A. PROPUESTA PROYECTO DE INVESTIGACIÓN

1. TIPO DE PROYECTO:

Interno	**X**	**Grupal**	
Semilla		**Multidisciplinario**	

2. TIPO DE INVESTIGACIÓN:

Básica		**Aplicada**	**X**

3. UNIDAD EJECUTORA *(Departamento, Instituto o Estructura de Investigación):*

Departamento de Matemáticas. Facultad de Ciencias.

4. LINEA(S) DE INVESTIGACIÓN:

1. Modelos Econométricos
2. Teoría de Probabilidades y Procesos Estocásticos

5. TÍTULO DEL PROYECTO *(mínimo 10 palabras):*

Credit risk contagion in private banking sector: a case study for Ecuador

6. RESUMEN *(máximo 200 palabras)*

Daily banking practice suggests that there may be contagion effects between credit portfolios, a fact that through current regulation has been explicitly recognized. This project will try to describe a model that distinguishes between delinquency of each credit portfolio and allows inter-portfolio credit risk contagion, including macroeconomic and financial factors. Also, it will be simulated multivariate scenarios to portfolios' credit risk. About thirteen years of the private banking system of Ecuador will be explored. Delinquency between consumer, microcredit, and housing portfolios as well as their exogenous determinants, will be simultaneously quantified using a Bayesian vector autoregressive model or a traditional VAR. Including inter-portfolio linkages in credit, risk quantification allows understanding the microdynamics of absolute risk better and evaluating individual shocks' systemic importance as their impact spreads among portfolios a domino effect. Further research in this area might also focus on how to use these techniques as an operational tool to incorporate financial stability considerations into control risk policy decision-making.

7. PALABRAS CLAVE *(4-6)*

Credit Risk · Liquidity Risk · feedback effects · Microfinance · Causality

8. OBJETIVOS

8.1. OBJETIVO GENERAL

To analyze and understand the overall relationship between credit risk portfolios; to determine the effects of this relationship on the management of credit risk in private financial sector

8.2. OBJETIVOS ESPECÍFICOS

a. To specify and standardize a database with information of credit portfolio delinquency and financial and macroeconomic variables for Ecuador
b. To establish an econometric model that incorporates the simultaneous endogeneity between credit risk portfolios.
c. To determine if there is a causal relationship between the variables that that determine delinquency in credit portfolios
d. To provide a referential quantitative analysis that allows establishing new recommendations that allow controlling and mitigating total risk exposure

9. HIPÓTESIS (opcional)

There is a causal relationship between Credit Risk Portfolios in private financial sector of Equador

10. DETALLE DE LOS RESULTADOS ESPERADOS *(con relación a los objetivos)*

a. Collection, processing, construction and validation of information for about thirteen years of the private banking system of Ecuador including macroeconomic variables.
b. Establishment of an econometric model that incorporates the simultaneous endogeneity between credit risk portfolios.
c. Group of exogenous variables which cause statistically delinquency in credit risk portfolios.
d. Establishment of recommendations for private financial sector under parameters that allow controlling and mitigating comprehensive total risk.

11. IMPACTO DE LA INVESTIGACIÓN (*científico, social, económico u otros)*

Research results are expected to provide several recommendations for the management of financial entities and control agencies of private financial sector of Ecuador. The expected results can provide regulators, policymakers, and bank management agencies with a better understanding of credit contagion between credit portfolios of financial institutions and their behavior in the face of absolute credit risk. The results should imply that joint management of cross selling could substantially increase the stability of the financial sector. Furthermore, this study support regulatory efforts mainly through the Basel III framework. The Basel Committee has motivated banking supervisors worldwide to implement the proposed principles for credit risk management in banks and financial institutions to evaluate their credit risk management systems. These principles focus specifically on the following areas: credit establishment, maintaining appropriate credit management, measurement and

monitoring process, and ensuring adequate controls over credit risk. The Basel Committee also details that, in recent years, financial institutions have improved their management and assessment of credit risk, jointly driven by experience in handling market events since the beginning of the financial crisis in 2007-2008 and by regulatory requirements. However, it urges that supervisors accurately capture their counterparties' exposures across different sectors as part of their credit risk management. For example, credit risk could arise from the risk of default on a loan or bond obligation or a guarantor's risk or even cross risks between credit products (BCBS, 2015). It is essential to strengthen the regulatory framework; this project will help to create reforms in the area of supervision to guarantee 'optimal' control and analysis of the deficiencies of the Ecuadorian financial system.

12. ESTADO DEL ARTE, E INVESTIGACIONES PREVIAS DEL EQUIPO *(máximo tres carillas)*

In Latin America, just a few studies have addressed the relationships between the banking system's credit portfolios' delinquency and macroeconomic and financial factors. Vazquez et al. (2012) propose a macro model of stress tests for credit risk based on the analysis of scenarios for the Brazilian banking system using autoregressive vectors (VAR). The results corroborate the presence of a pro-cyclical behavior in credit quality and show a stable negative relationship between delinquency loans and GDP growth,with a medium-term response. On the other hand, Mpofu & Eftychia (2018) investigate the macroeconomic determinants of credit risk in the banking system of 22 Sub-Saharan African economies. They employed dynamic panel data methods over the period 2000–2016. The results showed an increase in real GDP growth rate has a statistically significant reducing effect on non-performing loans' ratio to total gross loans. Furthermore, the inflation rate, domestic credit to the private sector by banks as a percent of GDP, trade openness, VIX as a proxy of global volatility, and the 2008/2009 global financial crisis positively and significantly impact on non performing loans.

The Working Paper 6/149 of the International Monetary Fund, Chan-Lau (2006) establishes two models based on macroeconomics to estimate companies and industries' default rate: models with exogenous economic factors where economic variables are exogenous, and econometric models with endogenous economic factors allow feedback on the probability of default between different industrial or financial sectors and the economic cycle. The VAR methodology is proposed in this study. It is highlighted that this type of models is especially suitable for Stress Testing analyzes carried out under the Financial Sector Assessment Program (FSAP) carried out jointly by the World Bank and the International Monetary Fund. However, the data series needs to cover at least one business cycle; otherwise, the model will not fully capture the business cycle's impact on default probabilities. Macro stress-testing has become an essential tool to assess financial stability. However, several methodological challenges remain concerning the correlation of market and credit risks over time and across institutions, the limited time horizon generally used for the analysis, and the potential instability of reduced-form parameter estimates because of feedback effects (Sorge, 2004;˘Cihák, 2007).

With the methodology we will adopt, it will be posible to consider the correlation and the Granger Causality across portfolios. It provides the possibility to compare different portfolios' vulnerability to a given shock or the impact of varying stress scenarios on a given portfolio. We also consider the analysis a considerable period between January 2005 and December 2018, which implies more than two economic cycles (Banco Central del Ecuador, 2014; Banco Central del Ecuador, 2020).

Regarding cross risk or contagion, there is literature related to contagion between countries, between banks, and the riskiness of credit allocation and financial stability across firms. Pienkowski (2019) outlines a three-country macroeconomic model designed to guide forecasts and undertake simulations. The model focuses on the transmission of external shocks to Portugal. This model differentiates between shocks originating from both inside and outside the euro area and domestic shocks. Each of these has different implications for Portugal. This framework is also used to consider the dynamics of the Portuguese economy over recent decades. It shows the importance of identifying both the type and origin of shocks for understanding the economic impact on the Portuguese economy.On the other hand, Brandão-Marques et al. (2019) explore empirically how the time-varying allocation of credit across firms with heterogeneous credit quality matters for financial stability outcomes.Their analysis indicates that credit allocation's riskiness is both a measure of corporate vulnerability and investor sentiment. Concerning cross risk between banks, Catalan & Hoffmaister (2020) establish tha tsimultaneous capital losses in multiple banks can prompt them to contract their balance sheets in the presence of adverse macroeconomic shocks. These bank responses generate externalities that propagatein the form of macro-financial feedback loops. The authors develop a model that integrates a disaggregate banking sector into an otherwise standard macroeconomic structural vector model.The model can thus be used to assess individual banks' contributions to systemic risk along the time dimension. In this sense, just as heterogeneity between banks is essential, heterogeneity in bank lending portfolio responses should matter because they determine how each portfolio fares under adverse conditions and the external effects that portfolios impose on each other and in the bank itself. That is the hypothesis addressed in this work and we will adopt the Bayesian VAR methodology for its study. Litterman(1986), Doan et al. (1984), Sims & Zha (1998), and Kadiyala & Karlsson (1997) proposed to introduce several probabilistic restrictions to improve the traditional VAR model estimation and predictions. These restrictions gave rise to the Bayesian VAR models (BVAR).

13. DESCRIPCIÓN DETALLADA DEL PROYECTO, INCLUIDO METODOLOGÍA (máximo tres carillas)

The methodology to be used in this work will be developed in the following activities:

1. Bibliographic compilation on vector autoregressive methodology and Bayesian VAR models for risk analysis. This will allow to know how different authors, entities (public or private) have approached this issue, the results obtained and problems in development.

2. Collection, processing, construction and validation of information. In this stage the database will be built and the information processed. The following phases are followed:

2.1 Preliminary analysis of the data.
2.2 Creation and preliminary selection of variables.
2.3 Treatment of missing data in the selected variables (data imputation).

3. Verification of stationarity in the series to be analyzed; For this, the unit roots test is carried out for each series using the EViews 4 program or R.

4. Estimation

4.1 Determination of the number of lags
4.2 Analyze the estimation results and compare the results obtained between different alternative models.

5. Diagnosis and validation of the model

5.1 Portmanteau test
5.2 LM test
5.3 Normality tests

6. Causality

6.1 Granger test

7. Analysis of results

With respect to the quantitave methodology:

The methodology used is that of Vector Autoregressive Models (VAR), in traditional or Bayesian version (whatever is necessary), which allows the study of two or more variables simultaneously, with the primary purpose of clarifying their possible interrelations and building a model that allows, among other things, to obtain forecasts of them and determine causality.

VAR is a model of simultaneous equations of reduced form without restriction. The fact that they are reduced form equations means that the contemporary values of the model variables do not appear as explanatory variables in any of the equations. On the contrary, the set of explanatory variables of each equation is constituted by a block of delays of each one of the variables of the model. That they are unrestricted equations means that the same group of explanatory variables appears in each one of them (Novales, 2014). Granger's causality test will be carried out to determine whether past observations of the credit risk variable enhance the explanatory power of the liquidity risk variable and vice versa, that is, to determine whether credit risk causes (in the Granger sense) liquidity risk and whether liquidity risk causes (in the Granger sense) credit risk.
Auto-regressive vector modeling (VAR) with Granger causality tests is one of the most exible ways to elucidate the causal mechanisms underlying time series data.

Basic Structure of VAR Processes

If *Yt = (Y1t; Y2t; :::; Ykt)* is a k dimension vector of time series variables, the basic autoregressive model to k variables with p lags (VAR (p)) is:

$$Yt = v0 + A1Yt1 + ::: + ApYtp + ut; t = 1; :::; T \qquad (1)$$

where Ai are matrices of coefficients (k x k), v0 is vector (k x 1) of model constants and ut is vector (k x 1) composed of the white noises of each of the k equations of the model (Capa, 2016), i.e

$$E[ut] = 0 \text{ for all } t; Cov[ut; us] = 0 \text{ for all } t; Var(ut) = \Sigma \qquad (2)$$

Representation of a V ARX(p) model

If we consider *Yt = (Y1t; Y2t; :::; Ymt)* an m-dimensional vector of stationary exogenous variables and B a matrix of fixed coeffcients having kxl dimension. Then a new model can be obtained from model (1):

$$Yt = v0 + A1Yt1 + ::: + ApYtp + BXt + ut; t = 1; :::; T \ (3)$$

This representation is referred to as the p order VAR model with k endogenous variables and m exogenous variables and denoted as VARX(p). We must clarify that in this model, vector Xt can include lagged variables.

Causality

In theory, the demonstration of causal relationships between the analysis variables provides a understanding of phenomena, especially economic ones. Knowing causality is vital for determining a link between economic variables (Capa, 2016).
In 1969 Granger raised the concepts of causality in time series. Variable Y2t is said to cause Y1t, if the prediction of Y1t improves if past observations of the Y2t variable are incorporated into the analysis. To facilitate the idea of this test, it is explained in the bivariate case: Consider the VAR (p) model, for which variables Y1t and Y2t are stationary:

$$\begin{pmatrix} Y_{1t} \\ Y_{2t} \end{pmatrix} = \begin{pmatrix} v_1^0 \\ v_2^0 \end{pmatrix} + \begin{pmatrix} a_{11}^1 & a_{12}^1 \\ a_{21}^1 & a_{22}^1 \end{pmatrix} \begin{pmatrix} Y_{1t-1} \\ Y_{2t-1} \end{pmatrix} + \begin{pmatrix} a_{11}^2 & a_{12}^2 \\ a_{21}^2 & a_{22}^2 \end{pmatrix} \begin{pmatrix} Y_{1t-2} \\ Y_{2t-2} \end{pmatrix} + ... + ... + \begin{pmatrix} a_{11}^p & a_{12}^p \\ a_{21}^p & a_{22}^p \end{pmatrix} \begin{pmatrix} Y_{1t-p} \\ Y_{2t-p} \end{pmatrix} + \begin{pmatrix} u_{1t} \\ u_{2t} \end{pmatrix}$$

A test of restrictions on the coecients of variables Y2t of the VAR representation is proposed to determine if Y2t causes variable Y1t, RVAR is denoted to the restricted model and UVAR to the model without restrictions (Capa2016).
Y2t does not cause Y1t, if the following hypothesis is accepted:

$$H_0 : a_{12}^1 = a_{12}^2 = ... = a_{12}^p = 0$$

Y1t does not cause Y2t, if the following hypothesis is accepted:

$$H_0 : a_{21}^1 = a_{21}^2 = ... = a_{21}^p = 0$$

The statistic for the test is as follows:

$$L* = (T - c)(ln|\Sigma_{RVAR}| - ln|\Sigma_{UVAR}|) \sim \chi^2_{2p}$$

where,

Σ_{RVAR}= matrix of variances and covariances of the residuals of the restricted model.

Σ_{UVAR}= matrix of variances and covariances of the residuals of the unrestricted Model.

T= number of observations.

c= number of estimated parameters of each equation of the unrestricted Model.

On the other hand, VAR models are not very parsimonious representations where many parameters are estimated compared to the number of available observations, resulting in imprecise estimates of the parameters (over-fitting), low predictions and, a limited number of freedom degrees.Litterman (1986), Doan et al. (1984), Sims & Zha (1998), and Kadiyala & Karlsson (1997) proposed introducing a series of probabilistic constraints in order to improve estimates and predictions. These restrictions were purely statistical, giving rise to the BVAR models.The Bayesian methodology has other advantages over to traditional estimation methods. Bayesian techniques allow easy treatment introduction of unobservable variables. These techniques do not require a large amount of data for estimates, which can be essential when working with narrow historical records. Furthermore, if the assumption of normality in a VAR model is not fulfilled, the BVAR models become a useful tool and allow to improve the estimation of the parameters and the forecasts.

Let Y be a vector of T observations:Y=(Y1,Y2,...,YT) and θ a vector of parameters. We denote the a priori distribution of the parameters by p(θ), representing what is known about θ before knowing the sample information. The posterior distribution of θ given Y represents θ after obtaining the sample information and is denoted by p(θ|Y). The posterior distribution is proportional to the product of the likelihood function and the prior distribution:

$$p(\theta|Y) \propto L(\theta|Y)p(\theta)$$

In this work, two types of priori distribution will be considered: Minnesota (Litterman) and Normal-Wishart.

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14. INFRAESTRUCTURA Y EQUIPOS

- *Indicar la infraestructura y equipos **disponibles** para la ejecución del proyecto, con la ubicación actual de los mismos*

Infraestructura	Equipos	
Laboratorio	**Nombre del Equipo**	**Ubicación del Equipo**
Oficina Departamento Matemática	Computador de Escritorio	Departamento de Matemática
	Computador Portátil	Teletrabajo

15. MONTO REQUERIDO

N/A

16. FONDOS ADICIONALES

- *N/A*

B. DATOS INFORMATIVOS

1. INFORMACIÓN DEL DIRECTOR, CODIRECTOR, COLABORADORES Y COLABORADORES TÉCNICOS

Apellidos y nombres	No. de Cédula	HSS*	Departamento	Rol	Título de mayor nivel y mención.
Adriana Uquillas	1711459261	8	Matemáticas	Director	Doctor en Ciencias. Programa Estadística

* HSS =Horas Semana Semestre: Es el número de horas que se dedica por semana a la investigación. Este número de horas se mantiene para todo el semestre

C. DECLARACIÓN FINAL
DECLARACIÓN DEL DIRECTOR DEL PROYECTO

El equipo de investigadores, representado por el Director del Proyecto declara lo siguiente:

- Que el presente proyecto es una creación original de mi autoría y del equipo de investigadores, y por tanto asumimos la completa responsabilidad legal en caso de que un tercero alegue la titularidad de los derechos intelectuales del proyecto, exonerando a la EPN de cualquier acción legal que se derive por esta causa.

- Que el presente proyecto no ha sido presentado en ninguna convocatoria de otra institución pública o privada. El incumplimiento será causal para que el proyecto no sea tomado en consideración.

- Que si el proyecto genera algún producto o procedimiento susceptible de obtener derechos de propiedad intelectual, de los cuales se deriven beneficios, aceptamos que éstos serán compartidos entre los investigadores y la institución o las instituciones participantes en el proyecto, conforme a lo establecido en el COESC.

- Que el equipo de investigadores y/o instituciones participantes se comprometen a mantener la confidencialidad de la información si ésta podría ser susceptible de protección por patentes, y solicitar la valoración de propiedad intelectual respectiva previa a cualquier publicación o difusión.

- Que para el caso de derechos de autor otorgamos una licencia de uso exclusivo con fines académicos para la o las instituciones participantes en el proyecto.

- Que aceptamos conocer y cumplir con la normativa vigente para la gestión de proyectos.

Firma del Director del Proyecto
Nombre: Adriana Uquillas Andrade
C.I.:1711459261

ESCUELA POLITÉCNICA NACIONAL

VICERRECTORADO DE INVESTIGACIÓN, INNOVACIÓN Y VINCULACIÓN

Proyecto de Investigación Interno

CRONOGRAMA DE ACTIVIDADES DEL PROYECTO

Título del Proyecto: **Credit risk contagion in private banking sector: a case study for Ecuador**

AÑO 1

Nº	Actividad	Mes 1				Mes 2				Mes 3				Mes 4				Mes 5				Mes 6				Mes 7				Mes 8				Mes 9				Mes 10				Mes 11				Mes 12			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	Objetivo específico 1: To specify and standardize a database with information of delinquency and financial and macroeconomic variables	X	X	X	X	X	X	X	X	X	X																																						
1,1	Bibliographic compilation on vector autoregressive methodology for risk contagion in Latin America and the rest of the world.	X	X	X	X																																												
1,2	Collection, processing, construction and validation of information.					X	X	X	X	X	X																																						
2	Objetivo específico 2: To establish an econometric model that incorporates the simultaneous endogeneity between credit risk portfolios											X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X												
2,1	Verification of stationarity in the series to be analyzed											X	X	X																																			
2,2	Estimation of the model														X	X	X	X	X	X	X	X																											
2,3	Diagnosis and validation of the model																					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X												
3	Objetivo específico 3: To determine if there is a causal relationship between the variables that determine deliquency in credit portfolios																																					X	X	X	X								
3,1	Causal Granger causality																																					X	X	X	X								
3,2	Diagnosis and validation																																							X	X								
4	Objetivo específico 4: To provide a referential quantitative analysis that allows establishing new recommendations that allow controlling and mitigating total risk exposure																																									X	X	X	X	X	X		
4,1	Impulse-Response Analysis																																									X	X	X	X	X	X		
4,2	Manuscript					X	X	X	X		X	X								X	X	X	X	X					X	X					X	X	X											X	X