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The impact of macroeconomic variables on commercial credit defaults in Mexico

El impacto de las variables macroeconómicas en la morosidad del crédito comercial en México

David Conaly Martínez Vázquez[1*], Marissa R. Martínez-Preece[1], Angel Cuevas Romero[2]

[1]Universidad Autónoma Metropolitana, México
[2]Universidad la Salle, México

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Abstract

A fundamental element for the economic and social development of any country is to have a sound business sector supported by credit resources. The objectives of this research is to analyze which economic variables (inflation, exchange rate, level of economic activity, interest rate, unemployment and consumer confidence) have the greatest influence on business delinquency within the total commercial banking system in Mexico, and to estimate the relationship between delinquency and bank profitability. The above was determined using elliptical and Archimedean copulations, during the period from January 2003 to March 2023. The main results show that an increase in economic activity, interest rates and consumer confidence decreases business delinquency, while a rise in unemployment increases it. Likewise, an increase in corporate defaults leads to a decrease in bank profitability.

JEL Code: E44, G21, E52, C13
Keywords: credit delinquency; impact of macroeconomic variables; copulas

*Corresponding author.
E-mail address: davidconaly@icloud.com (D. C. Martínez Vázquez).
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Resumen

Un elemento fundamental para el desarrollo económico y social de cualquier país es contar con un sector empresarial sólido respaldado con recursos crediticios. Los objetivos de la presente investigación son analizar cuáles son las variables económicas (inflación, tipo de cambio, nivel de actividad económica, tasa de interés, desempleo y confianza del consumidor), que influyen en mayor medida en la morosidad empresarial dentro de la banca total comercial en México, y estimar la relación entre la morosidad y la rentabilidad de la banca. Lo anterior, se determinó utilizando cópulas elípticas y Arquimedianas, durante el período de enero de 2003 a marzo del 2023. Los principales resultados muestran que el incremento de la actividad económica, tasa de interés y la confianza del consumidor disminuye la morosidad empresarial y, por el contrario, un aumento en el desempleo la incrementa. Asimismo, un crecimiento de la morosidad de las empresas provoca una disminución en la rentabilidad bancaria.

Código JEL: E44, G21, E52, C13
Palabras clave: morosidad crediticia; impacto de variables macroeconómicas; cópulas

Introduction

Companies play a crucial role in the economic development of any economy and society. They generate employment and welfare that directly and indirectly affect all sectors of any country. Nevertheless, companies can be considered to have a deficit-causing nature, so they will always demand resources to cover their renewal and expansion activities. Nonetheless, in Latin America, particularly in Mexico, access to resources is limited for small and medium-sized companies.

The social and economic crisis caused by COVID-19 exposed failures in the business sector worldwide, shortages of materials, disruption of supply chains, and lack of contingency funds. On the social side, unemployment increased, and inflation rose, which affected the population's purchasing power. Regarding Mexico, in 2020, the economy suffered a contraction of its Gross Domestic Product of -8.3% compared to 2019, which had repercussions in multiple economic and social sectors of the country.

Based on information obtained from the 2021 National Survey of Business Financing (ENAFIN; Spanish: Encuesta Nacional de Financiamiento de las Empresas) of the National Institute of Statistics and Geography (INEGI; Spanish: Instituto Nacional de Estadística y Geografía) and the National Banking and Securities Commission (CNBV; Spanish: Comisión Nacional Bancaria y de Valores), it is estimated that in Mexico there is a high dependence, firstly, on bank credit by companies, which reaches an average of 67%, and secondly, on supplier credit with approximately 45.8%[1]. This dependence generates fragility in

[1] The percentage of the various sources of financing can add up to more than 100 percent, as companies use various sources of credit.

companies (particularly small ones) that resort to these sources of financing since they contract high-interest loans to cover their operating expenses.

Among the main obstacles faced by companies in Mexico are the lack or high cost of financing, excessive red tape, insecurity, and criminality (INEGI, 2021). From the 2019 Economic Census conducted by INEGI, it is estimated that there were approximately 4 800 157 private and state sector economic units in Mexico, which decreased by more than one million due to the COVID-19 pandemic (INEGI, 2019). This situation caused a massive closure of activities that fractured the international economic fabric; banks had to restructure their clients' debts and apply reorganization policies.

This research aims to analyze the degree of influence of some of the main macroeconomic-financial variables that affect commercial credit default in Mexican banks: inflation, exchange rate, level of economic activity, interest rate, unemployment, and consumer confidence.

To determine the above, elliptic and Archimedean copulas (Frank, Gumbel, and Clayton) were used during the period from January 2003 to March 2023, using monthly data. Likewise, 100 000 simulations were generated based on the dependence parameter of the proposed copulas to observe the distribution and behavior of the correlation between the variables and the default. The relation between default and bank profitability was also analyzed.

The relevance of this research lies in four aspects; first, to identify which variables have the greatest influence on commercial bank credit default in Mexico. Second, to propose a relatively recent methodology for estimating correlation/dependence in these phenomena since traditional techniques start from assumptions such as normality or linearity in the distribution of variables, which are unrealistic. Third, to analyze whether profitability in commercial banking in Mexico is related to corporate and government defaults. Fourth, the results could provide evidence to generate an economic policy proposal to support the business sector in times of crisis.

The development of this article is structured as follows: in the following section, there is a review of the literature where the most relevant studies on corporate credit defaults are presented, mainly in Latin America and Mexico. The methodology section describes the analytical methods used. The third section presents the empirical evidence, and finally, the conclusions and recommendations are presented.

Review of the literature

As a starting point, it was found in the literature that the behavior of economic-financial variables is closely linked to the performance of companies, especially to the payment of loans they request from banks. Noteworthy is the work of Beck *et al*. (2015), who analyzed a set of 75 banks worldwide during the decade from 2000 to 2010, demonstrating through dynamic panel data estimations that the variables

that most influence bank defaults are the increase in real Gross Domestic Product (GDP), the value of shares, changes in the exchange rate, and the interest rate on loans.

Among the studies conducted in Europe and Asia, Polat (2018) analyzed the default in banks in Turkey and Saudi Arabia during the period from 2000 to 2016, showing that the phenomenon of default affects the macroeconomic stability of the country and similarly, through the beta regression model, determines the sense in which the default is especially affected by variables such as GDP, inflation, unemployment, and exchange rate. Tatarici et al. (2020) analyzed the determinants of non-performing loans in the European Economic Community (EEC) from 2005 to 2027. Among the main variables are macroeconomic, banking, and governance indicators. Using a dynamic GMM model, it was determined that the deterioration of the macroeconomic environment directly affects the level of loan defaults.

In their research, Delgado and Saurina (2004) examined the relation between macroeconomic variables (change in GDP, interest rate, degree of indebtedness, financial burden, and the value of assets) and credit risk in Spain over 20 years using cointegration techniques. The results show an inverse relation of default and insolvency with GDP growth and a positive correlation with interest rates, but not in the long-run equilibrium relation with indebtedness and financial burden.

Pastory (2021) analyzed the main macroeconomic variables that influence non-performing loans in Tanzania, a country that has experienced an increase in the condition of its loans. The study was conducted using a regression model, showing that credit evaluation, privileged loans, and macroeconomic conditions such as interest rates and unemployment have a meaningful impact on the rate of non-performing loans. On the contrary, the exchange rate, inefficient credit supervision, and poor credit policy did not reflect a significant influence on default.

In Latin America, Rivas (2010) analyzes financial indicators and bank default using autoregressive vector models for Central America (Costa Rica, Salvador, Guatemala, Honduras, Nicaragua) and the Dominican Republic from January 1997 to December 2009. The results show that the non-performing loan portfolio is a relevant indicator in analyzing macro-financial stress in the region in the face of an economic-financial crisis. In this context, the author links default with distortions in inflation, the nominal interest rate, and the exchange rate, concluding that among the macroeconomic factors affecting the financial sector's non-performing loan portfolio are the health crisis caused by COVID-19, political decisions, tax payments, international agreements, and the price of oil; in the microeconomic sphere, the following stand out: clients, suppliers, and prices.

Loayza (2019) studied the factors that influence the compliance of loans granted to small and medium-sized enterprises (SMEs) in Arequipa (Peru) and found that the main ones are low interest rates as generators of higher profitability and commercial activity, as well as the use of microcredit to encourage the growth of enterprises. Meanwhile, Guillén and Peñafiel (2018) investigated, with time series models

(ARIMA) and monthly data during the period from February 2010 to March 2015, the evolution of default by target sector in Ecuador concerning different factors that explain it, among which are: money supply variables, gross domestic product (GDP), value of raw materials, wages, unemployment rate, inflation level, currency depreciation, interest rates, debt ratio, and disposable income.

Using econometric and panel data models, Aguilar et al. (2004) reviewed the relation between macroeconomic and microeconomic variables and default in the Peruvian banking system (analyzing the different segments of the portfolio). Among the main results, they found that combining both types of variables influences default. Following the economic theory, they show that the banking sector's profitability has an inverse behavior with the default, so that when the default increases there is a reduction in the banking sector's profitability.

In Mexico, the study by Banco de México (2020) examines the impact of economic-financial variables. Through a linear regression analysis, it examines the impact of economic-financial variables: annual variation of the Global Indicator of Economic Activity (IGAE; Spanish: Indicador Global de Actividad Económica), Consumer Confidence Index- (CCI)[2], wages, inflation, unemployment, interest rate, and exchange rate on the default rate of commercial banks in the housing, consumer, and commercial sectors. The results show that the commercial portfolio's default rate (IMOR; Spanish: Índice de Morosidad) tends to increase due to increased unemployment and the cost of financing (interest rate). The consumer IMOR rises when the cost of consumer goods and unemployment increase due to reduced economic activity. Moreover, the housing IMOR rises with higher unemployment rates and an economic slowdown.

The pertinence of this research in terms of the financial literature lies in the focused analysis of bank default and profitability in relation to the selected variables, as well as in the proposal of a relatively recent methodology for estimating this correlation between the variables under study since traditional techniques (Pearson's correlation, linear regression, Kendall's tau) for estimating these phenomena start from unrealistic assumptions that lead to overestimations or underestimations.

Methodology

The default in the bank's loan portfolio is a sign of deterioration in the credit quality of these institutions. Its effects are reflected in the need for debt restructuring for the borrower, higher collection costs for the banking/credit institution, and the requirement by regulatory agencies for more capital to cover the risk of

[2] This statistic represents the current situation and expectations of the surveyed population about the economy and their personal situation.

insolvency. All these aspects generate a reduction in bank profits. From an economic and social point of view, the increase in uncollectible payments (defaults) can generate a reluctance on the part of financial institutions to grant loans, as well as an increase in interest rates and restrictions for borrowers, which has repercussions on lower levels of investment by companies and a slowdown in economic growth.

The default rate was estimated as follows:

$$\text{Default Rate (IMOR)} = (\text{Past Due Portfolio} / \text{Total Portfolio}) * 100 \quad (1)$$

In the particular case of Mexico, commercial banks group in their portfolios various products: commercial credit, which is granted to companies, financial institutions, and government agencies; consumer credit, in the form of credit cards, personal loans, automobile loans, and payroll loans; and finally, mortgage loans.

On the other hand, the ratio of past-due loans to total bank loans shows the probability of default. The accounting indicators most commonly used to analyze profitability are the return on assets (ROA) and return on equity (ROE) ratios.

$$\text{ROA} = \text{Net Profit/Total Assets} \quad (2)$$

$$\text{ROE} = \text{Net Profit/Total Shareholders' Equity} \quad (3)$$

The ROA estimates the profit on the total assets of the company. The ROE represents the institution's profit concerning the members' contributions. The correlation that could exist between the commercial IMOR and the economic variables is essential since the increase in defaults due to the movement of the selected variables would reflect the effect that public policy has on company loans. Likewise, the IMOR, ROE, and ROA ratios analysis shows how corporate and government defaults affect (positively or negatively) bank profitability.

Correlation or dependence in economic, financial, and social variables has been widely analyzed in the economic-financial literature, as well as the repercussions of these phenomena on society. One of the traditional correlation models used to measure the influence of one variable on another is Pearson's correlation coefficient; nevertheless, this is not the most appropriate due to the assumptions it is based on: normality in the distribution of values, absence of outliers, and presence of periods of high volatility.

Pearson correlation coefficient

$$\rho = \frac{\text{Covariance}(x,y)}{\sigma_x \sigma_y} \tag{4}$$

Despite being one of the best-known and most widely used statistics to measure the correlation between random variables in the financial literature, Pearson's correlation coefficient is based on assumptions that are difficult to find in economic-financial phenomena, such as the absence of outliers, linearity, and homoscedasticity[3]. The possible values of $-1 \leq \rho \leq 1$ only return a number that does not describe the dependence structure of the analyzed values.

Kendall's rank correlation coefficient tau (τ)

Kendall's rank correlation coefficient tau (τ) is defined in terms of the concordance of pairs of variables, where these are independent and must be analyzed on ordinal or interval scales.

$$\tau = \frac{\text{number of concordant pairs} - \text{number of discordant pairs}}{\frac{n(n-1)}{2}} \tag{5}$$

where n is the number of pairs y-$1 \leq \tau \leq 1$. The assumptions from which it starts are that pairs of observations are independent of each other, that two variables must be measured on an ordinal, interval, or ratio scale, and that there is a monotonic relation between them.

Copulas

Traditional methods for estimating the correlation between random variables assume a certain distribution of observations. Therefore, one of the fundamental objectives of this research is to incorporate a relatively new methodology for estimating this phenomenon, the copula theory. A copula is a multivariate distribution function with certain characteristics, whose marginals are uniformly distributed $U_i \sim U(0,1)$, with i=1,2,..., d. Some of the particularities of these functions are the following:

i) $C(u_1, u_2, \ldots, u_d)$ has an increasing behavior for each u_i.

[3] Property of random variables that have constant finite variance over time.

ii) $C(1, 1 \dots u_i, 1, \dots, 1) = u_i$

(iii) For all values $(a_i, \dots, a_d), (b_i, \dots, b_d) \in [0,1]^d$ with $a_i \leq b_i$, the following is observed:

$\sum_{i_1=1}^{2} \dots \sum_{i_{d=1}}^{2} \dots (-1)^{i_1+i_2+\dots+i_d} C(u_{1i}, u_{2i2}, \dots, u_{did}) \geq 0$, where $u_{j1=a_j}$ y $u_{j2=b_j,}$ for all values

$$j \in \{1,2, \dots, d\}$$

iv) For each $C(u_1, u_2, \dots u_d)$ there are limits:

$$\max\left\{\sum_{i=1}^{d} u_i + 1 - d, 0\right\} \leq C(u) \leq \min\{u_1, u_2, \dots, u_d\}$$

The limits of (iv) are known as the Frechet limits. Any function possessing these characteristics will be called a copula. The theoretical foundation of these mathematical structures was developed from Sklar's theorem (1959), which, in general terms and from the etymological origin of the word copula, *copulae*, joins several marginal distribution functions and generates a joint distribution function. Unlike traditional methods, these mathematical functions make generating a whole dependence structure possible, not just a number that often does not show the real relation between the variables.

Sklar's theorem

Starting from an n-dimensional distribution function, F, with continuous marginal distribution functions $F_1, \dots, F_n$, there exists a unique n-copula, $C: [0,1]^n \rightarrow [0,1]$, such that:

$$F(X_1, \dots, X_n) = C\,(F_1(X_1), \dots, F_n(X_n)) \tag{6}$$

Thus, the copula "C" joins or couples the marginals to generate a joint multivariate distribution function.

There are several types of copulas; among the main and most used ones in the economic-financial sector are the elliptic and the Archimedean families. In the former are the normal copula and the t-student copula, both of which owe their name to the probability distribution implicit in them, the normal distribution and the t-student. In general, the normal copula does not capture tail dependence in extreme events due to its distribution, unlike the t-student, which captures the probability in this distribution area.

Normal copula

The d-dimensional normal or Gaussian copula is constructed from the multivariate standard Normal distribution $\Phi_d, N(0, P)$, with P correlation matrix and Φ^{-1} the inverse of the standard univariate normal distribution.

$$C(u_1, \dots, u_d, P) = \Phi_d[\Phi^{-1}(u_1), \dots, \Phi^{-1}(u_d)] \tag{7}$$

In the case d = 2, bivariate copula, with correlation matrix ρ, its density is:

$$C(u_1, u_2, P) = \Phi_2[\Phi^{-1}(u_1), \Phi^{-1}(u_2)] = \frac{1}{\sqrt{\det\rho}} \exp\left(-\frac{1}{2} z^t(u)(\rho^{-1} - Id)(z(u))\right) \tag{7.1}$$

$$\text{With } z^t(u) = \Phi^{-1}(u_1), \Phi^{-1}(u_2) \tag{7.2}$$

T-student copula

In the t-Student copula, the correlation is determined by the multivariate t-Student distribution. In the bivariate case, a 2-dimensional t-Student distribution with v degrees of freedom and with correlation matrix ρ, the copula is:

$$C(u_1, u_2) = T_{2,\rho,v}[T_v{}^{-1}(u_1), T_v{}^{-1}(u_2)] \tag{8}$$

With t-Student copula density

$$C(u_1, u_2) = \frac{1}{\sqrt{\det\rho}} \frac{\Gamma\left(\frac{v+2}{2}\right)[\Gamma(\frac{v}{2})]^{2-1}}{[\Gamma(\frac{v+1}{2})]^2} \frac{\prod_{k=1}^{n}(1 + \frac{zk^2}{v})^{\frac{v+1}{2}}}{(1 + \frac{z^t\rho^{-1}z}{v})^{\frac{v+2}{2}}} \tag{8.1}$$

$$\text{With } z^t(u) = (T_v^{-1}(u_1), T_v^{-1}(u_2)) \tag{8.2}$$

The determination of the t-Student copula is a function of two parameters: the correlation matrix ρ and the degrees of freedom v.

Another family of copulas commonly used in economic-financial analysis is the Archimedean, notably the Frank, Clayton, and Gumbel copulas, which are specific mathematical functions with particular properties. These copulas are distinguished by their capacity and ease of estimation for modeling dependence in heavy-tailed variables and their flexibility in modeling correlation. The Frank

copula has similar characteristics to the normal copula in that it does not capture the probability of extreme events; it is a copula that tests the central behavior of the distribution. On the other hand, the Clayton and Gumbel copulas capture left and right tail dependence respectively to a greater extent.

Clayton copula

Within the family of Archimedean copulas, the Clayton copula is determined by the following expression:

$$C_\theta(u_1, u_2) = (u_1^{-\theta} + u_2^{-\theta} - 1)^{\frac{-1}{\theta}} \tag{9}$$

where the domain is (-1, ∞) \{ 0} . In this copula, perfect dependence occurs when $\theta \to +\infty$, and conversely it tends to independence when $\theta \to 0$. Thus, it enables capturing the left-tailed dependence.

Frank copula

Frank copulation is represented:

$$C_\theta(u_1, u_2) = -\frac{1}{\theta} \ln\left(1 - \frac{(1-e^{\theta u_1})(1-e^{\theta u_2})}{1-e^{\theta}}\right) \tag{10}$$

where $\theta \in (-\infty, \infty)\backslash\{0\}$, this copula does not capture tail dependence.

Gumbel copula

The Gumbel copula representation is:

$$C_\theta(u_1, u_2) = \exp\left(-\left[(-\ln(u_1))^\theta + (-\ln(u_2))^\theta\right]^{\frac{1}{\theta}}\right) \tag{11}$$

where $\theta \in [1, \infty)$. This copula shows perfect dependence when $\theta \to +\infty$ and independence when $\theta = 1$.

Kendall's τ correlation parameters regarding the selected copulas are expressed in Table 1.

Table 1
Kendall's τ parameter in terms of the copula

Copula	Kendall's τ
Normal/Gaussian	$\frac{2}{\pi}\arcsen(\theta)$
t-Student	$\frac{2}{\pi}\arcsen(\theta)$
Clayton	$\frac{1}{2\theta+1}$
Frank	$1-\frac{4}{\theta}+\frac{4}{\theta^2}\int_0^{\theta}\frac{x}{e^x-1}dx$
Gumbel	$1-\frac{1}{\theta}$

Source: created by the author

Pseudo-maximum likelihood method

There are several ways to estimate the copula parameters. The Pseudo-Maximum Likelihood method has been selected in the present investigation for its practicality and easy estimation. Knowing the marginal F_1, I, F_d, pseudo-observations $(\widetilde{U}i_1, \widetilde{U}i_2)$ are generated, with the function to be maximized being:

$$\theta = \sum_{i=1}^{n} \ln\left(U_{I,n}\right) \tag{12}$$

Unlike the maximum likelihood method, this estimation technique is the most widely used due to the simplicity of the calculations.

Goodness of fit

Once the parameters of the selected copulas have been estimated, an important step to follow is the determination of the copula that best fits the variables; among the most common methods are the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC).

Akaike Information Criterion (AIC)

$$\text{AIC}=-2\ln\left(\hat{\theta}\right)+2k \tag{13}$$

where ln, max is the natural logarithm of the function that maximizes the parameter vector, and k is the total number of marginals and parameters of the copula (Hofert *et al*., 2019).

Bayesian Information Criterion (BIC)

This criterion is another goodness-of-fit measure, which considers the sample size, unlike AIC.

$$\text{BIC}= -2\log(\hat{\theta}) + k\log(n) \tag{14}$$

where $\log(\hat{\theta})$ is the logarithm of the function that maximizes the vector of parameters in the sample size, and k, as in AIC, the number of estimated parameters. In both statistics, the smaller the value, the better the fit.

Tail dependency

This statistic enables the calculation of the probability of occurrence of an extreme event, i.e., in the tails of the distribution. Within the elliptic family, the normal copula, due to the symmetry of its distribution, does not capture this phenomenon, unlike the t-Student copula. In the case of the Archimedean family, the Clayton (left dependence) and Gumbel (right or positive) copulas do. On the contrary, the Frank copula has no dependence on the tails.

Table 2
Tail dependence parameter λ in terms of the copula

Copula	λ_u	λ_l
Normal/Gaussian	$\lambda = 2 \lim_{y\to\infty} \Phi\left(\frac{y-\theta y}{\sqrt{1-\theta^2}}\right) = 0$	$\lambda = 2 \lim_{y\to\infty} \Phi\left(\frac{y-\theta y}{\sqrt{1-\theta^2}}\right) = 0$
t-Student	$\lambda = 2\, t_{\nu+1}\left(-\sqrt{\frac{(\nu+1)(1-\theta)}{1+\theta}}\right)$	$\lambda = 2\, t_{\nu+1}\left(-\sqrt{\frac{(\nu+1)(1-\theta)}{1+\theta}}\right)$
Clayton	0	$2^{-\frac{1}{\theta}}$
Frank	0	0
Gumbel	$2-\frac{2}{1\theta}$	0

Source: created by the author

Copula rotation

The rotation of some copulas is a common practice in estimating dependence or correlation parameters of economic-financial variables. As Ruiz (2021) explains, this phenomenon is because some copulas capture

exclusively positive correlation; nevertheless, if the relation between the variables under study is negative, it is possible to apply a rotation of the axes without altering the estimation. For further discussion, see Li, F. and Kang, Y. (2018) and Durrleman *et al*. (2000).

Empirical evidence

The study of the influence of economic variables on the default of total commercial banks in Mexico is based on the selection of variables from January 2003 to March 2023; this information was obtained from different sources. The default rate (IMOR), the return on assets (ROA), and the return on invested capital (ROE) indicators, as well as the interest rate, are from the monthly reports of the National Banking and Securities Commission (2023). The monthly variation of inflation from the Bank of Mexico (2023) concerning the exchange rate was calculated using logarithmic differences, and the information was extracted monthly from Yahoo Finance. Regarding the Global Indicator of Economic Activity (IGAE), the unemployment rate (seasonally adjusted) and the Consumer Confidence Index (CCI) were obtained from the National Institute of Statistics and Geography (2023).

It is important to consider that the total commercial loan portfolio comprises financing granted to businesses, financial institutions, and governmental entities, with the first two comprising a greater proportion of this portfolio, as seen in Figure 1.

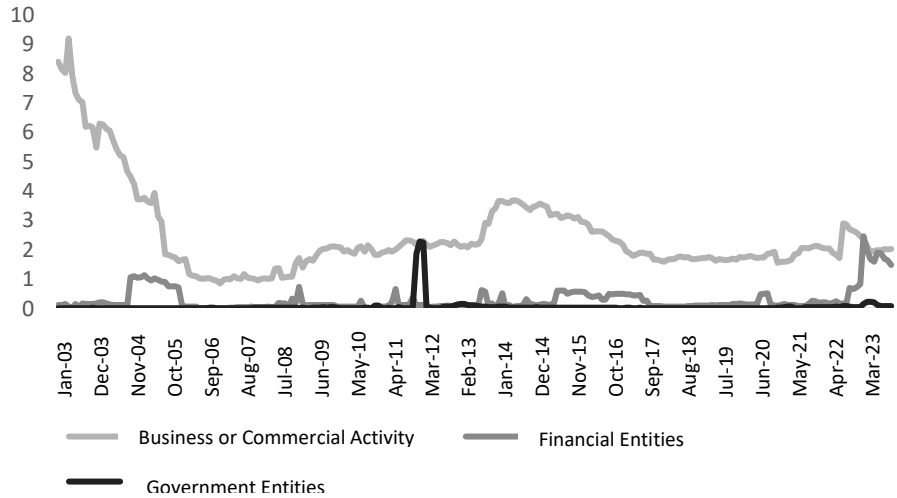

Figure 1. Composition of the total commercial loan portfolio in Mexico
Source: created by the author with information from CNBV (2023)

Table 3
Correlation via copulas of selected variables

IMOR Commercial vs	Family	Copula	Parameter	Log. Lik.	AIC	BIC	t-Kendall	Upper TD	Lower TD
Inflation	Elliptical	Normal	-0.0600	0.4000	1.2000	4.6900	-0.0400	0.0000	0.0000
		t	-0.0600	0.3540	3.2920	10.2790	-0.0400	0.0630	0.0630
	Archimedian	Gumbel rotated 270 degrees	-1.0200	0.1600	1.6700	5.1700	-0.0200	0.0000	0.0000
		Clayton Rotated 90 degrees	-0.0700	0.4100	1.1800	4.6700	-0.0300	0.0000	0.0000
		Frank	-0.4600	0.7100	0.5800	4.0700	-0.0500	0.0000	0.0000
Exchange Rate Return	Elliptical	Normal	0.0700	0.6300	0.7400	4.2300	0.0500	0.0000	0.0000
		t	0.0800	0.5595	2.8809	9.8670	0.0500	0.0873	0.0873
	Archimedian	Gumbel	1.0200	0.1400	1.7200	5.2200	0.0200	0.0300	0.0000
		Clayton Survival	0.0500	0.2300	1.5400	5.0300	0.0300	0.0000	0.0000
		Frank	0.0520	0.9600	0.0700	3.5600	0.0600	0.0000	0.0000
IGAE	Elliptical	Normal	-0.1700	3.3900	-4.7800	-1.2900	-0.1100	0.0000	0.0000
		t	-0.1300	4.5500	-5.1100	1.8800	-0.0800	0.0557	0.0557
	Archimedian	Gumbel rotated 270 degrees	-1.1700	12.2800	-22.5600	-19.0700	-0.1500	0.0000	0.0000
		Clayton Rotated 90 degrees	-0.4500	15.5400	-29.0700	-25.5800	-0.1800	0.0000	0.0000
		Frank	-0.5100	0.8500	0.2900	3.7800	-0.0600	0.0000	0.0000
Interest rate.	Elliptical	Normal	-0.5900	48.5400	-95.0900	-91.5900	-0.4000	0.0000	0.0000
		t	-0.5900	48.3000	-92.6000	-85.6100	-0.4000	0.0000	0.0000
	Archimedian	Gumbel rotated 90 degrees	-1.6100	45.5800	-89.1700	-85.6700	-0.3800	0.0000	0.0000
		Clayton Rotated 270 degrees	-0.9700	44.1600	-86.3200	-82.8300	-0.3300	0.0000	0.0000
		Frank	-4.7600	58.7700	-115.5400	-112.0400	-0.4400	0.0000	0.0000
Unemployment	Elliptical	Normal	0.3200	10.3000	-18.6000	-15.2700	0.2100	0.0000	0.0000
		t	0.3200	9.0300	-14.0600	-7.3900	0.2100	0.1987	0.1987
	Archimedian	Gumbel Survival	1.2200	7.1200	-12.2500	-8.9100	0.1800	0.0000	0.2400
		Clayton	0.3900	6.9000	-11.7900	-8.4600	0.1600	0.0000	0.1700
		Frank	2.2100	14.1500	-26.3000	-22.9700	0.2300	0.0000	0.0000
Consumer Confidence Index (CCI)	Elliptical	Normal	-0.2100	4.4300	-6.8500	-3.5200	-0.1400	0.0000	0.0000
		t	-0.2000	3.4200	-2.8400	3.8200	-0.1300	0.0350	0.0350
	Archimedian	Gumbel rotated 90 degrees	-1.1700	6.8700	-11.7500	-8.4200	-0.1400	0.0000	0.0000
		Clayton Rotated 270 degrees	-0.4100	10.9500	-19.9000	-16.5700	-0.1700	0.0000	0.0000
		Frank	-0.9300	2.6300	-3.2500	0.0800	-0.1000	0.0000	0.0000

Source: created by the author

Once the parameters of each copula have been estimated, it can be observed in Table 3 that, in most cases, the copulas that best fit the correlation phenomenon of the selected variables were the Frank and Clayton copulas of the Archimedean family. In the specific case of the commercial IMOR vs. inflation, the Frank copula presents a copula parameter of -0.46, $\tau = -0.0500$, log-likelihood of 0.71, and based on the goodness-of-fit criteria AIC of 0.580 and BIC=4.070. This is relevant and consistent with economic theory, particularly the business cycle. During the study period, the highest monthly inflation was 1.7 in January 2017, but it generally remained controllable. Nevertheless, it is important to note that several situations may arise when there is an increase in inflation (which is a phenomenon related to the supply and demand of goods and services).

If there is an increase in inflation, production costs will increase for companies, making it more difficult for them to repay their loans because they require more resources to produce. On the other hand, if there is an increase in the prices of goods and services above the product's value to the end customer, it will affect their purchasing power and could result in lower sales.

On the other hand, in periods of high inflation, two scenarios can occur: if the debt is contracted at a fixed rate, it could be easier for companies to pay their debts, but if the rate is variable, the central bank would modify the reference interest rate to control the flow of money in the economy, which would make credit more expensive (Samuelson *et al*., 2010). Concerning the fit of this copula, it is worth noting, following Llorens (2017), that the Frank copula captures positive or negative dependence but not dependence in the tails (extreme events), as well as the fact that it is radially symmetric, similar to the Normal and t-Student copulas.

Regarding the variation in the exchange rate return, the copula that presented the best fit is likewise the Frank copula with a parameter of 0.520, $\tau = 0.0600$, log-likelihood of 0.960, AIC of 0.070, and BIC of 3.560; the highest return observed was 0.1899 in March 2020 and the lowest in May of the same year, exactly in the most critical year of the pandemic.

From the point of view of the company's activity, variations in exchange rate return can impact several aspects. If companies have loans in foreign currency and the domestic currency depreciates, paying off their loans will be more difficult. On the other hand, if the company uses imported inputs to manufacture its products or services, and the domestic currency loses value, it will also generate losses, especially if it cannot pass on this cost to the consumer price, and in doing so would lose competitiveness (Krugman *et al*., 2016). Beck *et al*. (2015) show that the relation of this variable regarding default depends on the extent of foreign currency loans to borrowers who do not have a hedge against this risk, which is common in countries with a fixed exchange rate.

Business defaults relative to the Global Indicator of Economic Activity (IGAE) are closely linked to the economic cycle. From a statistical point of view, the copula that presented the best fit was

the Clayton copula with parameters -0.450, $\tau = -0.180$, log-likelihood of 15.540, AIC= -29.07, and BIC=-25.58. This represents an inverse relation between IGAE and corporate defaults in banking.

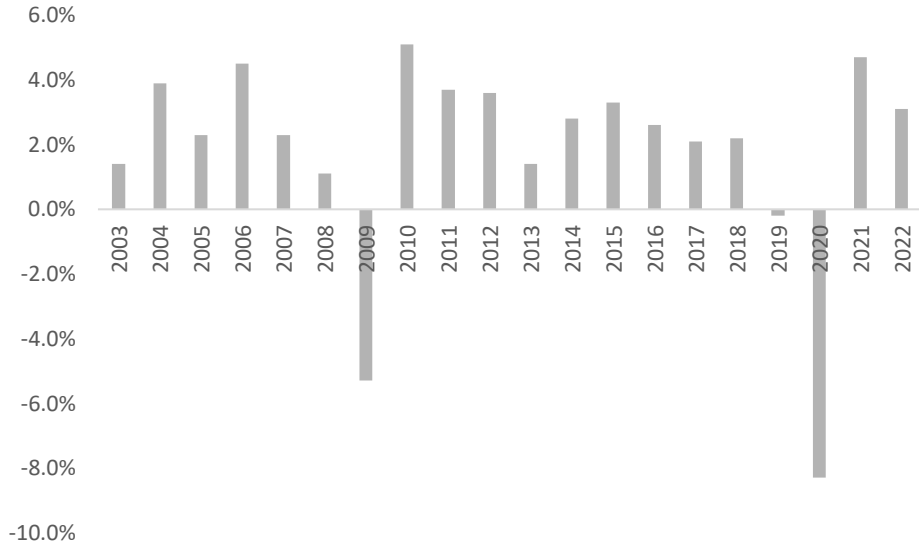

Figure 2. GDP in Mexico
Source: created by the author with information from the Bank of Mexico (2023)

During the economic expansion stage, companies use more factors of production, employment increases, and therefore inflation tends to increase. In the case of Mexico, there was a contraction of the economy during the pandemic, and therefore, unemployment increased, but in addition to this, there was an inflationary phenomenon at an international level. With the reactivation of the economy and the elimination of the social distancing measures, the economy recovered, generating growth in employment and the economy. This information is consistent with the results of Beck *et al*. (2015) and Bykova and Pindyuk (2019), which show an inverse relation between GDP and credit defaults.

Regarding the variable interest rate and default within commercial credit in Mexico, the copula that best fits the distribution of the data is the Frank copula of the Archimedean family, with a parameter of -4.76, $\tau = -0.44$, log-likelihood of 58.77, AIC= -115.540, and BIC=-112.0400. This is due to several factors; among them, the fact that there is an increase in the interest rate will generate a disincentive for the commercial sector (Business and Government) to borrow due to the higher cost of debt, so they will have a more conservative position when borrowing and this will cause a lower default level.

On the other hand, the interest rate has been the monetary policy mechanism to control inflation and improve the country's economic stability. Therefore, if the interest rate is increased, it is a sign of

economic control and stability, which, in economic terms, provides greater certainty and confidence in economic activity and the payment of loans. In contrast, a reduction in the interest rate would cause credit to become cheaper and increase effective demand, leading to greater use of resources, greater business activity, and consequently a reduction in defaults (Levy, 2012).

Unemployment and default are positively related and consistent with economic theory (economic cycle) and the national context. If unemployment increases, corporate defaults will increase. Nkusu (2011) shows that unemployment is positively related to defaulted loans (if unemployment increases, there is an increase in defaults), directly impacting the performance of companies and the entire economy. Without employment, it is more difficult for people to meet their responsibilities, consumption of goods and services is reduced, and economic activity slows down. Similarly, Ciukaj and Kil (2020) arrive at similar results supported by previous studies, showing a positive relation between unemployment and default. The best fitting copula for the unemployment variable is the Frank copula, with a parameter of 2.21, log-likelihood 14.15, τ =0.2300, AIC of -26.300, and BIC of -22.970.

Finally, the Consumer Confidence Index (CCI) is a statistic generated from the average of several indexes that consider respondents' current and expected situation regarding the economy and the financial situation of individuals. An inverse relation is observed with defaults in Mexico's commercial sector. The best fitting copula was the Clayton with parameter -0.41, τ= -0.17, Log. Lik. 10.95, AIC of -19.90, and BIC of -16.57.

Figure 2 shows a trend toward a slowdown of the Gross Domestic Product in the period under analysis; as there is a decrease in economic activity, unemployment tends to increase, and therefore the payment capacity of companies decreases (as there is higher unemployment, this causes lower demand for goods and services to companies and in general in the economy). This is mainly due to two aspects: first, if there are positive expectations of the population about their current and future situation, there will be a trend toward increased spending and investment on the part of families, generating greater income for the business sector. Secondly, for this sector, if there are positive expectations about the economy's future, decisions will be made for greater investment and growth, which will generate a general growth of the economy.

If, on the contrary, this index decreases, it would represent that the population has expectations of a slowdown or economic difficulties, which would cause a decrease in spending, and consequently, companies would be affected in their income and, therefore, in the payment of their loans and investments.

Table 4
Correlation of profitability vs. default

IMOR Commercial vs	Family	Copula	Parameter	Log. Lik.	AIC	BIC	t-Kendall	Upper TD	Lower TD
ROA	Elliptical	Normal	-0.6000	52.1400	-102.2800	-98.7900	-0.4100	0.0000	0.0000
		t	-0.5600	63.5600	-123.1100	-116.1300	-0.3800	0.0061	0.0061
	Archimedian	Gumbel rotated 90 degrees	-1.7400	62.6200	-123.2300	-119.7400	-0.4300	0.0000	0.0000
		Clayton rotated 270 degrees	-1.2800	59.4300	-116.8500	-113.3600	-0.3900	0.0000	0.0000
		Frank	-3.9900	40.8400	-79.6800	-76.1800	-0.3900	0.0000	0.0000
ROE	Elliptical	Normal	-0.5900	50.1500	-98.3000	-94.8000	-0.4000	0.0000	0.0000
		t	-0.5100	56.9800	-109.9500	-102.9700	-0.3400	0.0056	0.0056
	Archimedian	Gumbel rotated 90 degrees	-1.7500	67.1200	-132.2400	-128.7500	-0.4300	0.0000	0.0000
		Clayton rotated 270 degrees	-1.5000	73.3300	-144.6700	-141.1800	-0.4300	0.0000	0.0000
		Frank	-3.5500	35.0600	-68.1300	-64.6300	-0.3500	0.0000	0.0000

Source: created by the author.

Regarding bank profitability concerning commercial default, Table 4 shows that ROA and ROE present an inverse relation relative to the default of the commercial loan portfolio. In the case of commercial default vs. ROA, this presented a better fit with the Gumbel copula of parameter -1.740, Log. Lik. 62.62, AIC of -123.230, and BIC of -119.74, the τ= -0.4300. On the other hand, in the case of ROE, the best fitting copula was Clayton, with a parameter of -1.5, Log. Lik. 73.33, AIC of -144.670, and BIC of -141.180, the τ= -0.430. The above is consistent with economic theory and the lending institutions' activity due to various factors.

Heredia and Torres Vílchez (2019) and Braco and Alva (2022) show an inversely proportional correlation between non-payment and the profitability of savings and loan banks. First, as bad loans (defaults within the portfolio) increase, banks must restructure borrowers' debts, affecting their expected revenues and profit margin. Similarly, the fact that commercial loans are not covered generates recovery and collection costs for these institutions. With an impact of equal magnitude, the growth of the past-due portfolio generates a deterioration in the credit quality of these institutions, which has an impact on the risk perceived by investors and restrictions by the National Banking and Securities Commission (as regulatory agent), as well as minimum capital requirements for possible losses due to non-payment by borrowers.

Simulation

From the estimated parameters of the selected copulas, 100 000 simulations of their correlation behavior were generated; the results are shown in Figure 3.

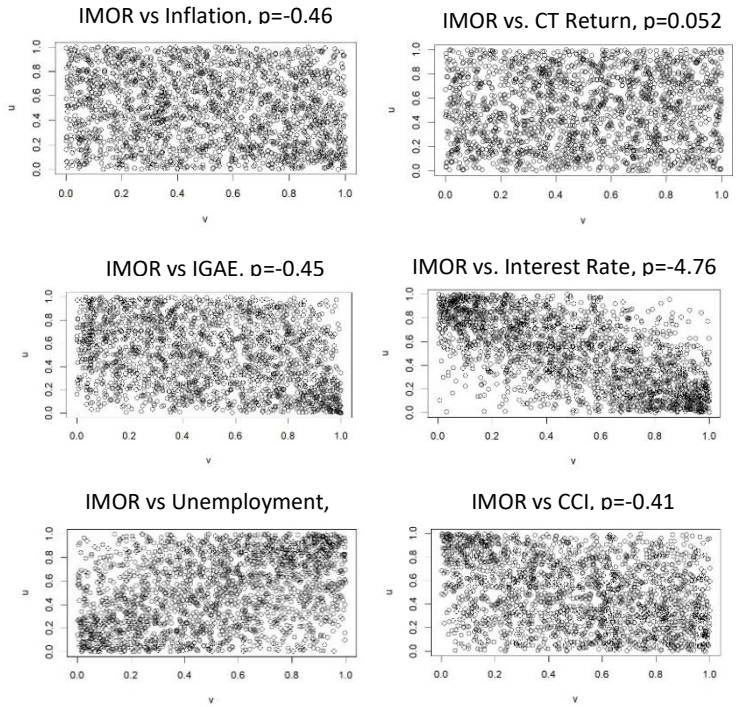

Figure 3. IMOR Business Simulation vs. selected variables
Source: created by the author

The previous graphs show that the variables with the highest correlation with commercial bank defaults in Mexico are the IGAE with an inverse relation (decreasing trend of the simulated observations), the interest rate with a negative correlation, unemployment with a positive correlation, and the CCI with a decreasing trend due to the negative correlation. On the other hand, regarding inflation and the exchange rate, the dispersion of the points is observed to be more homogeneous (as a result of the low correspondence in the study period).

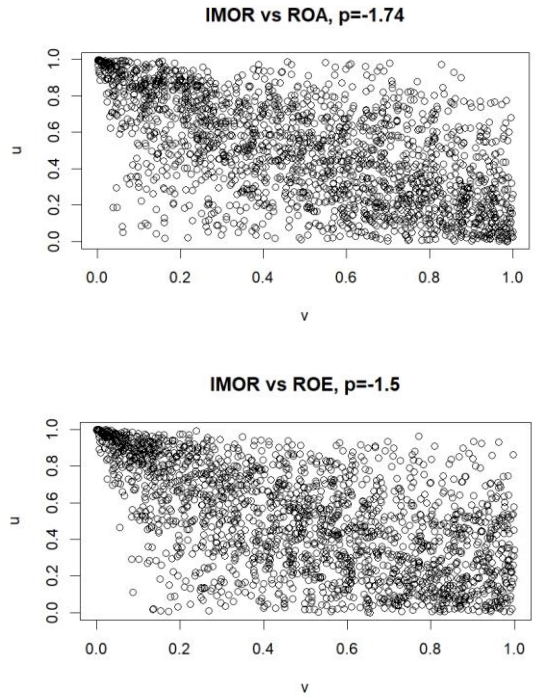

Figure 4. Business IMOR vs. ROA and ROE Simulation
Source: created by the author

Regarding default and its relation with profitability, the simulation of the observations, based on the parameter of the selected copulas, shows an inverse relation, which is related to the theory and analysis carried out in previous sections. In general terms, the increase in non-payment within the banks' loan portfolio generates a deterioration of their credit quality and a higher capital requirement by the regulatory agents due to the risk of bank and financial runs. Likewise, the collection costs and losses of these institutions increase.

Conclusions

The analysis of commercial credit defaults in Mexico shows that the Global Indicator of Economic Activity (IGAE), unemployment, the Consumer Confidence Index (CCI), and the interest rate influence commercial credit defaults most. These results are consistent with economic theory. On the one hand, the IGAE and default have an inverse correlation since companies use more production factors during the economic expansion stage and increase employment and the price of goods and services (inflation). This

is also present in the relation between inflation and default, which have a negative correlation (supported by the economic literature).

Concerning interest rates and defaults, these have an inverse relation; higher interest rates discourage indebtedness for both companies and the government due to the increased cost of debt, which promotes a more cautious approach to borrowing, resulting in lower defaults. In addition, interest rate increases are used as a monetary policy tool to control inflation and improve economic stability, which transmits confidence and certainty in economic activity and loan repayment.

As for the exchange rate and default, a very low correlation was demonstrated since, from the point of view of the type of companies (importing or exporting), the variations in the exchange rate may affect different aspects. If the companies have credits in foreign currency, it will be more difficult for them to pay their loans. If, on the contrary, they are importers or use raw materials for export, it will also generate losses for them. Regarding unemployment and default, there is a positive relation since as unemployment increases, there will be a lower demand for goods and services to companies and this will slow down the whole economy, making it difficult to pay loans.

Finally, the Consumer Confidence Index (CCI) and default show an inverse relation since, if there are positive expectations in the present and toward the future in people's financial income, this will generate greater spending and an increase in company investment.

This is relevant for both economic and financial theory since, according to the four aspects or objectives of this research, the empirical evidence shows that the identification of these variables helps to recognize which are the most relevant within commercial credit in Mexico (which is the type of credit that comprises the largest volume within the commercial bank credit portfolio).

Secondly, the proposal of a relatively new methodology compared to traditional methods for measuring correlation has made it possible to estimate the dependence and obtain more information on the behavior of the variables (such as tail dependence and simulation).

The third element analyzed, referring to bank profitability concerning commercial credit defaults, shows that the increase in bank defaults generates losses for the institutions due to the fact of having to restructure debts, the recovery and collection costs for banks or other intermediaries, and the deterioration of the institution's credit quality generated by these results.

Finally, the fourth aspect, related to providing empirical elements for an economic policy proposal to support the business sector in times of instability, with the estimated results and the analysis of the causes that generated them: it could be suggested that the government and the banking system work closely together to provide support to companies during times of crisis in various ways, for example, by reducing the minimum capital requirements of banks in times of crisis, lowering the interest rate corresponding to the credit default penalty, and debt restructuring programs in the most critical stages of

crises. Banks can also collaborate with regulators to promote and facilitate companies' access to government-backed lending programs, subsidies, or tax incentives.

Although it is true that in most of the variables that were analyzed, companies do not have a direct power of influence, there should also be public policies that support the strengthening of the internal market, better salaries, and unemployment policies in times of crisis or economic instability, since protecting people's employment generates greater consumption, investment, and growth expectations for the entire economy.

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