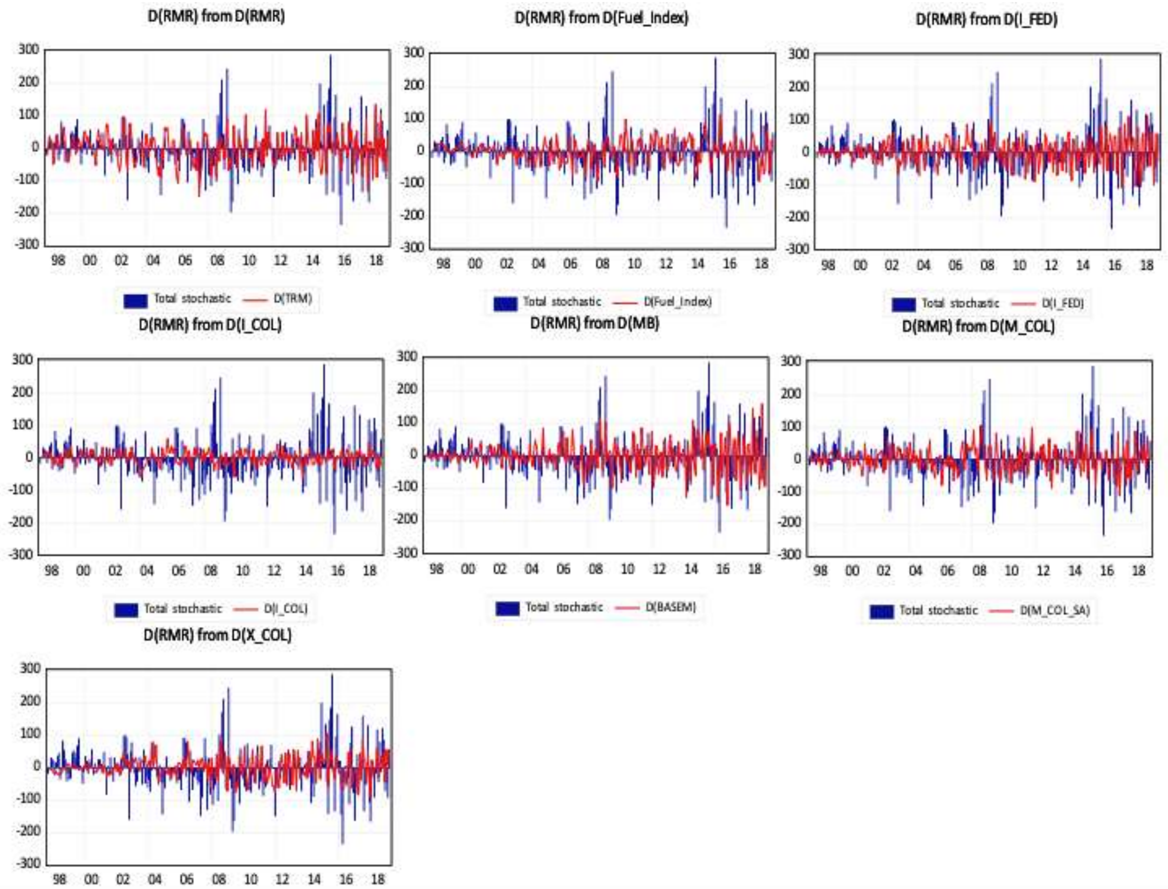
Source: Author elaboration, based on the variance decomposition process, which is, in turn, based on VAR model estimation. Note: IMF for the commodity fuel index (Fuel_Index), BR for RMR data, Exports (EX), Imports (IM), Monetary Base (MB) and Colombia Interbank Interest Rate (i_Col), FED for data for federal fund interest rates (i_FED).

Changes in the global index of commodity prices, the expectation of change in American federal fund rates, and Colombian exports affect the balance of payments, which directly impact the exchange rate. From the process of variance decomposition, using the Cholesky factors, with 60 periods and 30 lags, it was found that those that best explain all exchange rate behavior in Colombia are related to the external sector, and are not controlled by the Colombian economy. Thus, 36.26% of RMR variance may be explained by the global commodity price index (Rincón et al., 2017), American federal fund interest rates, and total exports. Although the latter depend on the national productive apparatus, they are really conditioned by demand and the international market.

The historical decomposition of the variance based on the generalized factors methodology applied to the market representative rate for Colombia permits the calculation of the contribution of the different accumulated shocks on the RMR (without the need to orthogonalize shocks) (Diebold and Yilmaz 2012). Thus, only induced shocks on endogenous variables in the system of equations were considered. Graph 5 shows the contribution of the shocks (red line) to RMR fluctuation, graphed in the form of bars (in blue). The results show that the shock, in total exports and the Federal Reserve interest rate have important effects on RMR fluctuation, confirming the findings of the present study. As a criterion, it is expected that this fluctuation and the behavior and contribution of the shock, follow a common pattern, although it is not exact, which reflects the impact that these two variables cause on the exchange rate in Colombia. Less pronounced but with a recurring pattern, it is possible to see the way in which RMR fluctuation moves similarly to the contribution in the shock of imports, which demonstrates that there is an effect, even when slight.

Similarly, the results suggest that which was anticipated in the study: the RMR in Colombia exhibits strong inertial behavior, that is reflected in the contribution of its shocks on its fluctuations, an aspect that opens a field for future methodological research, for the explanation of said inertial behavior.

Figure 4. Historical RMR variance decomposition, using generalized weights



Source: Author elaboration, in accordance with the variance decomposition process, based on VAR model estimation. Note: IMF for the commodity fuel index (Fuel_Index), BR for RMR data, Exports (EX), Imports (IM), Monetary Base (MB) and Colombia Interbank Interest Rate (i_Col), FED for data for federal fund interest rates (i_FED).

5. Conclusions

The objective of the present investigation was to identify those fundamental variables that impact the COP/USD exchange rate, in Colombia, by specifying and estimating a VAR model. The fundamental variables considered, seasonally adjusted by means of the X12-ARIMA method for the specification of the model are: RMR, exports, imports, the Colombian monetary base, American Federal Reserve interest rates, Colombia's interbank interest rate, and the global commodity price index. Thus, in this study, the order of the VAR model was determined with a 30-lag structure, in accordance with the Akaike Information Criterion (AIC). To contrast the correct specification of the model, unit root tests were considered to determine the order of integration. The series confirmed that all series are integrated in order I(1). Cointegration and causality tests were carried out that allowed for the conclusion that the best specification corresponds to a VAR model, not a VECM model. As such, the robustness of the model may be verified by means of the autocorrelation test and graphic analysis of stationarity of model residuals, guaranteeing that these are white noise. This analysis followed VAR estimation.

The analysis of the accumulated impulse response functions allows for the conclusion that the shocks induced in the RMR, due to their inertial effects, the global index of the prices of commodity goods, and exports impact the RMR in Colombia. From the statistical evidence, it may be concluded that Colombia presents high vulnerability to shocks in international fundamental variables. Exports generate massive capital inflows that tend to appreciate the exchange rate, and this effect is reflected in the investigative results. However, it is highlighted that the RMR has a strong inertial effect in the short term, a phenomenon that may be associated with persistence in series behavior, as verified in the unit root test in the original series of the Colombian exchange rate, and then verified in the variance decomposition analysis that reflects the important dependence of the variability of the RMR to changes in itself in the short term. On the other hand, positive variations in the commodity price index are fundamentally associated with variables that concern the international price of oil, which in turn influences total exports, due to the dependence on income derived from exports of primary goods. This effects channel impacts both volatility and RMR trajectory, in the short term. Finally, it should be noted that this study may be replicated, in its methodological structure, for the analysis of macro-fundamental determinants of the nominal exchange rate between different currency pairs, so as to more clearly understand the influence of macro-fundamental indicators on the exchange relationship in other countries.

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Annexes

Annex A. Breusch-Godfrey LM-Test serial autocorrelation test

VAR residual serial correlation LM tests

Sample: 1995M03 2020M1

Observations included: 258

Null hypothesis: No serial correlation at lag h

Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	56.41901	49	0.2173	1.173877	(49, 177.0)	0.2254
2	58.37869	49	0.1687	1.220884	(49, 177.0)	0.1759
3	48.71567	49	0.4846	0.993483	(49, 177.0)	0.4942
4	47.39504	49	0.5384	0.963246	(49, 177.0)	0.5477
5	46.99542	49	0.5548	0.954136	(49, 177.0)	0.5640
6	52.46233	49	0.3413	1.080355	(49, 177.0)	0.3508
7	46.24139	49	0.5856	0.936995	(49, 177.0)	0.5946
8	44.58038	49	0.6527	0.899464	(49, 177.0)	0.6610
9	60.72595	49	0.1215	1.277797	(49, 177.0)	0.1275
10	45.10125	49	0.6319	0.911200	(49, 177.0)	0.6404
11	48.70885	49	0.4849	0.993326	(49, 177.0)	0.4944
12	33.03929	49	0.9609	0.647099	(49, 177.0)	0.9624
13	53.13627	49	0.3179	1.096154	(49, 177.0)	0.3272
14	46.03210	49	0.5942	0.932249	(49, 177.0)	0.6031
15	35.84491	49	0.9195	0.707119	(49, 177.0)	0.9223
16	40.83274	49	0.7903	0.815918	(49, 177.0)	0.7963
17	50.16720	49	0.4269	1.026946	(49, 177.0)	0.4366
18	56.06172	49	0.2271	1.165356	(49, 177.0)	0.2354
19	42.02049	49	0.7496	0.842228	(49, 177.0)	0.7564
20	53.16911	49	0.3168	1.096926	(49, 177.0)	0.3260
21	42.38447	49	0.7366	0.850322	(49, 177.0)	0.7435
22	60.38484	49	0.1276	1.269485	(49, 177.0)	0.1338
23	47.29392	49	0.5425	0.960939	(49, 177.0)	0.5518
24	27.72707	49	0.9939	0.535731	(49, 177.0)	0.9941
25	56.66204	49	0.2108	1.179681	(49, 177.0)	0.2188
26	34.07574	49	0.9480	0.669174	(49, 177.0)	0.9499
27	31.64635	49	0.9743	0.617611	(49, 177.0)	0.9753
28	39.02646	49	0.8453	0.776205	(49, 177.0)	0.8501
29	46.33282	49	0.5819	0.939070	(49, 177.0)	0.5909
30	49.71321	49	0.4447	1.016454	(49, 177.0)	0.4544

31	54.39688	49	0.2765	1.125850	(49, 177.0)	0.2854

Source: Author elaboration, based on VAR model estimation.

Annex B. Lag selection criteria

Endogenous variables: D(TRM) D(FUEL_INDEX) D(X_COL) D(I_COL) D(I_FED) D(BASEM) D(M_COL)

Sample: 1995M03 2020M01

Included observations: 258

Lag	LogL	LR	FPE	AIC	SC	HQ

0	-8710.497	NA	5.26e+20	67.57749	67.67389	67.61626
1	-8469.160	467.7076	1.19e+20	66.08651	66.85769*	66.39661*
2	-8399.263	131.6655	1.01e+20	65.92452	67.37049	66.50595
3	-8341.980	104.7976	9.48e+19*	65.86031	67.98107	66.71308
4	-8305.175	65.33481	1.05e+20	65.95485	68.75039	67.07895
5	-8259.970	77.79458	1.08e+20	65.98427	69.45460	67.37970
6	-8210.075	83.15827	1.09e+20	65.97733	70.12245	67.64410
7	-8165.267	72.24949	1.14e+20	66.00982	70.82973	67.94793
8	-8130.465	54.22578	1.29e+20	66.11989	71.61458	68.32933
9	-8089.143	62.14313	1.40e+20	66.17941	72.34889	68.66018
10	-8055.434	48.86573	1.62e+20	66.29794	73.14220	69.05005
11	-8012.499	59.90912	1.76e+20	66.34495	73.86401	69.36840
12	-7933.501	105.9433	1.45e+20	66.11241	74.30625	69.40719
13	-7875.817	74.22909	1.43e+20	66.04509	74.91372	69.61121
14	-7834.357	51.10189	1.61e+20	66.10354	75.64695	69.94099
15	-7773.939	71.19035	1.58e+20	66.01503	76.23323	70.12382
16	-7718.667	62.12655	1.64e+20	65.96641	76.85940	70.34654
17	-7674.984	46.73116	1.88e+20	66.00763	77.57540	70.65908
18	-7632.153	43.49485	2.21e+20	66.05545	78.29801	70.97824
19	-7592.623	37.99813	2.71e+20	66.12886	79.04621	71.32299
20	-7514.881	70.51018*	2.52e+20	65.90605	79.49819	71.37152
21	-7445.594	59.08189	2.57e+20	65.74879	80.01571	71.48559
22	-7379.404	52.84921	2.74e+20	65.61554	80.55724	71.62367
23	-7316.750	46.62625	3.11e+20	65.50969	81.12619	71.78916
24	-7243.397	50.60758	3.36e+20	65.32091	81.61219	71.87171
25	-7180.825	39.77487	4.11e+20	65.21570	82.18177	72.03783
26	-7081.049	58.00937	3.96e+20	64.82208	82.46294	71.91556
27	-6957.831	64.95216	3.38e+20	64.24675	82.56239	71.61156
28	-6847.552	52.14729	3.42e+20	63.77172	82.76215	71.40786
29	-6746.591	42.26288	4.09e+20	63.36892	83.03414	71.27640
30	-6608.002	50.49346	4.10e+20	62.67444*	83.01444	70.85325

* indicates lag order, selected by criterion

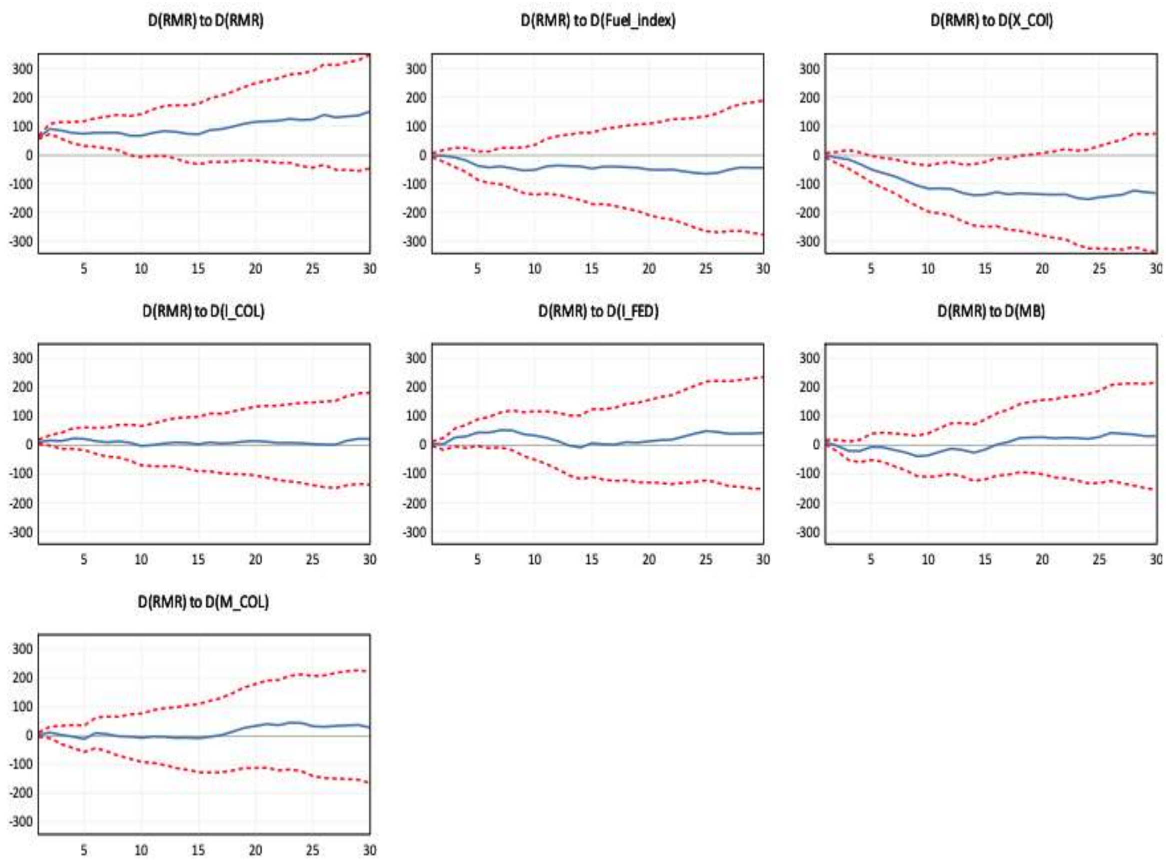
LR: sequential modified LR test statistic (each test at 5% level)

FPE: Final Prediction Error

AIC: Akaike Information Criterion, SC: Schwarz information Criterion, HQ: Hannan-Quinn information criterion

Source: Author elaboration, based on VAR model estimation.

Annex C. Generalized function impulse response, accumulated to an S.D. innovation ± 2 S.E.



Source: Author elaboration, based on VAR model estimation

Annex D. Unrestricted Johansen cointegration test

No. of ec(s)	Own value	Trace Statistical trace	Critical value 0.05	Prob.**
None *	0.359855	278.0372	125.6154	0.0000
At most 1 *	0.205619	163.3997	95.75366	0.0000
At most 2 *	0.182508	104.2402	69.81889	0.0000
At most 3 *	0.130951	52.45105	47.85613	0.0174
At most 4	0.042326	16.37951	29.79707	0.6853
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Source: Author elaboration, based on VAR models estimation Note: **MacKinnon-Haug-Michelis (1999) p-values, * denotes rejection of the hypothesis at the 0.05 level, Trace test indicates three cointegrating eqn(s) at the 0.05 level.

Annex E. Granger's causality test

VAR Granger Causality/Block Exogeneity Wald Tests

Sample: 1995M03 2020M01

Included observations: 258

Null hypothesis: Variables are not caused in granger sense

Dependent variable: D(TRM)

Excluded	Chi-sq	df	Prob.
D(FUEL_INDEX)	44.17183	30	0.0460
D(X_COL)	38.02078	30	0.1492
D(I_COL)	19.51539	30	0.9286
D(I_FED)	44.26183	30	0.0451
D(BASEM)	49.11896	30	0.0153
D(M_COL)	52.36407	30	0.0070
All	229.3315	180	0.0076

Dependent variable: D(FUEL_INDEX)

Excluded	Chi-sq	df	Prob.
D(TRM)	25.91269	30	0.6796
D(X_COL)	29.85768	30	0.4730
D(I_COL)	17.99794	30	0.9586
D(I_FED)	29.84674	30	0.4735
D(BASEM)	39.14560	30	0.1225
D(M_COL)	20.42314	30	0.9051
All	212.5931	180	0.0486

Dependent variable: D(X_COL_SA)

Excluded	Chi-sq	df	Prob.
D(TRM)	30.19527	30	0.4557
D(FUEL_INDEX)	30.03392	30	0.4639
D(I_COL)	9.279207	30	0.9999
D(I_FED)	16.13208	30	0.9816
D(BASEM)	32.21156	30	0.3578
D(M_COL)	31.07765	30	0.4116

All	175.2470	180	0.5861

Dependent variable: D(I_COL)

Excluded	Chi-sq	df	Prob.
D(TRM)	28.89766	30	0.5230
D(FUEL_INDEX)	31.90719	30	0.3719
D(X_COL)	22.76916	30	0.8246
D(I_FED)	48.48720	30	0.0177
D(BASEM)	23.70412	30	0.7852
D(M_COL)	24.51262	30	0.7484
All	108.5776	180	1.0000

Dependent variable: D(I_FED)

Excluded	Chi-sq	df	Prob.
D(TRM)	26.58818	30	0.6448
D(FUEL_INDEX)	18.82005	30	0.9437
D(X_COL)	20.52305	30	0.9022
D(I_COL)	38.12571	30	0.1465
D(BASEM)	31.62467	30	0.3852
D(M_COL)	26.77099	30	0.6353
All	179.0721	180	0.5055

Dependent variable: D(BASEM)

Excluded	Chi-sq	df	Prob.
D(TRM)	53.83586	30	0.0048
D(FUEL_INDEX)	47.44382	30	0.0225
D(X_COL)	47.09352	30	0.0244
D(I_COL)	20.69138	30	0.8973
D(I_FED)	38.21781	30	0.1442
D(M_COL)	43.24651	30	0.0557
All	321.5783	180	0.0000

Dependent variable: D(M_COL)

Excluded	Chi-sq	df	Prob.
D(TRM)	29.68628	30	0.4818
D(FUEL_INDEX)	30.81226	30	0.4247
D(X_COL_SA)	39.88107	30	0.1072
D(I_COL)	14.94056	30	0.9901
D(I_FED)	15.45060	30	0.9869
D(BASEM)	46.24633	30	0.0294
All	256.5325	180	0.0002

Source: Prepared by the authors, based on data provided by the IMF for the commodity fuel index (Fuel_index), BR for RMR data, Exports (EX), Imports (IM) and Colombia Interbank Interest Rate (i_Col), FED for data for the interest rates on American federal funds (i_FED). Note: Lags included in the test are equal to five.

Annex F. Global VAR estimate statistical data

Vector autoregression estimates

Included observations: 258, after adjustments

Standard errors in ( ) and t-statistics in [ ]

	D(TRM)	**D(FUEL_INDEX)**	**D(X_COL_SA)**	**D(I_COL)**	**D(I_FED)**	**D(BASEM)**	**D(M_COL_SA)**
R-squared	0.871226	0.872978	0.861641	0.840377	0.908468	0.957832	0.933850
Adj. R-squared	0.295855	0.305434	0.243442	0.127167	0.499497	0.769422	0.638284
Sum sq. resids	160771.8	3128.757	1815534.	162.9344	0.628697	49420751	1168805.
S.E. equation	58.48655	8.159001	196.5410	1.861905	0.115657	1025.429	157.6965
F-statistic	1.514199	1.538168	1.393791	1.178302	2.221350	5.083761	3.159533
Log likelihood	-1196.173	-687.9968	-1508.888	-306.7962	410.1153	-1935.103	-1452.077
Akaike AIC	10.90832	6.968968	13.33247	4.013924	-1.543530	16.63646	12.89207
Schwarz SC	13.81403	9.874683	16.23818	6.919639	1.362185	19.54217	15.79778
Mean dependent	7.375969	0.337209	9.416651	-0.069767	-0.012158	321.9690	11.66751
S.D. dependent	69.69876	9.789946	225.9602	1.992929	0.163481	2135.486	262.2034

Determinant	resid.	
Covariance (dof. adj.)		6.25E+18
Determinant	resid.	
Covariance		4.16E+13
Log likelihood		-6608.002

Akaike information criterion	62.67444
Schwarz criterion	83.01444
Number of coefficients	1477

Source: Author elaboration.

Capítulo

2

Chapter 2. The determining variables of domestic Colombian coffee prices (2003-2018)

Abstract

This study aims to identify the determining variables of the internal price of coffee in Colombia, through the proposal of a time series regression model for the period between 2003 - 2018, and a VAR model for the years between 2015 - 2018, based on a systematic review of literature on the subject. Among the main results of the present study, based on the VAR model, is that the domestic price of coffee in Colombia is sensitive, in the short term, to changes in coffee prices in Brazil, and to the short-term inertial effects of domestic prices.

Key words: coffee price, modeling, forecast, determinant variables

1. INTRODUCTION

Throughout recent history, commodity markets (i.e. commodities) have been the subject of economic research Vogelvang (1992). Coffee was among the first basic products (i.e. commodities) for which an attempt was made to control world trade. This began in 1902, with the process of "valorization", carried out by the Brazilian state of São Paulo (Ponte, 2002). Then, between 1956 and 1976, there was a period characterized by international production and price stability, due to the International Coffee Agreement (ICA). This was signed in 1962, and sought to establish a quota system export for producing countries. The ICA ended in 1989, and affected the balance of power in the coffee market. In order to curb the price collapse, in May of 2000, the ACPC (Association of Coffee Producing Countries) adopted a new withholding plan that became effective on October 1, 2000. The plan focused on withholding 20% of total world production. In the 2000s, in regards to basic products (i.e. commodities), in this case coffee, it became clear in producing countries that ICA system reactivation, with quotas and price bands, was not feasible in the short term.

According to Andres and James (2002), between 1981 - 2014, coffee prices in the world market fluctuated greatly and became less predictable.

During the third quarter of 2018, the international price of coffee reached historical lows during the last 12 years, as shown in Figure 1, breaking the barrier of $100 cents per pound.

This generated a crisis in the sector, affecting everyone from coffee farmers to large exporters, highlighting the need for greater, in-depth understanding of those determining elements of Colombian internal coffee prices, which would allow for efficient risk management and sound decision making.

Figure 1: The international price of Arabica coffee, expressed in cents per pound

Source: Author elaboration, based on investment experience

Therefore, there is a need to understand the dynamics of the international market and its repercussions on coffee sales, on a national level, in order to have better tools available to contribute to sector growth. Additionally, the present study is motivated by the need to provide instruments to organizations that employ researchers, so as to serve as support for risk management decision-making within the supply chain processes. To date, these poorly planned processes are carried out empirically and reactively.

Given the above, this study aims to understand the dynamics of the formation of the internal price of coffee in Colombia, to subsequently determine those variables which explain the internal price of coffee, in Colombia, from 2003 - 2018.

For this purpose, the present document is divided into four sections: a literature review of the main research on the subject, data and methods, which explains the methodology used herein, results, which show proposed model estimates and their discussion, and finally, conclusions.

2. LITERATURE REVIEW

For the systematic literature review, in accordance with the identified problem, the following keywords were proposed: coffee price, modeling, and forecasting, which were provided by the following authors and theories, which will serve as input for the analysis of the determining variables for the internal price of coffee in Colombia:

Vogelvang (1992) was the first seminal author to analyze the cointegration of spot prices for the different types of coffee on the market. His study found that the similarities in the behavior of basic product prices can be explained by elements that influence all prices, simultaneously. These include world inflation, interest rates, and common expectations about the general economic outlook. He further encountered that, when goods were more closely related to each other, the more specific factors related to said markets would also be relevant, such as replacement rates, changes in supply or aggregate demand, and the existence of international product agreements.

The second recognized reference is Ponte (2002), who, in his study, identified that the high volatility of future coffee prices is normally triggered by market fundamentals (demand-supply-stocks), and is magnified by speculation. Additionally, the author describes the characteristics of the coffee trade, and explains the way in which Arabica coffee prices are established as differentials, in relation to the price of futures listed on the New York Stock Exchange. Due to the characteristics of the elasticity of demand and supply, coffee prices in the international market are highly variable. Overproduction, due to technological innovations and new plantings, has also contributed to a fall in international coffee prices. It also states that price volatility is not a new phenomenon in the coffee market. An important factor in volatility is that coffee yields are vulnerable to changes in both temperature and precipitation, as well as pests or diseases. On the other hand, the high volatility of coffee is related to increases in activity in the markets of the future.

Additionally, the contributions of Johansen (1988), from the statistical point of view, are important references for the other consulted authors, owing to their cointegration test, which proves that there is a long-term relationship between the variables, as explained.

On an international level, a study related to the determinants of Vietnamese coffee prices, Hong (2016), was found. Therein, quantitative and qualitative methods were mixed, so as to analyze and measure the effects of important factors for the export price of coffee from Vietnam. With 34 years of data, from 1981 to 2014, it identifies a cycle for the price of coffee, which has fluctuated with a cycle that increases for five years and decreases for seven years. Said study identified that the main factors in the fluctuation of coffee prices in Vietnam are the exchange rate and export prices of other exporting countries, such as Brazil and Colombia. In Hong's (2016) study, the export price of Brazilian coffee had a positive effect on the price of coffee in Vietnam, suggesting competition between the two countries, in the world coffee market. Given that Colombia produces other types of coffee, Carter and MacLaren (1997), cited in Hong (2016), establish that the prices of export commodities of one country may be affected by that of many other countries. The aforementioned study was based on time series data collected from different organizations and official databases. In addition to descriptive statistics, linear regression models were applied, which described the price of coffee in Vietnam.

In the national context, there is no recent research on this specific topic, thus the work of Perez (2006), in which he identifies that the fundamental factors that influence the establishment of coffee prices are production, consumption, and stock movements, is relied upon. This paper presents a review of the GARCH model (Generalized Autoregressive Conditional Heteroskedasticity) and describes several properties of the process, with the corresponding demonstrations. Additionally, Perez (2006) presents an application for the ARIMA-GARCH models, considering the price of coffee between January 2, 2002 and April 17, 2006.

Although no studies on the determining variables of the internal price of coffee in Colombia were identified at the local level, a study published in "Essays on the Coffee Economy" entitled "Dynamic relationships between fundamental coffee variables", by Clavijo *et al.* (1994), analyzes the causal relationships between domestic prices and production, between external prices and world inventories, and additionally, the dynamic relationships between these variables and the real exchange rate. Therein, they estimated a model of autoregressive vectors, whose results indicate that, for the period between 1975 and 1993, world inventories, external prices, and the real exchange rate make up a group of exogenous variables that explain the behavior of the real internal price, and Colombian production.

Additionally, Sánchez’s (1992) investigation on inflation, crop value, and domestic coffee prices was analyzed. This establishes that, due to the indisputable impact of coffee on the behavior of the Colombian economy, it could impact not only inflation, but also a number of price indicators. Sánchez's (1992) literature review showed that, between 1952 and 1980, changes in international coffee prices led to a low exchange and high inflation rate. He also found that, the greater the transfer to coffee growers, the further momentum and pressure for monetary expansion generated. The main conclusion of their study was that there is no empirical evidence that confirms that harvest value or coffee prices explain monthly inflation rates, or vice versa.

Echavarría, Orozco, & Telléz (1992), which concerns the function of coffee production, was also considered. Therein, five categories are identified, which group variables that could be considered relevant for the establishment of a coffee production function. These categories include: climate, plant, soil, management, and social factors. Within the social factor is the price variable. However, the authors mainly focus on those variables related to productivity, such as planting density, age of the coffee planting, fertilization, climate, pruning, and bienniality.

Finally, another of the studies analyzed at the local level was that of Araque & Duque (2019), which focused on “Agronomic Variables Determining the Productivity of Coffee Growing on Farms in the Department of Caldas”. It established that the sale price of coffee in Colombia is determined by three elements: the price of coffee on the New York stock exchange, the quality premium paid for Colombian coffee, and the current exchange rate. Likewise, this study established that, for a coffee farmer to improve their profits, they can focus on improving productivity and the efficient use of production resources, as they do not have tools to intervene in the elements of price formation. For this reason, the study focuses on those variables that affect productivity, obtaining five significant variables as a result: crop density, upland area, age of the coffee plantings, percentage of area planted in resistant varieties, fertilization levels. Sowing density is the variable that contributes the most to productivity per hectare.

3. DATA AND METHODS

In accordance with the factors identified by Clavijo et al. (1994) and Hong (2016), the following variables were considered in official databases, as shown in the following table[3]:

Table 1: Main variables to consider.

Variable	Source	Description
Representative market rate COP/USD	page of the Banco de la República de Colombia	Continuous quantitative variable, expressed in pesos per dollar.
International price of Arabica coffee	ing website	Continuous quantitative variable, expressed in cents per pound of green coffee.
Internal price of Arabica coffee in Colombia	Federation of Coffee Growers	Continuous quantitative variable, expressed in pesos per load (1 load = 125 Kg)
Internal price of Arabica coffee in Brazil	for Advanced Studies in Applied Economics- CEPEA- University of Sao Paulo	Continuous quantitative variable, expressed in reales per 60 kilogram bag.

Source: Author elaboration

In addition to the variables proposed by Hong (2016), it was important to analyze the following:

Table 2: Additional variables to consider.

Variable	Source	Description
Differential UGQ Colombia	The ICE (Intercontinental Exchange) website	Continuous quantitative variable, expressed in cents per pound of green coffee.

[3] The internal price of Colombian coffee is expressed in LOADS (125 kg) of dry parchment coffee. Therefore calculations must be made to convert it to pounds of green coffee for export. The internal price of coffee in Brazil is given in 60 kg bags, which must also be converted to pounds. Conversions to pounds of export-type green coffee are made because coffee is traded internationally in this unit of measure. The remaining variables did not undergo conversion procedures.

International cocoa price	Investing website	Continuous quantitative variable, expressed in cents per pound of cocoa.
International robust coffee price	Investing website	Continuous quantitative variable, expressed in cents per pound of green coffee.
Representative market rate REAL/USD	Investing website	Continuous quantitative variable expressed in reales per dollar

Source: Author elaboration

As for the UGQ (Usual Good Quality) differential, this corresponds to the premium recognized for the quality of Colombian coffee, which, according to Araque & Duque (2019) forms part of the elements that determine the sale price of coffee in Colombia. This differential is expressed in cents per pound of green coffee, and information is available from January 2015 to December 2018. According to Traoré & Badolo (2016), basic products have a constant tendency to move together, and find co-movement between the prices of commodities, including wheat, cotton, copper, gold, crude oil, wood, coffee, and cocoa. As such, it was considered important to contemplate the variable international price of cocoa for the period between 2003 and 2018.

As established by Jesús Otero & Milas (2001), given that the coffee market is divided into two important types: Arabica and Robusta coffees, and that, according to Perez (2006), different coffee prices implicitly assume that they are cointegrated, or that there is a relationship between Robustas and Arabicas, it was therefore important to consider the international price variable for Robusta coffee, for which information is available for the period between 2008 and 2018.

In accordance with the discussion of results in Hong (2016), specifically regarding the effects of the exchange rate on the export price of coffee from Vietnam, it identifies that, in the world market, exporting countries rely on exchange rates to support their exports. Considering the specific weight of Brazil, according to Ponte (2002), the its exchange rate, expressed in reales per dollar, for the period between 2003 and 2018, was also analyzed herein.

For the analysis of the previously established variables, first, a time series regression model was run, both for the period between 2003 - 2018 and for the period between 2015 - 2018, with the following structure:

$$Y_t = \beta_0 + \beta_1 X_{1t} + \beta_2 X_{2t} + \beta_3 X_{3t} + \beta_4 X_{4t} + \beta_5 X_{5t} + \beta_6 X_{6t} + \beta_7 X_{7t} + \mu_t$$

Where:

Y_t: Internal price of Arabica coffee in Colombia.

X_{1t}: International price of Arabica coffee.

X_{2t}: Internal price of Arabica coffee in Brazil.

X_{3t}: Nominal exchange rate or Representative Market Rate in Colombia (COP/USD).

X_{4t}: Nominal exchange rate or Representative Market Rate in Brazil (REAL/USD).

X_{5t}: International price of cocoa.

X_{6t}: International price of Robusta coffee.

X_{7t}: Colombian UGQ differential.

μ_t: Stochastic disturbance component.

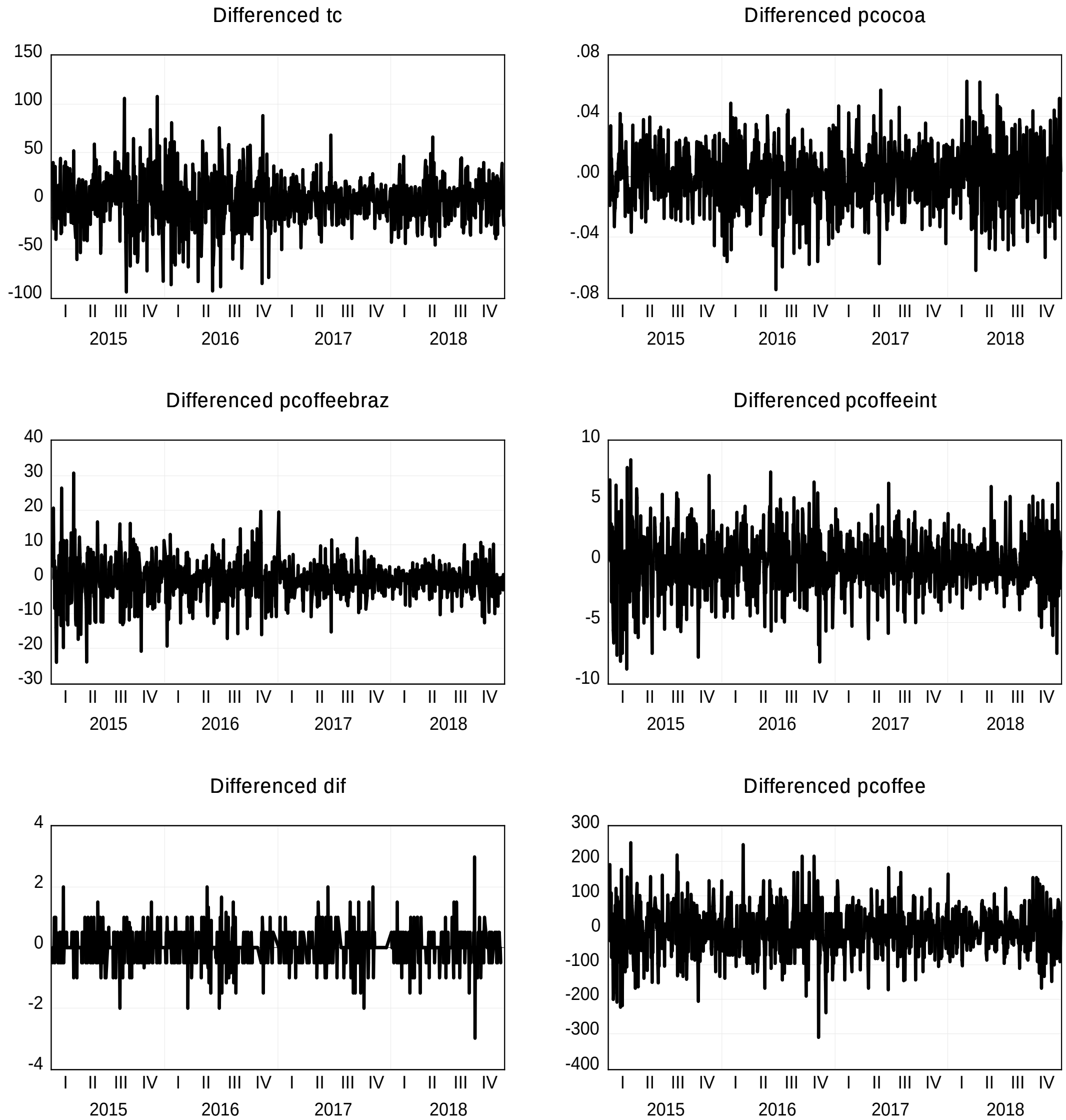
The betas correspond to the coefficients that capture the partial effects of the aforementioned variables (except $\beta_{0,}$ which is the intercept).

Considering the presence of endogeneity among the aforementioned variables, the construction of a model of Autoregressive Vectors (VAR) was proposed, in order to capture these interactions and identify the incidence of shocks in the model. Based on Sims (1980), Enders (2015), and Stock & Watson (2001), the proposed VAR may be represented by the following matrix notation:

$$\overrightarrow{Z_t} = A_1 \overrightarrow{Z_{t-1}} + A_2 \overrightarrow{Z_{t-2}} + \cdots + A_p \overrightarrow{Z_{t-p}} + \overrightarrow{\varepsilon_t}$$

Where: $\overrightarrow{Z_t}$ is a vector of k variables $z_1, \ldots, z_k$ corresponding to those previously stated, A_i are coefficients of the matrices, each with dimension $k \times k$, and $\overrightarrow{\varepsilon_t}$ is a vector of k disturbances. Additionally, it is assumed that the variables included in the vectors $\overrightarrow{Z_t}$ are stationary, as shown in Figure 2.

Figure 2: Differenced variables



Source: Author elaboration

Similarly, it is assumed that $\overrightarrow{\varepsilon_t}$ are white noise disturbances:

$(E(e_t) = 0, E(e_t, e'_t) = \Sigma, E(e_t, e_s) = 0\ \forall t \neq s)$. Once the estimation process occurred, two valuable ex-post tests were carried out for the purposes of the study: Impulse Response (FIR) and Decomposition Analysis of Variance (ADV) functions, where the first allowed for evaluation of the change in the analysis variable caused by shocks in innovations (shocks), and the second allowed for analysis of the weight of one variable in the variance of the analysis variable (mainly the internal price of coffee). It is important to mention that all results were analyzed at a significance level of 5%.

4. RESULTS

For the analysis of results of the variables previously established, this paper employs three sections. The first and second sections present results for the periods between 2003 - 2018 and 2015 - 2018 with a linear regression model, while the third exhibits the construction and analysis of a VAR model.

4.1 Linear regression models

The construction and analysis of a regression model under the assumptions of the classical linear regression model, for the period between 2003 - 2018:

The variable response for this model was the domestic price of coffee in Colombia, defined as the price, in Colombian pesos, per pound of green coffee. A model was obtained from the procedure used, based on five variables, which were significant at 1% (p-value <0.01). The following table depicts the values of the β parameters found for the variables that were significant in the model.

Table 3. ***Linear regression model 2003 - 2018***

Variables	Model 1-variables without treatment	Model 2 - First differences	Model 3 - Correcting for heteroskedasticity
Domestic price of coffee in Colombia	Coefficient β (SE)		
International price of Arabica coffee	7.2805 *** (0.0358)	15.1945 *** (0.3322)	15.1946 *** (0.4358)
Exchange rate COP: USD	1.3672 *** (0.0269)	0.1020 *** (0.0342)	0.1019853 ** (0.0457)
Exchange rate REAL: USD	-779.9866 *** (23.9917)	97.8408 *** (21.9739)	97.8408 *** (27.8344)
International cocoa price	647.7306 *** (20.5663)	-131.7769 *** (30.7177)	-131.7769 *** (37.5151)
Domestic price of coffee in Brazil	5.1989 *** (0.1375)	1.7645 *** (0.1649)	1.7645 *** (0.2008)
R2 Adjusted	0.9196	0.6521	0.6525
Prob. (f)	0.0000	0.0000	0.0000

Skewness / Kurtosis test. Chi2	0.0000	0.0000	0.0000
Breusch-Pagan / Cook-Weisberg test. Prob. Chi2	0.0000	0.0000	N/A
Durbin-Watson test	0.0389	2.1410	2.1410
Dickey-Fuller test	0.0000	0.0000	0.0000
*** significant at 1%			
** significant at 5%			
*** significant at 10%			

Source: Author elaboration

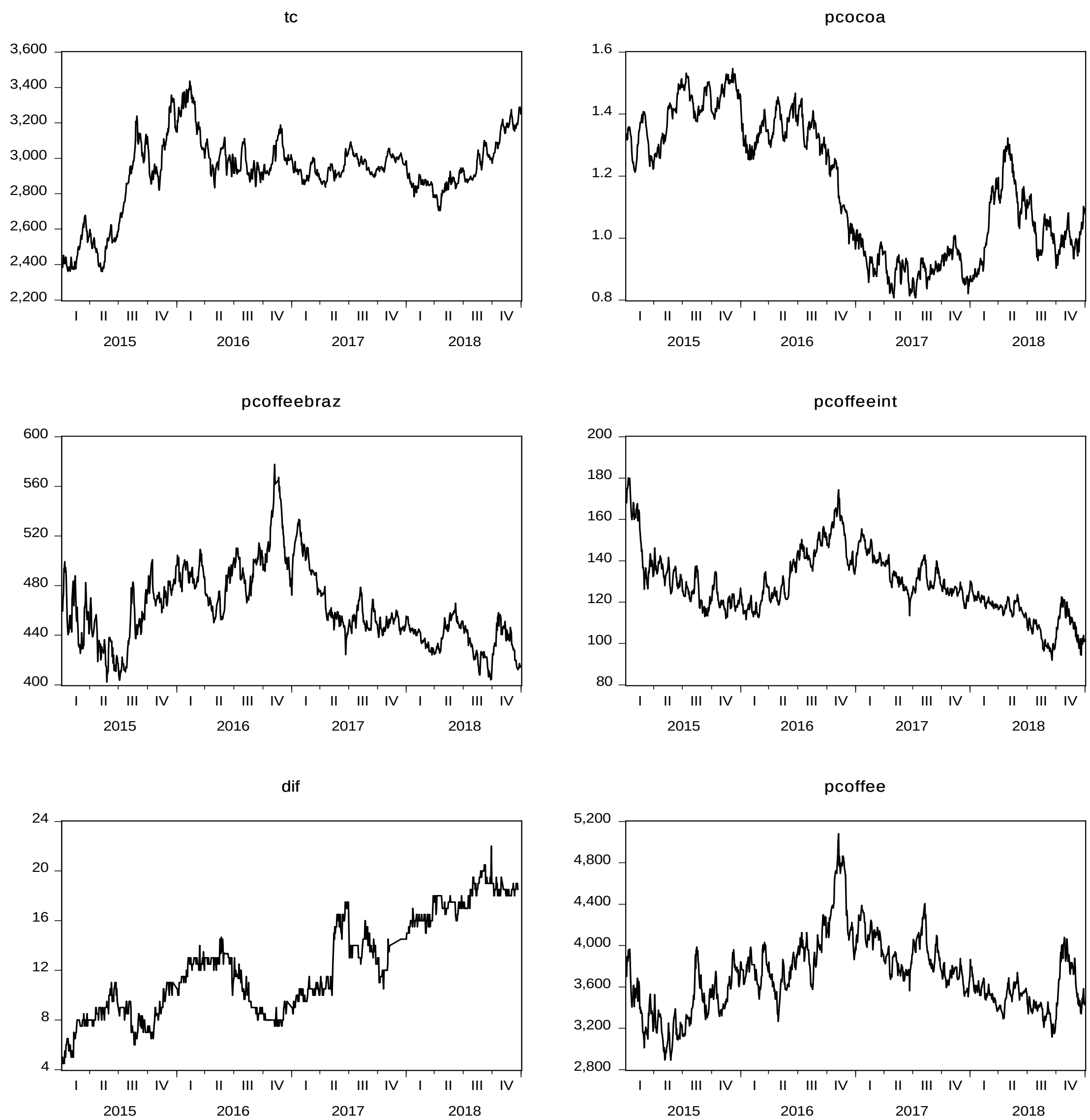
Linear regression model 1, in Table 3, was neither suitable for analysis nor prognosis, due to problems with heteroskedasticity, autocorrelation, and error non-normality, which would lead to spurious relationships. It was, therefore, suggested that variables in first differences be used.

With respect to Model 2, in Table 3, which corresponds to the linear regression model with the first differences, the relationships were positive between the first differences of the domestic price of coffee and the first differences in the international price of Arabica coffee, the exchange rate in Colombia, the exchange rate in Brazil, and the domestic price of coffee in Brazil. On the other hand, there was a negative relationship between the first differences of the domestic price of coffee in Colombia and that of the international price of cocoa. However, since the model presents heteroscedasticity problems, this was corrected with robust standard errors, and the regression was run again to obtain the model.

Finally, Model 3 in Table 3 did not present any heteroscedasticity or autocorrelation problems. The variables analyzed in this model account for 65.25% of the differences in the domestic price of coffee in Colombia. This model exhibited positive relationships amongst the first differences of the domestic price of coffee with that of the international price of Arabica coffee, the exchange rate in Colombia, the exchange rate in Brazil, and the internal price of coffee in Brazil. This coincides with the literature review, in particular with the results of Hong (2016) , who established that the main factors of price fluctuation are the exchange rate and export prices of other exporting countries, such as Brazil, as well as the results of Clavijo et al. (1994) , who indicates that the external price and real exchange rate are part of a block of exogenous variables which explain the behavior of real domestic prices. From another perspective, there is a negative relationship between the first differences of the domestic price of coffee in Colombia and that of the international price of cocoa. Below are the time series used in the estimation by OLS, as well as the VAR model.

Construction and analysis of a regression model, with the assumptions of the classical linear regression model, for the period between 2015 – 2018, considering the following variables:

Figure 3 Variables included in Linear regression model 2015 - 2018



Source: Author elaboration

Table 4. Linear regression model 2015 - 2018

Variable	**Model 1- Variables without treatment**	**Model 2 - First differences**	**Model 3 - First differences - without tcbra**
Domestic price of Arabica coffee in Colombia	Coefficient β (SE)		
International price of Arabica coffee	17.7145 *** (0.6844)	19.01421 *** (0.9029)	18.5830 *** (0.8483)
Exchange rate COP: USD	0.9987 *** (0.0227)	0.1497 *** (0.0522)	0.1496 *** (0.0522)
Exchange rate BRL:USD	125.9881 *** (21.5137)	50.9800 (36.6869)	-
Cocoa Price	-109.8637 *** (21.9412)	-175.3360 ** (68.7116)	-182.7196 *** (68.5450)
Domestic price of Arabica coffee in Brazil	2.0665 *** (0.2337)	1.8378 *** (0.3502)	1.9752 *** (0.3361)
International price of Robusta coffee	917.2402 *** (52.0456)	251.0106 * (140.2159)	234.0121 * (139.7611)
Differential UGQ for Colombia	21.2963 *** (1.1404)	-4.5829 * (2.5158)	-4.5763 * (2.5172)
R2 Adjusted	0.956	0.6804	0.6800
Prob. (f)	0.0000	0.0000	0.0000
Skewness / Kurtosis test	0.0032	0.0000	0.0000
Breusch-Pagan / Cook-Weisberg test	0.0000	0.2577	0.5509
Durbin-Watson test	0.3884	2.1703	2.1579
*** significant at 1%			
** significant at 5%			
*** significant at 10%			

Source: Author elaboration

Model 1 in Table 4 was neither suitable for analysis nor prognosis, due to problems with heteroskedasticity, autocorrelation, and non-normality of errors. This fact would lead to a spurious relationship. Therefore, it was suggested that the variables in first differences be utilized.

In Model 2 in Table 4, which corresponds to the linear regression model with first differences, the variable rate of change for Brazil was not significant for a four-year period. Additionally, this model presented further specification problems that made its interpretation and analysis difficult. Therefore, the exchange rate for Brazil was eliminated, and a new Model 3 was run.

Finally, Model 3 in Table 4 did not present heteroscedasticity or autocorrelation. The variables analyzed in this model explained, at 68%, the differences in the domestic price of coffee in Colombia. In this model, the relationships were positive amongst the first differences of domestic coffee prices with the first differences of the international price of Arabica coffee, that of the exchange rate in Colombia, differences in the internal price of Arabica coffee in Brazil, and the international price of Robusta coffee. This coincides with the literature review, specifically with the results of Hong (2016), which establishes that the main factors influencing price fluctuation are the exchange rate and export prices of other exporting countries, such as Brazil. It also coincides with the results of Clavijo et al. (1994), which highlight that the external price and real exchange rate are part of a group of exogenous variables that explain the behavior of the real domestic price. Similarly, Araque & Duque (2019) state that the differential UGQ is among of the determinants of the sale price in Colombia. Perez (2006) also indicated that the different coffee prices are implicitly assumed to be cointegrated, or that there is a relationship between Robustas and Arabicas. From another perspective, there was a negative relationship between the first differences of the domestic price in Colombia with the differences in the international price of cocoa, as with the first differences of the Colombian differential UGQ, which is consistent with the market reality, as the differential compensates losses for Colombian exporters and producers, derived from the drop in price, thus the relationship tends to be inverse.

4.2 VAR model

It is important to indicate that, had evidence of cointegration been found in variables, the model would have been estimated by including an integration equation, as an additional regressor in the VAR system, and would thus have taken the form of a Vector Error Correction Model (VECM). Appendix A confirms the non-existence of cointegration in the variable system, or that there is N-1 = 5 cointegration equations, such that the VAR can be estimated and not a VEC model with a confidence level of 99%, based on the Unrestricted Cointegration Rank test (trace).

A model of autoregressive vectors, for the period between 2015 - 2018 was run, considering the results of the regression model evaluated. The reduced form of the vector autoregressive model estimated was in order ρ -VAR(3). Although this is interesting, it had to be harnessed because of the results on the limit of non-autocorrelation. In the same sense, the LM test for serial auto-correlation was applied in the VAR (3) model. The result indicates that there was no autocorrelation.

Table 5. VAR residual serial correlation LM tests

Lag	LRE*Stat	Prob.	Rao F-stat	Prob
1	42.20680	0.2204	1.174006	0.2204
2	31.9538	0.6615	0.887293	0.6615
3	42.46512	0.2124	1.181242	0.2124

Source: Author elaboration

Note: Null hypothesis. No serial correlation at lag h.

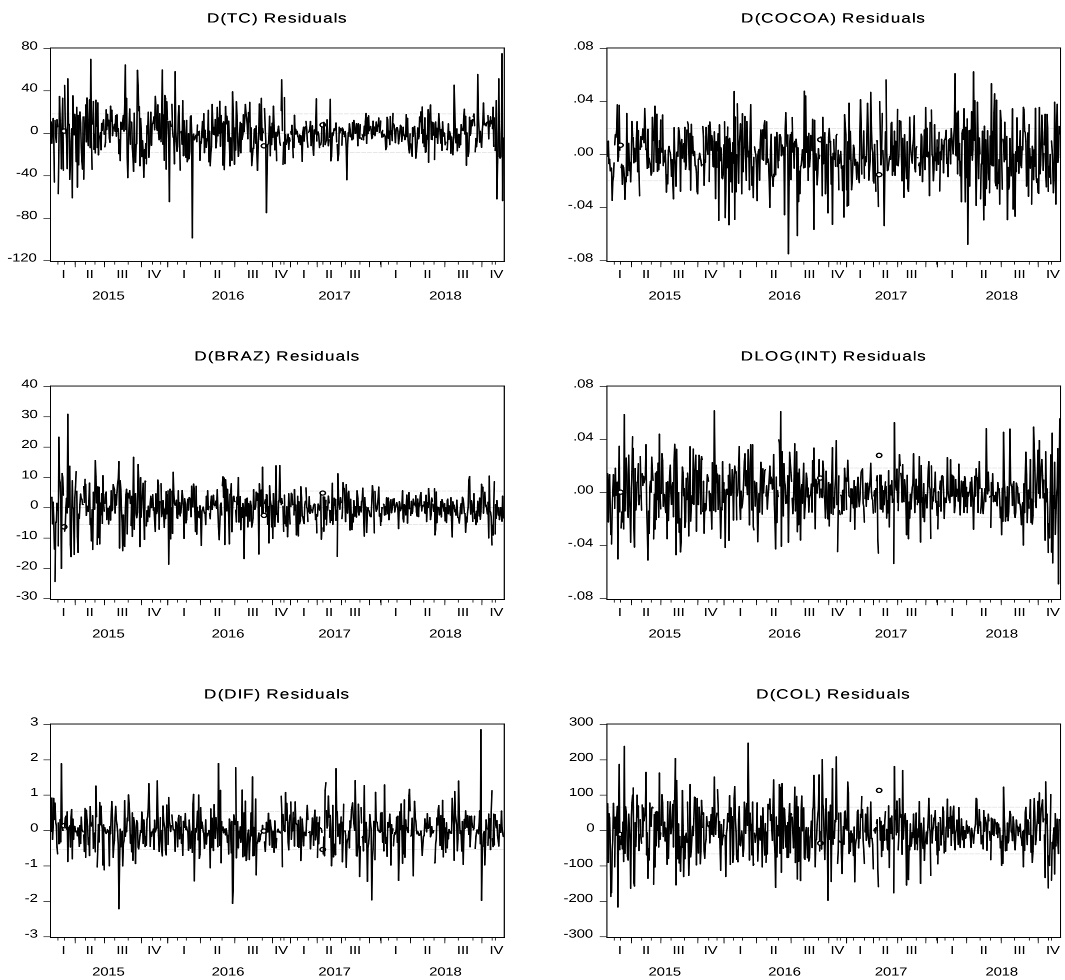
Additionally, it was relevant to evaluate this period, since this database contains the UGQ differential variable.

In accordance with Enders' criterion (2015), associated with the fact that the best information criterion for the identification of lags is that of Hannan-Quinn, the VAR model proposed presented lag. Additionally, this criterion was suitable because it met with the invertibility criterion of the roots of the vector autoregressive model.

In order to identify the presence of exogeneity/endogeneity in the variables, it was identified that only the first difference in Robustas causes Granger the first difference in the domestic price of coffee (at a significance level of 5%).

On the other hand, the residuals followed a white noise distribution that was consistent with the presence of no autocorrelation and homoscedasticity, which allowed for continuation with the ex-post analysis process of the VAR model.

Figure 5: VAR residuals



Source: Author elaboration

When analyzing the decomposition of the variance, 45.17% of the variance of the first difference of the domestic price of coffee, this is explained by the variance of the first difference of the price of Brazil, see Appendix B. This is consistent with Vogelvang (1992), who states that Brazil is a fairly dominant producer country in the worldwide market, and has been listed as a price reference, followed by an inertial component, and finally the variance of the first differences of the international price. On the other hand, the variance of the differences with the least influence the variance of the first difference of the domestic price of coffee are those of the exchange rate, the international price of cocoa, and the differential. Unlike the results obtained by Hong (2016) and the composition of the domestic price indicated by the National Federation of Coffee Growers, the exchange rate did not constitute a large percentage of the variance of the first difference of the domestic price of coffee. However, as in Hong's (2016) study, the price of coffee in Brazil had a considerable effect on the variations in the differences of domestic coffee prices in Colombia. Finally, in terms of conclusions stated by Araque & Duque (2019) on the determining elements of the sale price of coffee in Colombia, it was only found that the variance of the first difference of the price of coffee in the New York stock exchange had an important effect on the variance of the first differences of the domestic price of coffee in Colombia, while the variance of the first difference, in both quality premium paid for Colombian coffee and the current exchange rate, did not explain, to a large extent, the variance of the first differences in the internal price of coffee in Colombia

5 CONCLUSIONS

In the linear regression model for the period between 2003 - 2018, it was found that this explained 65.25% of the differences of the domestic price of coffee in Colombia. The findings of all variables were significant for the model, and coincided with the review of literature, particularly with the results of Hong (2016). Conversely, for the period between 2015 - 2018, the model explains, at 68%, the differences in the domestic price of coffee in Colombia, and its results are also consistent with literature, Hong (2016), and Clavijo *et al*. (1994). It also coincides with that established by Araque & Duque (2019), that the UGQ differential is part of the elements that determine the sale price of coffee in Colombia, and the conclusions of Perez (2006), who points out that the different prices of coffee are implicitly assumed to be cointegrated, or that there is a negative relationship between

Robustas and Arabicas. On the other hand, in this four-year model, the Brazilian exchange rate variable was not significant and therefore was not considered.

In accordance with the results of the VAR model, it was concluded that the domestic price of coffee in Colombia was sensitive to changes, in the very short term, of the internal price of coffee in Brazil (less than five days), which is consistent with Hong (2016), who indicates that the export price of Brazilian coffee has a positive effect on the price of Vietnamese coffee, as in the case of Colombian coffee. An inertial effect of the internal price was identified (in the very short term, five days), making it evident that there were several hidden internal elements that determined the internal price of coffee in Colombia. This is not consistent with what is established by the National Federation of Coffee Growers on the determinants of the sale price of coffee in Colombia, as these results indicate that there are internal hidden factors that are not identifiable, and which impact domestic prices. As such, making a prediction of the internal price of coffee, taking into account the inertial effect and explanatory capacity of the analyzed variables could lead, according to Enders (2015), to inappropriate results, in terms of the rigor of the econometric analysis. For future studies must consider those variables that capture institutional dynamics, as they are currently hidden, as well as the production variable, since, according to Leibovich (1989), for the case of agricultural products such as coffee, supply is the main source of price instability.

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Appendix

A. Cointegration test

Unrestricted Cointegration Rank Test (Trace)

Hypothesized no. of CE(s)	Eigenvalue	Trace sStatistic	0.05 Critical value	Prob.**
None *	0.334813	1138.774	95.75366	0.0000
At most 1 *	0.318540	866.4386	69.81889	0.0000
At most 2 *	0.260739	610.2486	47.85613	0.0000
At most 3 *	0.203542	408.4429	29.79707	0.0000
At most 4 *	0.180061	256.4185	15.49471	0.0000
At most 5 *	0.169174	123.8035	3.841466	0.0000

Trace test indicates six cointegrating eqn(s) at the 0.05 level

* denotes hypothesis rejection at the 0.05 level

**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (maximum Eigenvalue)

Hypothesized no. of CE(s)	Eigenvalue	Max-Eigen statistic	0.05 Critical value	Prob.**
None *	0.334813	272.3353	40.07757	0.0000
At most 1 *	0.318540	256.1900	33.87687	0.0000
At most 2 *	0.260739	201.8057	27.58434	0.0000
At most 3 *	0.203542	152.0244	21.13162	0.0000
At most 4 *	0.180061	132.6150	14.26460	0.0000
At most 5 *	0.169174	123.8035	3.841466	0.0000

Max-eigenvalue test indicates six cointegrating eqn(s) at the 0.05 level

* denotes hypothesis rejection at the 0.05 level

**MacKinnon-Haug-Michelis (1999) p-values

B. Variance decomposition

Period	S.E.	D(TC)	D(COCOA)	D(BRAZ)	DLOG(INT)	D(DIF)	D(COL)
1	18.30353	1.689494	0.673383	45.83471	18.10730	0.361034	33.33408
2	25.65306	1.732869	0.897354	45.94316	17.90793	0.534485	32.98421
3	25.82378	1.729661	1.028604	45.50304	18.31636	0.757685	32.66465
4	25.89800	1.727895	1.310872	45.22140	18.22347	0.951508	32.56486
5	25.97499	1.741698	1.310858	45.18661	18.22991	0.971605	32.55931
6	25.98166	1.741682	1.311042	45.17807	18.22699	0.990165	32.55205
7	25.98335	1.741851	1.310985	45.17728	18.22700	0.990284	32.55261
8	25.98422	1.741870	1.311273	45.17544	18.22626	0.993910	32.55124
9	25.98459	1.741866	1.311329	45.17528	18.22630	0.994067	32.55116
10	25.98463	1.741934	1.311326	45.17522	18.22625	0.994183	32.55108
11	25.98464	1.741934	1.311339	45.17521	18.22625	0.994183	32.55108
12	25.98465	1.741935	1.311341	45.17521	18.22625	0.994194	32.55107
13	25.98465	1.741935	1.311342	45.17521	18.22625	0.994195	32.55107
14	25.98465	1.741935	1.311342	45.17521	18.22625	0.994195	32.55107
15	25.98465	1.741935	1.311342	45.17521	18.22625	0.994195	32.55107
16	25.98465	1.741935	1.311342	45.17521	18.22625	0.994195	32.55107
17	25.98465	1.741935	1.311342	45.17521	18.22625	0.994195	32.55107
18	25.98465	1.741935	1.311342	45.17521	18.22625	0.994195	32.55107
19	25.98465	1.741935	1.311342	45.17521	18.22625	0.994195	32.55107
20	25.98465	1.741935	1.311342	45.17521	18.22625	0.994195	32.55107
21	25.98465	1.741935	1.311342	45.17521	18.22625	0.994195	32.55107
22	25.98465	1.741935	1.311342	45.17521	18.22625	0.994195	32.55107
23	25.98465	1.741935	1.311342	45.17521	18.22625	0.994195	32.55107
24	25.98465	1.741935	1.311342	45.17521	18.22625	0.994195	32.55107
25	25.98465	1.741935	1.311342	45.17521	18.22625	0.994195	32.55107
26	25.98465	1.741935	1.311342	45.17521	18.22625	0.994195	32.55107
27	25.98465	1.741935	1.311342	45.17521	18.22625	0.994195	32.55107
28	25.98465	1.741935	1.311342	45.17521	18.22625	0.994195	32.55107

29	25.98465	1.741935	1.311342	45.17521	18.22625	0.994195	32.55107
30	25.98465	1.741935	1.311342	45.17521	18.22625	0.994195	32.55107
31	25.98465	1.741935	1.311342	45.17521	18.22625	0.994195	32.55107
32	25.98465	1.741935	1.311342	45.17521	18.22625	0.994195	32.55107
33	25.98465	1.741935	1.311342	45.17521	18.22625	0.994195	32.55107
34	25.98465	1.741935	1.311342	45.17521	18.22625	0.994195	32.55107
35	25.98465	1.741935	1.311342	45.17521	18.22625	0.994195	32.55107
36	25.98465	1.741935	1.311342	45.17521	18.22625	0.994195	32.55107
37	25.98465	1.741935	1.311342	45.17521	18.22625	0.994195	32.55107
38	25.98465	1.741935	1.311342	45.17521	18.22625	0.994195	32.55107
39	25.98465	1.741935	1.311342	45.17521	18.22625	0.994195	32.55107
40	25.98465	1.741935	1.311342	45.17521	18.22625	0.994195	32.55107
41	25.98465	1.741935	1.311342	45.17521	18.22625	0.994195	32.55107
42	25.98465	1.741935	1.311342	45.17521	18.22625	0.994195	32.55107
43	25.98465	1.741935	1.311342	45.17521	18.22625	0.994195	32.55107
44	25.98465	1.741935	1.311342	45.17521	18.22625	0.994195	32.55107
45	25.98465	1.741935	1.311342	45.17521	18.22625	0.994195	32.55107

Cholesky ordering: D(TC) D(COCOA) D(BRAZ) DLOG(INT) D(DIF) D(COL)

Capítulo

3

Chapter 3. Financial risk for companies listed on the Lima stock exchange between 2016 and 2018

Abstract

Financial risk was evaluated through a probabilistic model, based on the liquidity, debt, and portfolio risks of the companies listed on the Lima Stock Exchange, and which reported the financial statements to the stock market superintendence (SMV), for 2016, 2017, and 2018. Said risk analysis was carried out in terms of the "dummy" variable, for 174 Peruvian companies. Subsequently, the LOGIT model, together with specific econometric tests and hypotheses, were applied to evaluate model consistency and reliability.

It was determined that the year which presented highest financial risk was 2017, the tertiary sector being that with the highest risk rates. Of the 174 companies observed, over 80% thereof presented portfolio recovery risk, as the highest frequency risk, for the three years.

KEY WORDS: *financial risk, portfolio recovery risk, liquidity risk, indebtedness risk.*

Classification JEL: D81, G24, G32, G35

Introduction

The present dynamic of financial risk at the global level, has been characterized by constant changes and by high market uncertainty levels. Some studies indicate that "moments of risk" have been experienced recently, as market globalization has caused events in one region or country to indirectly affect other regions, or even the rest of the world, due to economic interrelationship. The following are examples of said moments of risk: the devaluation of the Mexican peso (Tequila Effect, 1995); Asian Crisis (Dragon Effect, 1997), devaluation of the real in Brazil (Zamba Effect, 1999), fall of the North American NASDAQ index (2000), economic slowdown in the United States and general increase in energy prices (2001), collapse of the Argentine economy (Efecto Tango, 2002), financial economic crisis (2008). In each of these situations, uncertainty has been present, and it has been essential to assess the risk that these situations imply. Said elements lead to the reflection of Pascal (Pascal, 1999), that: "the world from a financial point of view, it is a riskier place". From the above arise the needs for new methods, procedures, and models to measure and control increasingly complex risks.

Around the world, small and medium-sized companies constitute the bulk of businesses, in numerical terms. According to the Central Business Directory (DIRCE), as of January 1, 2016, there are 3,232,706 companies in Spain, of which 99.88% are MSMEs (between 0 and 249 employees). As a result, it is necessary to investigate and learn the risks to which these companies are exposed, to generate instruments would allow them to act opportunely. There are few studies in this field, and research is nonexistent in context analyzed herein, particularly in the areas of liquidity, debt, and portfolio management.

Similarly, this topic also requires additional examination because small and medium-sized companies do not usually have (a priori hypothesis) financial departments that would perform complete and adequate monitoring of the various risk indicators, and use these conclusions, make relevant decisions and apply strategies conducive to mitigating those risks in which they are immerse, as indicated by Miller (1994).

Specifically, financial risk is a term introduced into modern theory by Markowitz (1952), in his article, “Portfolio Selection: Efficient Diversification of Investments”, published in The Journal of Finance, it encompasses the possibility of any event which might occur, that could result in negative financial consequences. A whole field of study has been developed around financial risk to reduce its impact on companies, investments, commerce, etc. Risk can also be understood as the possibility that the benefits obtained are lower than those expected, or that there is no return at all.

Mascareñas (2008) defines risk as the uncertainty associated with return on investment, due to the possibility that the company may not meet its financial obligations (mainly, interest payment and debt amortization). On the other hand, it is important to mention that companies face different financial risks, which vary in accordance with company and activity types. Specifically, they can be classified into systematic (market, exchange, legal, transaction, translation, economic, among others) and non-systematic risk (interest rate, insufficient equity, operating, indebtedness, liquidity, among others) categories (Lewent (1990), Fragoso (2002), Jorion (1999), Baca (1997), Díaz (1996), Ayala (2005)).

Once the risks to which a company may be exposed have been defined and reviewed, the next step is to administrater or manage said risk. In modern financial theory, authors such as

Biodie & Merton (1999), in portfolio theory, conceptualize risk management as the quantitative analysis of optimal risk management. Its application consists of formulating and evaluating trade-offs between risk-reduction benefits and costs, in order to arrive at an optimal decision. This requires an evaluation of the advantages and disadvantages of receiving higher returns and taking on greater risks.

With this in mind, companies and their managers must be prepared to manage risks in accordance with company type and exposure. Certain organizations, due to their sizes, structures, or the environments in which they operate, may be exposed to additional risks: the short or medium-term, risks inherent to those environments closest to the market of influence, etc. Large companies, conversely, may be affected by longer-term risks, and those corresponding to global markets, etc.

Once this conceptualization has been carried out, it is importantto observe what is the behavior of financial risk in the companies listed on the Lima stock exchange. For this, a series of main and secondary objectives was established, including: characterization of financial risk in Spanish companies, refinement of the financial statements from the SMEs under study, determination of the liquidity, indebtedness, and portfolio recovery indices which affected the financial risk of a group of Spanish companies, establishment of the risk condition of those companies subject to study, and analysis of financial risk, in accordance with the productive sectors for said companies.

This investigation aims to offer elements that would provide companies tools that balance the results of calculated indicators, and which have controllable risk. According to San-Martín-Albizuri & Rodríguez-Castellanos (2011), the current crisis has revealed the close interrelationship of three aspects inherent to the development of financial markets in recent decades: the globalization process, volatility of financial magnitudes, and uncertainty.

Peru as a context of the companies under study, and a Latin American country, follows the same trend in the business composition of Latin America. The vast majority are family businesses and SMEs, as reflected in the latest data published by the Peruvian National Institute of Statistics and Informatics (INEI 2019). With regard to private formal employment, for the year 2019, the unemployment rate was expected to continue to decrease, as in the previous year, and growth of 3.7% was expected in the number of workers registered in electronic spreadsheets, a figure equal to that registered in 2018.

On the business level, improvements in the margins of large companies were expected, as was the implementation of mining projects and the growth of the trade and services sectors, although the fishing sector continues to be very important for the country's economy. Among the risks that the Peruvian economy might face was the stagnation of China as a commercial power and Peru's foremost commercial partner, due to the deterioration or a lack of institutional framework, and political instability, which is the result of corruption and confrontation or separations in congressional political parties.

All of the above augurs a positive outlook for both the business sector in general and for companies that trade in the stock market.

Background

Regarding the literature most closely related to the objectives set out herein, strong growth is observed in publications that correspond to financial risk, framed within the stock market dynamics of the capital market. This growing trend in publications highlights studies specific to Asian and developed countries, and tend to use a wide range of methodologies, including the tools provided by econometrics and statistics, self-experimentation models based on previous studies, and stock market indices for the time periods analyzed.

Given the literature from the past decade, it is important to note that studies regarding systemic financial risk have become more frequent since the 2008 financial crisis. Events of that magnitude have generated panic and countless negative reactions, which are prudent to prevent in advance with the information provided by these types of studies, which makes them vital. This background section is based upon those articles which carry the most weight, in terms of citations, and include a classification, by definition, of systemic risk, causes and characteristics of financial institutions that address risk, and ways in which risk may be measured.

Adrian & Brunnermeie (2010) suggest that the definition of systemic financial risk stems from the malfunction of a given entity, that extends its disorganization towards the supply of credit and economic capital. Similarly, Acharya & Richardson (2009) state that financial risk appears before the joint failure of financial institutions and capital markets that shorten the supply of real capital in the market. K.Patro, MinQi, & XianSun (2013) state that it is a situation in which the entire financial system is affected simultaneously, achieving an evident crisis in credit and liquidity, caused by major events, above all the system, such as downturns in financial institutions, which influence the economy as a whole.

One important factor to evaluate, in terms of financial risk, is the identification of characteristics of financial institutions that push financial systems to obvious risks. Caccioli & Vivo (2009) state that the uncontrolled proliferation of financial instruments can lead the market to a state in which trading volumes expand rapidly, as a result of a saturated demand from investors, which implies a cost in the stability of everything in the system. On the other hand, Battiston, Gatti, Gallegati, Greenwald, & Stiglitz (2012a) assert that the diversification of individual credit risk can generate ambiguous effects on a systemic level, especially during a credit crisis. Vallascas & Keasey (2012) say that leverage restrictions and the imposition of liquidity can improve the resistance of financial institutions to systemic phenomena. Battaglia & Gallo (2013) argue that titling increases systemic risk in banking, as occurred in 2008, because they limit the ability of investors to monitor their risk. These conclusions are similar to those reached by Carbo-Valverde, Degryse, & Rodríguez- Fernández, (2015). For Anginer, Demirguc-Kunt, & Zhu, (2014), competition from private banking provokes risk diversification, indirectly making the system less vulnerable. Ghosh (2016) and Nicolò & Juvenal (2014) suggest that the presence of foreign banks implies greater financial stability in the financial systems of the recipient countries. On the other hand, Glasserman & Young, (2014) consider the understanding of modern interconnectivity in terms of globalization to be key, as an indication for the management of financial risk.

For the management of systemic risk, it is vitally important to measure this, which is part of what this study seeks to do: to understand financial market dynamics. According to Huang, Zhou, & Zhu (2009), the ideal way to assess financial system health is to look at market data, in real time, from constant monitoring, since traditional regulatory measures focus on information from bank balance sheets. However, this information is available only a few times per year, which implies a considerable delay. More concisely, the literature shows several risk measurement methods, such as those of: Segoviano & Goodhart (2009), which uses the multivariate density of companies in the financial sector, with the adjusted portfolio tail, Hu, Pan, & Wang (2013) which makes use of liquidity measures, Li, Wang, & He (2013), which makes use of the Mahalanobis distance metric, Adrian & Brunnermeier (2010), which measures the Value at Risk (VaR) of the financial sector, with a conditional analysis of the

VaR of a single bank, using quantile regressions, Zheng, Podobnik, Feng, & Li (2012), which uses the growth rate of the main components of the asset returns correlation matrix, and Patro, Qi, & Sun (2013), which uses the correlations of the returns of financial institution shares.

Finally, in relation to research published in the last year, articles that correspond to econometric methodologies, such as: regression analysis, panel data, causality analysis, spatial econometrics, and error correction models, stand out. In this regard, the list may begin with the contributions of Lee (2020), which uses a panel data model in order to examine the impact of the social responsibility activity of companies on their market value, with special emphasis on the market capitalization of tour operators listed on Chinese stock markets. They conclude that corporate social responsibility activities may lead to short-term financial risk. Also using a panel data methodology, but with generalized least squares, Dang, Phan, Nguyen, & Thi Hoang (2020) implement an analysis of the factors that affect the financial risk of companies listed on the Vietnam stock market. This is very closely related to the research objective of the present study, highlighting its conclusion to pay careful attention to those variables that reflect the liability structure coefficient, rapid coefficient, return on asset, total volume of business assets, volume of business accounts receivable, net asset ratio and fixed asset ratio, and emphasizing that impacts are not equivalent between state and non-state companies.

In terms of panel data methodology, Helseth, Krakstad, Molnár, & Norlin (2020) analyze twelve stock markets, based on what they call implicit volatility, as a financial risk prevention measure, and show that implicit volatility is high when markets are falling, but is less informative about future market movements. Akinmade, Adedoyin, & Bekun (2020) use an error correction model to empirically analyze stock market manipulation in the Nigerian Stock Exchange and its consequences on economic performance. They conclude that trading manipulation negatively affects financial performance and economic aggregates.

Investigations such as those of Chia, Liew, & Rowland (2020) and Muktadir-Al-Mukit (2020) use regression analysis to evaluate the risk factors of price volatility in the capital market, highlighting the importance of the dynamics of aggregate economic movement and monetary policy in stock market dynamics, and measure contagion tolerance, in terms of systemic risk and the possible sociodemographic factors that directly influence this. Xu, Chen, Jiang, & Yu (2020) use a simple predicted regression model to estimate two popular financial risk measures: value at risk and predicted deficit, with simulated data and four stock indices, to compare the performance of said model with that of several popular models. Likewise, using a time series regression analysis, from the interaction of economic uncertainty and changes in stock trading volumes, Cai, Tao, & Yan (2020) conclude that increases in economic uncertainty caused by trade-geopolitical frictions, especially of powers, exacerbate financial risks.

Using the spatial econometric model, in addition to complex network theory, Zhang, Zhuang, & Lu (2020) analyze the indirect spatial effects of volatility among the G20 stock markets. They further explore the influencing factors of financial risk, highlighting that there are significant indirect spatial effects on world stock markets, resulting in the volatility of stock markets, public debt, and inflation positively correlated with systemic risk, while current account and macroeconomic results are negatively correlated.

On performance of a causality and ARDL analysis, between stock indices and exchange rates, Mroua & Trabelsi (2020) found that exchange rate movements significantly affect short and long-term equity market indices: in that case, in BRICS group countries. Also, through the application of ARDL tests, such as the DOLS and Markov Switching tests, to determine factors that influence possible financial risks for publicly traded companies in Taiwan, Kirikkaleli (2020) determined that the combination of national and foreigners has a long-term effect on the stock index, and that the decrease in economic, political, and financial risks is associated increases in the Taiwanese stock index between 1997 and 2015. On the other hand, Zhao, Wen, & Li (2021) carried out a causality analysis, which showed the bilateral contagion effect of bubbles between oil markets and the Chinese stock market, thus inviting investment portfolio diversification.

Additionally, in relation to “traditional” statistical-econometric models, Zhao (2020) proposes a dynamic bivariate peaks-over-threshold model, in order to study variable behavior, over time, of joint tail risk in financial markets. This suggests that markets on the same continent have time-varying, high-level joint tail risk, and that tail connection increases during periods of crisis.

Finally, with respect to studies that experiment with the real-time behavior of stock indices, studies such as Mashalaba & Huang (2020) and Vasileiou & Pantos (2020) stand out. They study the behavior of Value at Risk (VaR) as an element fundamental to the measurement and management of financial risk, and similarly conclude that VaR does not contribute to financial stability, dependent on the organization and stability of financial institutions themselves. Finally, Jiang, Zheng, & Wang (2020) construct an index of the spillover effect, with respect to international financial markets, to measure financial risks in China's real estate markets. They thus verified a significant, indirect effect of information, between Chinese real estate and related stock markets.

Methodology

The investigation presented herein is a quantitative case study with empirical measurement, not only because of the size of the observed population, but also because of the inference level that can be gleaned from the results. It only describes financial risk behavior in certain companies listed on the Lima Stock Exchange.

It is clear that, for any organization, the results presented in a given period must be analyzable (Vimrová, 2015). In this sense, the present study aims to and characterize the reality of certain Peruvian companies. The population under study encompasses 273 companies in the database reported by the Superintendency of the Securities Market (SMV), and is complemented by information published by the Lima Stock Exchange (BVL). The information and financial statements for 193 companies, which continuously reported their information throughout 2016, 2017, and 2018, was filtered.

This study may be defined as a multi-centric macro project. In an initial phase, previous studies were implemented in Colombian capital cities including: Manizales, Pereira, Armenia, Cali, Medellín, Bogotá, where the model was applied for measurement and its respective econometric validation. There was also a previous study conducted in Spain, with the companies listed on the stock exchange and Spanish markets, and in Mexico, with companies on the Mexican Stock Exchange.

The following working hypotheses were raised:

H_1. The liquidity, indebtedness, and recovery of portfolios negatively influence the financial risk of companies listed on the Lima Stock Exchange.

H_0 The liquidity, indebtedness, and recovery of portfolios do not negatively influence the financial risk of companies listed on the Lima Stock Exchange.

In the first phase of the macro project, a pilot test was carried out, both to refine the methodology, instruments, and data applied, and to establish reference values through central tendency statistical data, with which the presence of risk was determined. In the case of Peru, the value was the following: liquidity 2.73. This last reference value used is not very far if we return to that expressed by Altman (1968), who, in the discriminant analysis carried out in his studies on the risk of insolvency with various financial ratios, demonstrated how they acted as predictors of thereof. For portfolio recovery, a company has portfolio management risk when the result of the portfolio recovery calculation yields a value of greater than 60 days, and whose value, with the "dummy" variable, is 1. A company has debt risk when the result of the calculation is greater than 51%, since it compromises capital adequacy, and the value assigned for the "dummy" variable is 1.

For the calculations of debt and portfolio recovery risks, formulations of conditional made, allowing the model and its dispersions to be smoothed. This formulation, in the case of the portfolio, was carried by all the values of those companies that provide over 360 days of recovery, presenting atypical data in the model, and also exceeding the maximum accounting period (portfolio greater than 360 days). This is punished by companies as a lost in the income statement for the following period. Likewise, the formulation of the conditional was applied to indebtedness, converting all levels above 100%, since companies cannot have indebtedness values greater than the value of their assets, although calculations may present this.

The individual liquidity, indebtedness, and portfolio turnover risks were measured, using the measures of central tendency for the entire study target population as reference values for their determination, and converting these into dummy variables, for said purpose, and at their own expense. This, instead, determined financial risk through a conditional probabilistic model, and also, as a dichotomous variable. These three types of indicators were chosen from operational risks because they are those that have the largest effects in the short and medium terms, considering the possible impact on company performance and viability in the long term.

Once each risk was calculated (liquidity, debt, and portfolio recovery), these results were converted into risk terms, as a dichotomous or dummy variable, defined as 1, if the company has financial risk, and 0, if the company has no risk. This occurred via a conditional model and generation of a risk table, and risk was determined under the following premise or criteria: if the sum of the three individual risks was equal to or greater than 2, then the company had risk (1), and companies with two or three of the indicators in no risk conditions (0), had no financial risk (0).

Among the risks described in the literature, which may affect companies, is operational, or business risk, understood as the derivative of the decisions made daily within the company, either in relation to production, distribution, or prices, among other things. Jorion (2001) defines financial risk as the risk of not being in a position to cover company financial costs. According to (Valencia and Restrepo, 2016), "risk indicators are the essential instruments to measure said performance through formulas and mathematical calculations that are applied to financial statements, results that will help us measure the health of individual financial institutions".

Once company financial risks were calculated, a descriptive analysis of risk behavior was carried out, by type of company and productive sector, in accordance with conglomerate, by cluster analysis.

Finally, the database was verified and validated, and the independent variables used to explain variations of the dependent variable (no financial risk, financial risk) were clarified, using econometric techniques to determine and quantify risk exposure (Uribe , 2015). The SPSS program was used to run the Logit model, which allowed for establishment of the goodness, consistency, and reliability of the model, acceptance or rejection of the work hypothesis, and prediction of possible financial risk behavior.

Results

The following is an analysis of the results obtained, after data processing, based on basic financial statements: cash flow, balance sheet, and profit and loss statement, as reported to the Superintendency of the Securities Market (SMV) and Lima Stock Exchange (BVL).

Graph 1. Financial risk.

Source: Author elaboration.

Subsequently, an analysis was generated for financial risk to the 193 companies studied might present for the evaluated period. This indicator permitted determination of the existence or not of financial risk, in accordance with liquidity, debt, and portfolio risks. On implementation of this evaluation, it was found that over half of companies, in 2016, presented financial risk. Since then, as shown in Graph 1, 42% did not present financial risk, in contrast to 58% of companies with financial risk. In 2017, the same occurred: over half of the listed companies on the Lima Stock Exchange presented financial risk, with a participation of 61.7%. With respect to a non-presence of risk of 38.3%, in the same way for 2018, the financial risk participation is lower than that presented for 2017. When obtaining participation of 60.1%, a reduction of 1.6 percentage points, over half of the listed companies presented this type of risk.

Similarly, it should be noted that the highest peak found with this type of risk, in the analyzed period, occurred in 2017, with an increase in risk from 2016 to 2017 of 3.7% in the risk share for these companies. Note that, in accordance with the results of this study, it was observed that, for 2016, 2017, and 2018, listed companies all presented risks in the same proportions for the three years, with an average of 33%.

Financial risk by sector

Table 1. Financial risk by sector.

SECTOR	RISK PRESENT 2016	RISK PRESENT 2017	RISK PRESENT 2018	RISK FREE 2016	RISK FREE 2017	RISK FREE 2018
PRIMARY	12	12	10	11	11	13
%	35.29%	35.29%	29.41%	32.35%	32.35%	38.24%
SECONDARY	23	21	25	22	24	20
%	33.33%	30.43%	36.23%	31.88%	34.78%	28.99%
TERTIARY	48	55	52	77	70	73
%	30.97%	35.48%	33.55%	49.68%	45.16%	47.10%

Source: Author elaboration.

Table 1 shows the financial risk for each sector, by number of companies and participation percentage, as compared to the 193 companies studied. Risk was analyzed both within the sectors and in the various years under study. The percentages showed that all sectors, proportionally, present the same level of risk, with an average of 33.3% per sector, during the three years examined. Montoya, s.f. states that, “The economic sector of the manufacturing industry, handicrafts, community services and transformation of primary sector products into new products and consumer goods in Peru, as in most countries, is the second largest in the economy It also drives a large part of the country's economic growth, close to 50% of it ”. For example, in January of 2018, according to data from the INEI (National Institute of Statistics and Informatics of Peru), in its bulletin for the first quarter of 2019, regarding the behavior of the Peruvian economy, during 2018, the secondary transformation sector took first place, with 6% of global supply and demand, in relation to the country's GDP. Manufacturing was third in terms of participation in GDP during 2018, with 6.2%. This type of sector is characterized by the latent need to constantly innovate and invest, in order to improve processes. For this reason, it is subject to greater risks, thanks to the constant financial movement generated to leverage these activities.

Regarding the primary sector, there is evidence of a decrease in the percentage of companies with considerable risk. This explained by the nature of these sectors and the minimal financial mobility they possess. For example, in the agri-food and rural sector, the sector's low capitalization is evident, and isderived from the lack of investment of rural productive units, in productive assets, such as private infrastructure, machinery, and equipment, and also in fixed assets and scant incorporation of agricultural technologies and technical models (De

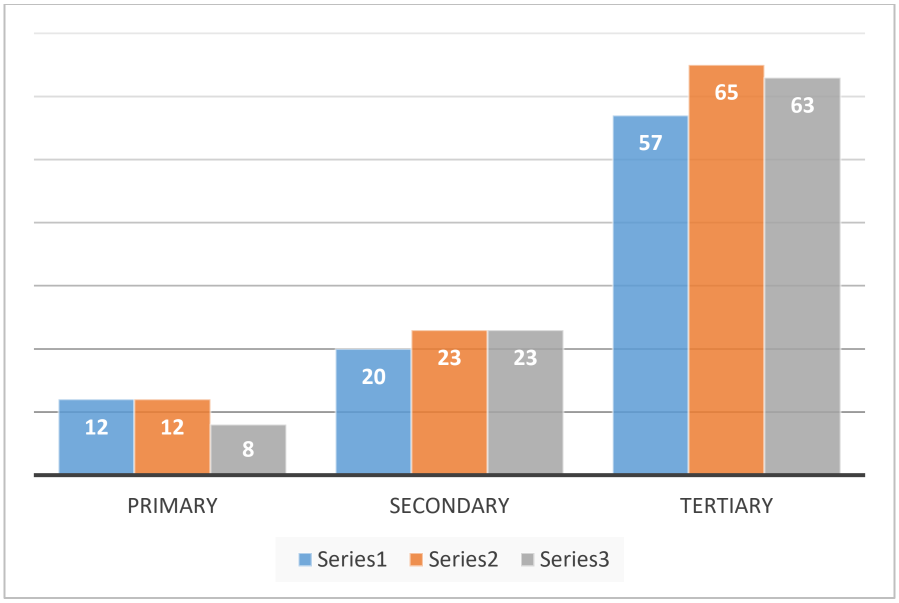
Olloqui and Fernández, 2017). The lack of investment in these types of assets generates little productivity or financial dynamism in the sector, due to having insufficient financing access. This may finally translate into the availability of working capital for the purchase of inputs, the acquisition of management models and production, and the adoption of technologies and technical-productive capacities, among other things, which create greater productive unit profitability. For example, in the case of Peru, access to credit could increase agricultural productivity by 26%, and profits by between 17% and 27% (De Olloqui and Fernández, 2017).

Graph 2. Liquidity risk.

Source: Author elaboration.

In a second phase, individual risks were analyzed. This began with liquidity risk, which reveals whether companies, after paying its short-term obligations, still have working capital and investment resources. As shown in the graphs for 2016, 2017, and 2018, almost half of the companies under study were liquid. In 2016 and 2018, 50% of the companies listed on the Lima Stock Exchange had liquidity risks, and only in 2017 did the risk increase above 50%.

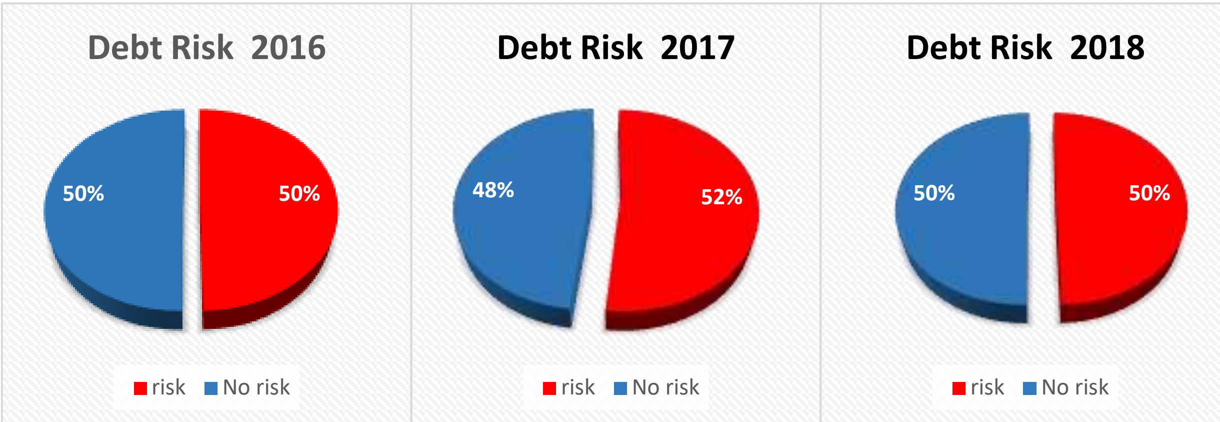
Graph 3. Liquidity risk by sector.



Source: Author elaboration.

For the analysis by sectors, risks were determined by means of the same sectors, with liquidity for the primary sector at an average of 1.22, for the secondary sector, 1.6, and for the tertiary sector, 1.17. The tertiary sector had the highest number of companies at risk over the three years of observation, representing 60% of all companies. Additionally, note that the tertiary sector, during the three consecutive years, generated minimal increases, while in the primary sector, companies with liquidity risks increased for the year 2017, this increase may have been due to the slowdown of the economy, as a consequence of the fall in the international price of raw materials, among these, copper, a product of great importance for Peruvian exports. For the year 2018, a decrease was generated in this sector, which may have owed to the recovery of the prices of raw materials, which translated into a new wave of mining investment. Finally, the secondary sector, which consists of industrial companies in different areas, generated a slight, gradual decrease over the three years of observation.

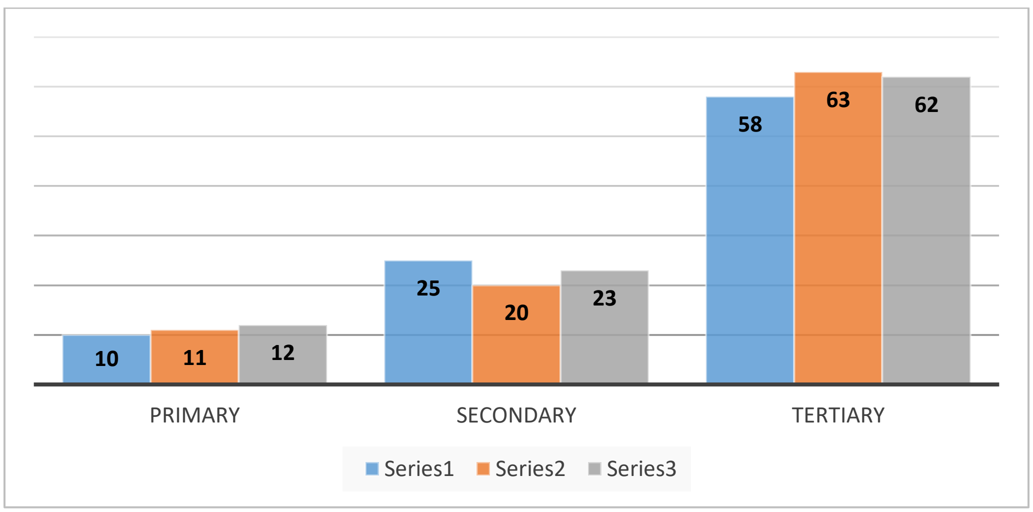
Graph 4. Debt risk.



Source: Author elaboration.

The debt risk analysis also reveals the ways in which company equity sufficiency was compromised. The results obtained were based on the calculations carried out, and reflected the same liquidity risk trend. Over the three years of observation, risk was or exceeded 50%, with 2017 at 52%, the year that presented the highest number of companies with debt risk.

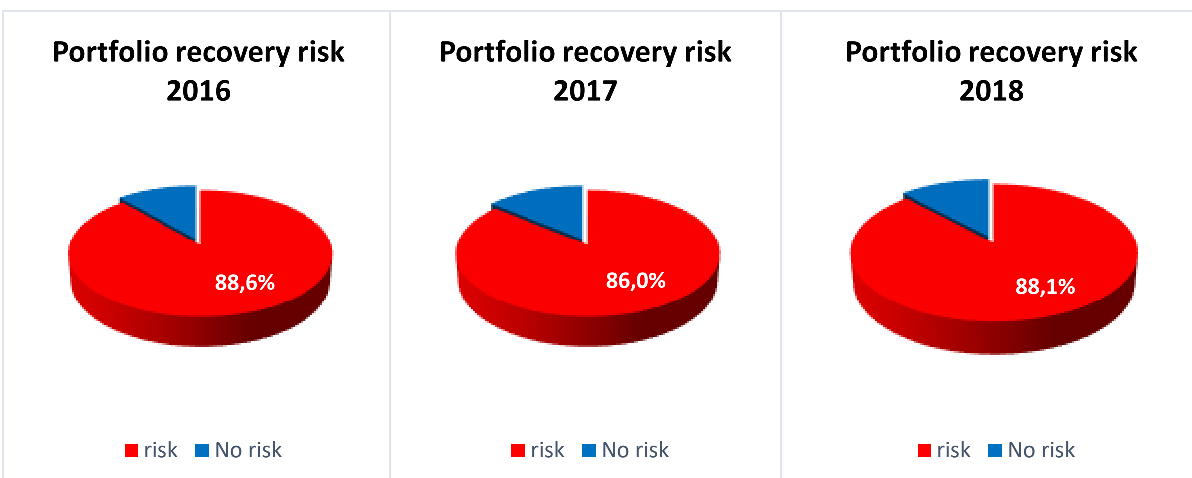
Graph 5. Indebtedness risk by sector.



Source: Author elaboration.

For the risk of indebtedness, the medians defined to determine risk values were 42% for the primary sector, 43% for the secondary sector, and 59% for the tertiary sector. The debt risk graph shows that the primary sector continued to be that with the lowest number of companies at risk, during 2016 and 2017. Approximately the same level of indebtedness remained, with a slight increase for 2018. This may be explained by the growth of the Peruvian economy, by 2.81%, in January of 2018, in accordance with figures from the National Institute of Statistics and Informatics (INEI). This result is associated with the favorable evolution of external demand, reflected in higher exports (13%), both of traditional (12.8%) and non-traditional products (13.5%). On analysis of the secondary sector, it was observed that, although the risk was higher than the primary sector, there was a stable trend throughout the three years of observation. Finally, in terms of the tertiary sector, this not only continued to have the largest number of companies exposed to risk, but also demonstrated slight growth year after year. This might be explained by Peruvian economic improvement, and the need for working capital to supply the demand. Likewise, it was determined that this increase was most likely due to the fact that the service sector, in the respective year, employed approximately 6.5 million workers, representing an increase of 3.6%.

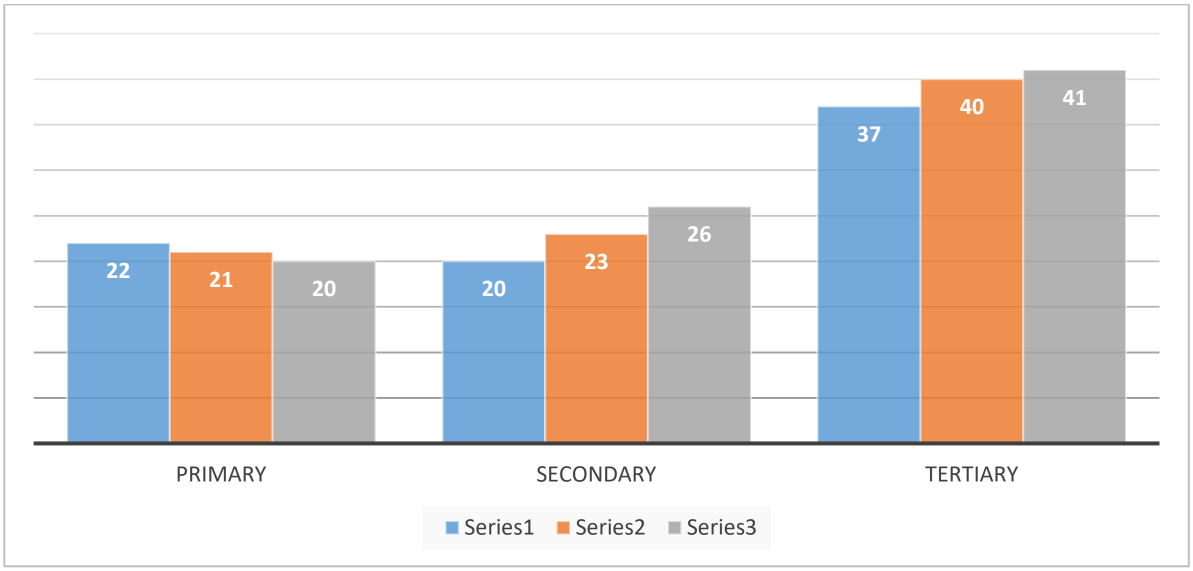
Graph 6. Portfolio recovery risk.



Source: Author elaboration.

As shown in the graphs for each year, the risk of portfolio recovery was high: for the three years under observation, it was above 80%. The years 2016 and 2018 had the highest number of companies at risk, and the above shows that Peruvian companies have managed their portfolios poorly in recent years. This is very risky because most companies collect in timeframess exceeding 60 days, but because this, in turn, affects liquidity and adds to their level of indebtedness by over 50%, and additionally compromises company capital adequacy.

Graph 7. Portfolio recovery risk by sector.



Source: Author elaboration.

Regarding the risk of portfolio recovery, the average values determining risk were 434 days, for the primary and secondary sector, and 545 days for the tertiary sector. As shown in the graph, the primary and secondary sectors showed the same trend in both numbers and behavior towards risk during the three years of observation, while the tertiary sector continued to be that with the most companies with risk. The data with which the different graphs herin were made indicate that most companies that belong to the tertiary sector form part of the financial services sector. Therefore, these companies' corporate purposes include the placement of resources to finance third parties, especially in the long term. This have skewed the results found. Were this the case, it would be recommended that said data be cleaned up, in order to specifically analyze short-term portfolio management in said type of organization (360 days), as well as the medium (1,800 days) and long term (7,200 days). The secondary sector increased, by 17 companies, from 2016 to 2017. The primary sector remained relatively stable.

Table 2. Risk type by sector.

SECTOR	PRIMARY			SECONDARY			TERTIARY		
TYPE OF RISK	**2016**	**2017**	**2018**	**2016**	**2017**	**2018**	**2016**	**2017**	**2018**
Indebtedness	10	11	12	25	20	23	58	63	62
%	30.30%	33.33%	36.36%	36.76%	29.41%	33.82%	31.69%	34.43%	33.88%
Liquidity	12	12	8	20	23	23	57	65	63
%	37.50%	37.50%	25.00%	30.30%	34.85%	34.85%	30.81%	35.14%	34.05%
Portfolio recovery	12	11	12	20	23	26	37	40	41
%	34.29%	31.43%	34.29%	28.99%	33.33%	37.68%	31.36%	33.90%	34.75%

Source: Author elaboration.

The table above compares the behavior of the types of risks in each economic sector for three consecutive years, and reflects the following:

- In the tertiary sector, all individual risks occurred in their highest numbers of risk for all years.
- The primary and secondary sectors maintained the risk trend during all years of observation.
- The primary sector presented the lowest percentage of companies with risk, especially for the year 2017, possibly due to the fact that commodity prices remained low that year, and that the Peruvian currency weakened against the dollar, resulting in a shortage of readily available sources of cash (both cash and committed lines of credit) to cover short-term debt maturities or free cash flow deficits.

Econometric testing and analysis

Following the risk analyses performed, the same data from model variables were used to apply a logit regression and various econometric tests that validate model fit, consistency, and goodness, as well as the hypothesis test. As tables A1, A2, and A3 show, all data from the study population were included in the model, and there were no missing cases.

Model fit can be evaluated, as shown in tables A4, A5, and A6. Therein, the model better and correctly classifies companies with financial risk by 99.1% for 2016, and 100% for 2017 and 2018. Likewise, the global percentage of company classification was 98.4% for 2016, and 99.5% for 2017 and 2018.

On the other hand, as compared to the analysis of the proposed hypothesis, tables A7, A8, and A9 show the results of the Wald significance test, which is less than 0.05 for the three years studied. This allows for the rejection of the null hypothesis for this study. On the other hand, in tables A10, A11, and A12, the bivariate analysis is shown, between predictive model variables, for which, in all cases, significance was less than 0.05, which confirms the rejection of the null hypothesis.

The Omnibus and chi square econometric tests also present appropriate significance for the three years studied. These show a model adjustment for the variables used (tables A13, A14, and A15). The Negelkerke econometric tests also yielded significance, with the exception of the Cox and Snell test, whose significance was slightly high for said three years. The model presents a good likelihood and fit of the model for the variables used (tables A16, A17, and A18).

With the Hosmer and Lemeshow tests, which are more exact tests of model goodness of fit, the predicted (expected) values were compared, by the model, with observed values. The null hypothesis of the Hosmer-Lemeshow test is that there are no differences between the observed and predicted values. The rejection of this test would indicate that the model was not well adjusted. The results shown in the table for those three years, in terms of the significance value, prompt acceptance of the test's null hypothesis, which confirms that the model fits the data well, in accordance with the test summary and 2x2 table, with greater precision in financial risk data (tables A19, A20, A21, A22, A23, and A24).

Finally, compared to the proposed model, the Wald test allowed for the determination that all the variables used were predictors of financial risk, thanks to the significances shown, with greater consistency, mainly during 2016, in the liquidity risk variable.

For the three years, the variable that showed the least favorable results, as compared to its prediction level, was indebtedness, as reflected in its significance (tables A25, A26, A27, and A28). Pearson's chi-square permitted rejection of the null hypothesis, since its value was less than 0.05, additionally it allowed for verification of the goodness of the model and the lack of discrepancy between the proposed and complete model. In turn, the plausibility test showed model goodness, which was appropriate, since all of the significances of the predictive variables were less than 0.05 (Table A29).

Discussion of results

Regarding the discussion of the results obtained, a possible consequence of the liquidity results may be due to the fact that inflation, during these years, in accordance with the Central Reserve Bank of Peru, with its economic studies management office, reached the the highest levels in twelve years. The CPI jumped from 125.72, in 2016, to 130.23, in 2018, possibly due to, among other causes, the rise in price of oil and basic foodstuffs, although unemployment remained, for said years at 4.5 %. There were also decreases in household consumption and an increase in the national production index by 5.27%, mortgage loans increased by 8.17%, and tax collection increased by 13.8%, etc.

The INEI (National Institute of Statistics and Informatics), in bulletin issue no. 01 in January of 2019, showed how the employment rate for the observation years remained at 93% levels, keeping the unemployment rate in one-digit indices.

It is evident that company values were impacted, depending on the level of financing incorporated (Hincapié, J, 2007). The indebted companies have a lower tax expense, caused by the subsidy of the payment of interest on the debt, an advantage that a company without debt does not have, so it is advantageous to incorporate it into the financing structures of the companies. This may be a reason for companies to present financial risk, since they take on debt, increase the percentage of debt in financial structures, but are exposed to the high rates presented by financial markets. This reduces the benefits of financial leverage and increases the likelihood that the business will be unviable.

Adequate strategic planning, including risk assessment, and especially financial risk, can in some way minimize exposure to excessive debt costs and risks.

Financial planning can be an essential tool for the achievement of objectives, the rational use of resources, and the ability to foresee different scenarios and strategies in the face of significant market uncertainty.

In the study, The Spanish Economic Crisis from 2007 (Ocon Galilea, 2013), it is concluded that the banking sector cannot grant credit and recapitalize at the same time, during periods of economic recession. For this reason, Spain is committed to the creation of organizations focused on bank restructuring and facilitation of company access to financial institutions. Latin American markets have presented relative stability in recent years, but this does not imply that they are not exposed to falls or sudden changes. As such, companies listed on the stock market must have the healthiest possible finances that would allow it, in cases of crisis, to access credits that reactivate their production and operations, as job generators, bearing in mind that the latter becomes one of the countries' priorities to overcome the crisis.

Regarding indebtedness, as one of the most important results of the present study, a possible cause may be the lags in the 2008 economic crisis, as a result of the so-called real estate bubble, where companies were able to drag the credits they accessed to reactivation. When considered that a large part of the listed companies are from the financial sector, indebtedness is an implicit part of their corporate purpose and will have affected that which occurred with financial institutions in Spain during said crisis, as "Financial entities, subject to high competition in attracting assets, offered considerable facilities to access mortgage loans" (Spanish Economic and Social Council, 2016).

In accordance with the above, in accordance with the economic report from the Lima Chamber of Commerce (Peñaranda, 2019) in 2018, the tertiary sector represented 60.5% of the total gross domestic product, where the largest participation in said sector consisted of financial entities. However, added to the above, it primarily represents 22.2% of the GDP, and presented a growth of 35% in the past decade. This could also explain the prevalence of the risk of indebtedness, because, as is well known in this sector, mining has important participation. It had an average annual advance of 3.7% during the study period, which requires significant financing for its exploration and operation. All of the above data is very much in accordance with the behavior of the sector in Latin America in accordance with statistical data from the Economic Commission for Latin America (CEPAL).

Therefore, companies, in the years following the crisis, may be considered to have maintained or dragged their levels of indebtedness, due to the need to reactivate and continue their operations.

Faced with the sector that presented the highest financial risk, behavior similar to that presented in studies carried out in the National Securities Market Commission of Spain was observed. There, financial risk was also more prevalent in the tertiary sector, and represented the highest percentage (Castañeda, 2019) said the director of the Institute of Economics and Business Development, who mentioned in their economic report, that in 2019, the tertiary sector represented 60.5% of the total product, with a high concentration of financial services. From the data taken from CMNV, it was determined that the sectors with the highest risk in portfolio recovery were banking, the service sector, as well as the industrial and energy sectors and was the risk with the most prevalence for Spanish companies, very similar to that found in the present study.

This may be related to that mentioned in the different situations. Their consequences have strongly affected the country's economy, and generated, in many companies, increases in employees and production, among other things, including the addition ofnew small and medium-sized companies in the market, a situation reflected in the growth of Peruvian industry, by 3.7% in 2018, despite a slight decrease during 2017, as mentioned (Arribas Barreas, Josa, Bravo Duran, Garcia Hiljding, & San Miguel Aguirre, 2016).

Conclusions and implications

This study provides a model that allows companies to analyze the sectors and levels of risk they face, and how they can anticipate decisions, and thus avoid adverse conditions. Companies in the region studied must be prepared for the introduction of new international regulations in the management of their operational risks, as these will have effects on credit costs and accessibility. As stated in the theory, higher bank capital requirements can translate to lower levels of credit.

It is further vital to understand that one of the main obstacles for companies to access the stock market are problems of asymmetry and lack of information, since, as is well known, the financial market has multiplied the supply of instruments for the provision of business service packages broader than just credit, and thus facilitate knowledge about the financial instruments available to companies, especially smaller companies. As such, this suggests that financial assistance should be accompanied by public policies, in order to favor the meeting of supply and demand, and to train companies in legal and financial matters.

It should be noted that listed companies must implement rigorous reviews of their financial structures, sources, and destinations of financing. It is relevant that entrepreneurs determine policies for their financial structure, because the financial risk they assume requires special care for its implementation, as there is a direct relationship of risk with the economic activities in which they are engaged. In order for companies to improve their risk outlook, they must know how financing sources are structured, and pay special attention to resources generated on their own account, as well as those obtained by third parties.

In relation to the results obtained, it is important to highlight that these allowed for the establishment that those companies listed on the Lima stock exchange presented financial risk for 2016, at 58% of the companies, for 2017, 61.7%, and for 2018, 60.1%. The most frequent individual risk was that of portfolio recovery, at above 80% throughout the three-year period. Additionally, taking the business classification presented by the Lima Stock Exchange as a reference, a sector analysis was carried out, in which it was possible to determine that the sector that presented the most companies with financial risk was the tertiary sector, with a participation of 60%, over the total number of companies and the individual risk of indebtedness being the one that companies presented the most, the above being a quite sensitive sector given its impact on the GDP and the generation of employment on the national level.

Based on the statistical tests carried out, the null hypothesis H_0 may be rejected (liquidity, indebtedness and the portfolio do not negatively influence company financial risk), and in turn, the results obtained are validated against financial risk. The above results provide companies with a tool for the analysis of financial risk, in order to encourage the use of tools for the management of non-systemic or operational risks, in order to allow them to improve decision-making and remain through time.

Finally, based on the results obtained, it is suggested that collection policies be improved. This can be done through the establishment of a clear regulation to debtors, granting benefits for prompt payment that allow for portfolio recovery, having funds for creditor payments, and that the terms granted to clients are in accordance with financial needs and costs. On the other hand, companies can reduce the risk of indebtedness by searching for new and better financing alternatives, opting for credit options with longer terms that offer more competitive rates, avoiding supplier credits, as they are more expensive, conducting analyses of financing costs, looking for portfolio coverage alternatives, such as repos or factoring, adopting financing policies that offer returns above financial cost, and adjusting financing payment cycles. Also, portfolio recovery must be less than financial payments.

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ANNEX: Statistical and econometric tests

Table A1. 2016 Case Processing Summary

Unweighted cases[a]		N	Percentage
Selected cases	Included in the analysis	193	100,0
	Lost cases	0	,0
	Total	193	100,0
Unselected cases		0	,0
Total		193	100,0

a. If weighting is in effect, see leaderboard for total number of cases.

Table A2. Case Processing Summary 2017

Unweighted cases[a]		N	Percentage
Selected cases	Included in the analysis	193	100,0
	Lost cases	0	,0
	Total	193	100,0
Unselected cases		0	,0
Total		193	100,0

a. If weighting is in effect, see leaderboard for total number of cases.

Table A3. Case Processing Summary 2018

Unweighted cases[a]		N	Percentage
Selected cases	Included in the analysis	193	100,0
	Lost cases	0	,0
	Total	193	100,0
Unselected cases		0	,0
Total		193	100,0

a. If weighting is in effect, see leaderboard for total number of cases.

Table A4. Classification 2016

			Predicted		
			RiskFinance		
Observed			,00	1,00	Percentage correct
Step 1	RiskFinance	,00	79	2	97,5
		1,00	1	111	99,1
	Overall percentage				98,4

The cutoff value is ,500

Table A5. Classification 2017

Observed			Predicted RiskFinance ,00	1,00	Percentage correct
Step 1	RiskFinance	,00	73	1	98,6
		1,00	0	119	100,0
	Overall percentage				99,5

a. The cutoff value is ,500

Table A6. Classification 2018

Observed			Predicted RiskFinance ,00	1,00	Percentage correct
Step 1	RiskFinance	,00	73	1	98,6
		1,00	0	119	100,0
	Overall percentage				99,5

a. The cutoff value is,500

Table A7. Variables in the 2016 equation

		B	Error estándar	Wald	gl	Sig.	Exp(B)
Step 0	Constant	,324	,146	4,936	1	,026	1,383

Table A8. Variables in the equation 2017

		B	Error estándar	Wald	gl	Sig.	Exp(B)
Step 0	Constant	,475	,148	10,297	1	,001	1,608

Table A9. Variables in the 2018 equation

		B	Error estándar	Wald	gl	Sig.	Exp(B)
Step 0	Constant	,410	,147	7,771	1	,005	1,506

Table A10. The variables are not in the 2016 equation

			Punctuation	gl	Sig.
Step 0	Variables	RiksLiquidity	88,729	1	,000
		RiskIndebtedness	118,335	1	,000
		RiskPortfolio	16,190	1	,000
	Global statistics		150,854	3	,000

Table A11. The variables are not in the equation 2017

			Punctuation	gl	Sig.
Step 0	Variables	RiksLiquidity	68,536	1	,000
		RiskIndebtedness	103,529	1	,000
		RiskPortfolio	29,137	1	,000
	Global statistics		148,532	3	,000

Table A12. The variables are not in the equation 2018

			Punctuation	gl	Sig.
Step 0	Variables	RiksLiquidity	69,226	1	,000
		RiskIndebtedness	107,707	1	,000
		RiskPortfolio	28,778	1	,000
	Global statistics		150,275	3	,000

Table A13. Omnibus tests of 2016 model coefficients

		Chi- square	gl	Sig.
Step 1	Step	238,763	3	,000
	Block	238,763	3	,000
	Model	238,763	3	,000

Table A14. Omnibus tests of model coefficients 2017

		Chi- square	gl	Sig.
Step 1	Step	248,652	3	,000
	Block	248,652	3	,000
	Model	248,652	3	,000

Table A15. Omnibus tests of 2018 model coefficients

		Chi- square	gl	Sig.
Step 1	Step	259,619	3	,000
	Block	259,619	3	,000
	Model	259,619	3	,000

Table A16. 2016 model summary

Step	Logaritmo de la verosimilitud -2	R square of Cox y Snell	R square of Nagelkerke
1	23,791[a]	,071	,055

a. La estimación ha terminado en el número de iteración 20 porque se ha alcanzado el máximo de iteraciones. La solución final no se puede encontrar.

Table A17. Summary of the 2017 model

Step	Logaritmo de la verosimilitud -2	R square of Cox y Snell	R square of Nagelkerke
1	8,314[a]	,072	,084

a. La estimación ha terminado en el número de iteración 20 porque se ha alcanzado el máximo de iteraciones. La solución final no se puede encontrar.

Table A18. 2018 model summary

Step	Logaritmo de la verosimilitud -2	R square of Cox y Snell	R square of Nagelkerke
1	,000[a]	,074	1,000

a. La estimación ha terminado en el número de iteración 20 porque se ha detectado un ajuste perfecto. Esta solución no es exclusiva.

Table A19. Hosmer and Lemeshow Test 2016

Step	Chi- square	gl	Sig.
1	,165	3	,983

Table A20. Hosmer and Lemeshow test 2017

Step	Chi- square	gl	Sig.
1	,000	3	1,000

Table A21. Hosmer and Lemeshow test 2018

Step	Chi- square	gl	Sig.

1	,000	3	1,000

Table A22. Contingency for the 2016 Hosmer and Lemeshow test

		RiskFinance = ,00		RiskFinance = 1,00		
		observed	expected	observed	expected	Total
Step 1	1	15	15,000	0	,000	15
	2	61	61,128	1	,872	62
	3	5	4,744	18	18,256	23
	4	0	,128	27	26,872	27
	5	0	,000	66	66,000	66

Table A23. Contingency for the Hosmer and Lemeshow test 2017

		RiskFinance = ,00		RiskFinance = 1,00		
		observed	expected	observed	expected	Total
Step 1	1	19	19,000	0	,000	19
	2	50	50,000	0	,000	50
	3	5	5,000	23	23,000	28
	4	0	,000	31	31,000	31
	5	0	,000	65	65,000	65

Table A24. Contingency for the 2018 Hosmer and Lemeshow test

		RiskFinance = ,00		RiskFinance = 1,00		
		observed	expected	observed	expected	Total
Step 1	1	19	19,000	0	,000	19
	2	50	50,000	0	,000	50
	3	5	5,000	23	23,000	28
	4	0	,000	31	31,000	31
	5	0	,000	65	65,000	65

Table A25. Variables in the 2016 equation

		B	Standard error	Wald	gl	Sig.	Exp(B)
Step 1[a]	RiksLiquidez	- 6,520	1,258	26,879	1	,000	678,830
	RiskEndeuda	23,626	0,7142	4,371	1	,049	493,033
	RiskCartera	22,487	0,703	7,400	1	,049	337,371
	Constant	26,737	2,303	10,000	1	,063	,000

a. Variables specified in step 1: Liquidity Riks, Debt Risk, Portfolio Risk.

Table A26. Variables in the equation 2017

		B	Standard error	Wald	gl	Sig.	Exp(B)
Step 1[a]	RiksLiquidez	- 3,954	3,438	18,50	1	,009	261,600
	RiskEndeuda	50,120	0,503	6,050	1	,011	830,000
	RiskCartera	36,206	0,752	8,350	1	,029	746,000
	Constante	47,025	2,195	11,00	1	,071	,000

a. Variables specified in step 1: Liquidity Riks, Debt Risk, Portfolio Risk.

Table A27. Variables in the 2018 equation

		B	Standard error	Wald	gl	Sig.	Exp(B)
Step 1[a]	RiksLiquidity	- 4,9 04	4,438	21,23	1	,002	231,600
	RiskIndebtedness	41,120	0,503	7,08	1	,071	394,000
	RiskPortfolio	33,456	0,752	8,13	1	,002	746,000
	Constant	57,025	2,188	9,09	1	,061	,000

a. Variables specified in step 1: Liquidity Riks, Debt Risk, Portfolio Risk.

Table A28. Goodness of fit 2016

	Chi- square	gl	Sig.
Pearson	,0295	2	,0090
Desvianza	,0549	2	,0069

Table A29. Likelihood ratio tests 2016

	Model fit criteria	Likelihood ratio tests		
Effect	Logarithm of the reduced model likelihood -2	Chi- square	gl	Sig.
Intersection	96,304	91,262	1	,000
RiksLiquidity	79,591	74,548	1	,000
RiskIndebtedness	115,032	109,989	1	,000
RiskPortfolio	42,567	37,525	1	,000

The chi-square statistic is the difference in log-likelihood -2 between the final model and the reduced model. The reduced model is formed by omitting an effect from the final model. The null hypothesis is that all the parameters of this effect are 0.