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## Article

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## Macro Stress Testing Credit Risk: Case of Madagascar Banking Sector

**Abstract:** This study proposes to assess the vulnerability of banking sector's credit portfolio under macroeconomic shocks and to evaluate its impact on banking system capitalization. Our method uses the Global Vector Autoregressive (GVAR) Model to generate adverse macroeconomic scenarios. The GVAR model is combining by the satellite credit risk equation to find the non-performing loan under stress conditions. The advantage of using GVAR model is that on the one hand, it captures the transmission of global, external and domestic macroeconomic shocks on banks non-performing loans. On the other hand, this model considers the nonlinear pattern between business cycle and the bank credit risk indicator during the extreme events as highlighting by the macro stress test literature. The forecast of non-performing loan is then used to obtain stress projections for capital requirement for the banking system level. This article attempts to fill the lacks concerning the stress testing works about Madagascar which study is a recent framework, whose no study on dynamic macro stress testing was treated before. The Results outline the interaction of aggregate non-performing loan with macroeconomic evolution. The horizon of capital prediction shows that banking sector reacts most to a GDP shock. Also, Madagascar banking sector is quite resilient and remains sufficiently capitalized under all macroeconomic scenarios designed with a solvency ratio higher than the minimum regulatory CAR ratio.

**Key words:** Madagascar, macroeconomic stress test, credit risk, banking sector, GVAR

**JEL classification:** C33, G32, E44

## 1. Introduction

The recent financial crisis has highlighted the importance of assessing financial stability as a whole and the implementation of macroprudential policy into the general line of political policy. This is why the Financial Stability Committee has been constituted to ensure financial stability, improve the openness and transparency of the financial sector, and apply international financial regulation. In addition, to support the macroprudential policy assessment, the International Monetary Fund (IMF) and the World Bank in the Financial Sector Assessment Program (FASP) has periodically conducted a comprehensive and in-depth assessment of their country members' financial sector. This program analyzes among others the resilience of the financial sector's analysis, of which a stress tests. Since then, stress test has been developed much more by regulatory authorities and central banks as a tool of macro-prudential policy which continues to evolve so far. Foglia (2008) provides an overview of the stress testing practice of different authorities.

At the African countries level, the consultative group for Sub-Saharan Africa is part of the regional advisory groups of the Financial Stability Committee. Subsequently, African Central Banks have given increasing importance to the assessment of financial stability and macroprudential supervision at the regional level by the end of 2011. As well, the FSAP program conducted by the IMF and the World Bank continues to cover most of African countries<sup>1</sup> including Madagascar (IMF, 2016). Concerning growing stress testing literature, apart from authorities report for assessing financial stability, we identify for example the studies of H.de Wet *et al.* (2009) and Havrylchuk (2010) for South Africa and Aboagye and Ahenkora (2017) for Ghana.

For Madagascar's case, the first traces of the macro-prudential policies application lies in the establishment of the Financial Stability Unit in 2013 and the Financial Stability Committee internal to the institution in 2014 by the Central Bank of Madagascar in 2013 (BCM, 2015). Thereafter, the Central Bank of Madagascar publishes annually a financial stability report.

Thus, Madagascar financial sector stress testing is still a recent study. Besides, the recommendations of Bank for International Settlements (2009) want those banks to regularly apply and update their stress testing environment. Also, the Basel II objective requires the banks to conduct stress tests to find out their minimum

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<sup>1</sup> Such as Rwanda (IMF, 2011), Nigeria (IMF, 2013), South Africa (IMF, 2014), Chad (IMF, 2016), Ghana (IMF, 2014), CEMAC (IMF, 2016), Zambia (IMF, 2017)

capital requirements as future potential and to consider at least the effect of mild recession scenarios.

This paper aims to carry out macro stress testing that links macroeconomic scenarios and banking sector capital position. The non-performing loan (NPL) is the credit risk indicator used to capture dynamic macroeconomic shocks. A Satellite GVAR approach, which is the combination of GVAR model and credit risk satellite equation, will be applied as an econometric model to generate macroeconomic scenarios and to assess the impact of shocks on banks portfolios. The GVAR model has been adopted in this study because it carries out the international interaction between economic variables. As a small open economy, Madagascar is supposed to be influenced by international macroeconomic evolution. Hence, the research intends to evaluate the relationship between NPL and domestic, foreign and global macroeconomic variables. Then, the forecast of NPL ratios is used to calculate the projection of bank's capital position under stress scenarios.

The paper contribution on the existing literature is double. Firstly compared with stress test literature in Madagascar banking system case, the practice of the stress test approach is still a recent evaluation method. Thus, this survey attempts to fill the gap and to extend the literature on financial evaluation stability already conducted. There are the IMF assessments under the FSAP program (IMF, 2016) and those conducted by the Central Bank of Madagascar in the Financial Stability Reports (BCM, 2014, 2015, 2016).

Secondly, compared to the macro stress testing literature, this study tries to extend a specific GVAR model as a tool for assessing credit risk management for Madagascar. For that, the survey follows Pesaran *et al.* (2004) and Dees *et al.* (2007) methodology to construct the country and region to form the specific GVAR model to the economic situation. The model constructed is used for generating the macroeconomic scenario. Also, a study on macroeconomic stress test using a compact econometric model for the linkages between various econometric risk factors and quality of credit portfolio has not yet been done for the case of Madagascar.

Results suggest that the evolution of the non-performing loan and the GDP follow the cyclical pattern. The banking sector capital position is also sensitive and reacts most to global shocks of oil price and to domestic GDP shock.

This paper is organized as follows. The second section reviews the related literature in macro stress testing which includes related researches as well for Madagascar's case. The third section describes the empirical framework, the data and

outlines the estimation process. Section 4 provides the estimation results from econometric models and discusses the issue of the stress testing credit risk and projection of capital adequacy under the scenario designed in the model. The last section concludes the whole study.

## 2. Related literature

The literature describes several approaches for conducting stress testing in order to assess banking sector vulnerabilities to macroeconomic shocks. Several studies distinguish various modeling of credit risks with macroeconomic variables as a risk factor. Sorge (2004) provides an overview of the several methodologies on stress testing in the financial system.

Most of previous studies analyzed the relation between macroeconomic factors and credit risk indicators such as Non-Performing loan ratio (NPL) and Loan Loss Provision ratio (LLP). The choice of these indicators depends on each study and particularly on the data availability. Studies using the non-performing loans are for example those performed by Kalirai and Scheicher (2002) for an Australian bank, Babouček and Jančar (2005) for the Czech banking sector, Zeman and Jurca. (2008) for Slovak Banking sector. For those using of the LLP as credit risk indicator, we can distinguish the study of Virolainen (2004) for the bank of Finland, Kosmidou and Moutsianas (2015) for Greek banking sector. Likewise, some authors use both of these indicators, as an example we can cite Kattai (2010) works about the Estonian Bank credit risk model.

The credit risk model based on NPL ratio gives an advantage in the sense that the model is able to run both at the aggregate, sectoral or individual levels. So, using NPL ratio as a credit risk indicator is appropriate to perform aggregate, sectoral and individual portfolios analysis. Besides, as noted by Åsberg and Shahnazarian (2008), model based on individual portfolios is needed to be conducted if we want to obtain a specific result.

The interaction between the credit risk indicator of banking sector and the evolution of macroeconomic situation are exposed by several studies. Chaibi and Ftiti (2015). carried out a study on the determinants of credit risk of commercial banks in a market-based economy, represented by France, compared with a bank-based economy, represented by Germany; and found that except for the inflation rate, the other macroeconomic variables used in their study influence the NPLs. Koju *et al.* (2018) shown the effects of remittance, public debts and interest spreads on NPL of each specific bank within the Nepalese banking system. Asanović (2018)

performed an analysis of the determinants of banking crisis in Southeast European Countries and the results of the study shown that the banking system indicators have higher impact on probability of systemic banking crisis occurrence compared to macroeconomic indicators.

Drawing macroeconomic scenario constitutes the steps in scenario stress testing as performed in this study. Literature in macroeconomic scenario stress testing distinguishes econometric model to generate scenario analysis. The literature shows many kinds of econometric model but we note the predominance of vector autoregressive (VAR) approach. Anyway, either VAR or vector error correction model (VECM) is used if there is no available proper macroeconomic model to generate desired scenarios (Foglia, 2008). Among the Stress testing Studies that use either VAR or VECM model to generate macroeconomic figure the study of Blaschke *et al.* (2001) which suggested VAR model is by to assessing the transmission of macroeconomic indicators impact on financial indicators, such as NPL ratio or banking assets; Hoggarth *et al.* (2005) in the stress test analysis of UK banking sector tries and measures the link between economic cycle and bank fragility; and Zeman and Jurca (2008) in the stress test of the Slovak bank and use the VECM model to identify long-term relationships between macroeconomic variable and financial indicator.

However, the VAR model has some limitations for the generation of extreme scenarios. The studies conducted by some authors van den End *et al.* (2006) and Drehmann *et al.* (2006) demonstrate the non-linear distribution of the default probability under macroeconomic shocks conditions. Authors argue that the non-linearity of the default rate distribution increases with the magnitude of the macroeconomic shock. Fong and Wong (2008) note that stress tests using standard linear model underestimates the probability of conditional default under macroeconomic shock.

To deal with nonlinear relationships between corporate credit risk and macroeconomic factors, there are some studies to be highlighted. We can distinguish for example the global vector autoregressive (GVAR) model introduced by Pesaran *et al.* (2006) and mixture vector autoregressive (MVAR) model developed by Fong *et al.* (2007). However, following the literature overview, the most model recently used is the GVAR model. Chudik and Pesaran (2014) provide surveys of the latest developments in the GVAR modeling which outlines the theoretical foundations of the approach and its empirical applications such as financial and credit risk applications. The advantage of the GVAR model is that it takes into account the non-linear relationships between macroeconomic variables and financial variables without modifying the model structure (Castrén *et al.*, 2010).

In addition, Pesaran *et al.* (2006) in their study about the conditional credit loss distribution based on GVAR model, found that the effects of these shocks on losses are asymmetrical and non-proportional, reflecting the highly non-linear nature of the credit risk model. Another advantage of GVAR approach is that it links the credit risk of diversified international loan portfolios in a detailed macroeconomic model that allows for country-region differences (Castrén *et al.*, 2010). So, the GVAR approach carries out the international and global interaction of macroeconomic risk factors and not only the domestic dynamics.

The Global VAR approach (GVAR) is originally introduced by Pesaran *et al.* (2004), and provides a relatively simple but effective way of modeling complex, high-dimensional systems such as global economies. The model is designed initially to analyze the effects of real and financial shocks, at the national and international level, on credit or model risk. Thereafter, the GVAR model has undergone several developments according to the composition of the regions and countries composing the model.

The GVAR model by Pesaran *et al.* (2004) is known as PSW version. The model is made of 25 countries in the world classified in 11 regions. Later, Dees *et al.* (2007) update the countries included in the model as version. This version covers 33 countries from the different region of the world so far. Hence, the Dees *et al.* (2007) model, known as DPdS version, is the best endowed to carry out an analysis that takes into account the international dynamic. Therefore, the countries selected in the model do not cover African components. So, H.de Wet *et al.* (2009) propose to add an African component to the PSW (2004) GVAR model. The model includes main countries of South Africa trade partners and develops to be a credit risk management tool.

There are some studies which apply GVAR model as a tool for assessing the credit risk of corporate sectors. Pesaran *et al.* (2004) conducted a study on stress testing credit risk and the business cycle. The authors use the GVAR model to generate the scenarios to assess the impact of macroeconomic variables on business default probabilities. The model includes 25 countries grouped into 11 regions for a quarterly period from 1979 to 1999. The Global VAR model is used as an input for simulations of corporate returns, which are then linked to the distribution of losses of a corporate portfolio loan. Alessandri *et al.* (2009) developed a quantitative framework for assessing the systemic risk that explicitly characterizes bank balance sheets and allows for macro-credit risk, interest income risk, market risk, network interactions, and returns effects on the assets. The basic macroeconomic model is a GVAR version of two countries: the United Kingdom as a small open economy and the United States taken as the representative of the rest of the world.

The study focuses on projections on the system-wide bank assets in the UK. The investigation shows how a combination of commercial losses and extreme business losses can precipitate widespread claims and trigger a contagious defect associated with network effects and the sale of distressed assets.

H.de Wet *et al.* (2009) developed a South African component of the GVAR model for the purpose of credit portfolio management in South Africa. All domestic factors for South Africa taken into account are both at global and individual level. The GVAR model includes 14 countries trading partners of South Africa and South Africa itself. The global macroeconomic variables such as GDP, the general price index, the exchange rate, the interest rate and the money supply. Concerning the South African correlation VECM model, all these variables are retaken and added with housing price, household debt, and oil price. The main objective of their investigation is to provide specific elements of South Africa to the GVAR model. The results of their survey show that the correlation model could be used as a specific credit risk portfolio management tool for South Africa.

Castrén *et al.* (2010) conducted a study about euro area case with corporate default probability under a range of domestic and global macroeconomic scenarios for the period 1992-2005. They use GVAR model in order to generate the macroeconomic scenario. In addition, they use a satellite approach to link firms default probabilities to domestic euro area macroeconomic factors. Once estimated, the satellite model is integrated into a GVAR model to form a satellite GVAR model. Expected default frequencies are used as credit risk indicator to capture the default probabilities of firms. Their study includes both aggregate and sectorial expected default frequencies. The authors indicate the usefulness of the Satellite GVAR model as a useful tool for analyzing macro-financial shock scenarios designed for stress testing exercises and to link this to a micro level of expected default information.

For stress test study that has been done in the case of Madagascar, we can distinguish IMF stress testing exercises in the FSAP program and the stress test performed by the Central bank of Madagascar in the Financial Stability Report. The methodology used by the IMF (Hardy, Daniel C. and Guerra Ivan, 2016) is the ascending stress test or bottom up approach using the financial soundness indicators. The study covers solvency, liquidity and risk stress test. The results of the study demonstrate the robustness of the banking system as a whole in the face of normal economic fluctuations, and credit risk remains predominant and other risk factors remain as important. The scenarios were based both on historical events and future forecasts, and tests focus on one-year effects.



In the Financial Stability Reports, the Central Bank of Madagascar (BCM, 2014, 2015, 2016) conducted a stress testing of the banking sector. Stress testing exercise includes solvency, liquidity and risk stress test. The methodology used focuses on the indicators of soundness and financial stability such as the adequacy of capital or solvency ratio, the quality of assets, liquidity, the coefficient of use of deposits and return on equity. The financial soundness analysis uses the Herfindahl-Hirschmann Concentration Index (HH), applied to banks' assets. The results of the analysis show the soundness and profitability of the banking sector in general, despite some signs of the small banks fragility.

### 3. Methodology and data

In order to assess the impact of macroeconomic shocks on credit risk indicator, the methodology is divided into three steps. First of all, we estimate the GVAR model to capture the global and foreign shocks effect on Madagascar macroeconomic variables. Separately, in the satellite model, we estimate the relation between domestic macroeconomic factors in the GVAR model and the credit risk indicator. Then, the result of satellite model will be integrated into the GVAR model in order to capture the effect of macroeconomic shocks on the non-performing loan by implementing the generalized impulse response functions. The satellite approach combined to the GVAR model forms the Satellite GVAR model. Finally, the forecast of non-performing loan is used to predict the capital adequacy of banking system under stress condition.

#### 3.1. The model

The construction of the GVAR model which carries out Madagascar components is based on the Pesaran *et al.* (2004) and Dees *et al.* (2007) methodology. Countries and regions to make up the GVAR model are considered as best suited for the economic situation of Madagascar.

GVAR model is a global model that combines individual country VECMX\* or VECM with exogenous variables models, in which domestic variables are related to country-specific foreign variables. The model assumes that there is an  $N+1$  countries in the global economy, where  $i=0,1,2,\dots,N$ , where 0 is the cross-reference country. In the most case, reference country is the United States. GVAR model has the following reduced form:

$$x_{it} = a_{i0} + a_{i1} + \Psi_{i0} d_t + \Psi_{i1} d_{t-1} + \phi_{i1} x_{i,t-1} + \phi_{i2} x_{i,t-2} + \Lambda_{i0} x_{i,t}^* + \Lambda_{i1} x_{i,t-1}^* + \varepsilon_{it} \quad (1)$$

For  $t = 1, 2, \dots, T$  et  $i = 0, 1, 2, \dots, N$

Where,  $x_{it}$  is a  $k_i \times T$  vector of country specific variables

$a_{it}$  is a  $k_i \times 1$  vector of linear coefficient

$x_{it}^*$  is a  $k_i^* \times T$  vector of specific foreign variables of country  $i$ ; with  $\Lambda_{i0}$  and  $\Lambda_{it}$  matrix  $k_i \times k_i^*$  matrix of fixed coefficient

$d_t$  is a  $s \times T$  vector of global variables such as oil price, raw material price and metal price, and they are exogenous for all country; with  $\Psi_{i0}$  and  $\Psi_{it}$  as a  $k_i \times s$  matrix of fixed coefficient

$\phi_{i1}$  et  $\phi_{i2}$  are the lagged coefficient matrix of domestic variables

and  $\varepsilon_{it}$  is a  $k_i \times 1$  vector of country specific shocks

Thus, in this study, we use four countries versions DPdS (2007) GVAR model and add Madagascar as an individual country in the model. The four countries which are the main trade partners of Madagascar are countries of Euro zone, United Kingdom, Japan and the United States. In fact, Madagascar is considered in the GVAR model as a small open country whereas the foreign countries represent its four major trade partners. Therefore, specific macroeconomic foreign variables in the model (star variables) are constructed by using each associated trade weight (table 1). Trade weight is needed to capture the impact of the global economy on domestic variables. These trading partners' in our model are the countries used by the Central Bank of Madagascar to calculate real effective exchange rate.

**Table 1: Madagascar major trade partners and foreign weight**

Country	Trade weight
United States	0,093
Euro zone countries	0,760
Japan	0,110
United Kingdom	0,037
Total	1

Source: Central Bank of Madagascar, 2017

### 3.2. Variables in the GVAR model

Macroeconomic variables in our GVAR model follow Déés et al. (2007) specification. All variables used for the model and their transformations are listed below. Sets of foreign variables are the gross domestic products (GDP), consumer price index (CPI), the exchange rate of the currency to US Dollars (E), short-term interest rate (R) and long-term interest rate (LR). Global variables include oil price (OIL), raw material price (RM) and metal price (MT). Their transformations are:

$$y_{it} = \ln\left(\frac{GDP_{it}}{CPI_{it}}\right), q_{it} = \ln\left(\frac{E_{it}}{CPI_{it}}\right), p_{it} = \ln(CPI_{it}), r_{it} = 0.25 \ln\left(1 + \frac{R_{it}}{100}\right)$$

$$lr_{it} = 0.25 \ln\left(1 + \frac{LR_{it}}{100}\right), oil_t = \ln(OIL_t), rm_t = \ln(RM_t), met_t = \ln(MT_t)$$

Where  $i$  stands for the index representing Madagascar trading partner

For the case of Madagascar, domestic variables include gross domestic products (GDP), consumer price index (CPI), short-term (R) and long-term (LR) interest rates. For the case of exchange rate variable, real effective exchange rate (E) is used rather than domestic currency to US dollar.

$$y_t = \ln\left(\frac{GDP_t}{CPI_t}\right), p_t = \ln(CPI_t), e_t = \ln(E_t), lr_{it} = 0.25 \ln\left(1 + \frac{LR_{it}}{100}\right), r_t = 0.25 \ln\left(1 + \frac{R_t}{100}\right)$$

### 3.3. Data sources

The survey uses a quarterly data from 2005Q2 to 2015Q2 due to the unavailability of financial data out siding this period. The serial of non-performing loan (NPL) is available only for that time period. The data source of macroeconomic global and foreign variables is the same as employed in the DPdS version and the lasted GVAR toolbox by Smith et al. (2014). However, the serial data of this package end at the 2013Q1. But, this study extends to the period 2015Q2 by using the same data source. Missing value was approximated by interpolating annual available data. Madagascar macroeconomic data comes from the national statistical office (INSTAT) and from the Central Bank of Madagascar. All variables data sources are summarized in table 2.

After estimating the GVAR model (1), the satellite approach will be performed separately to estimate relations of macroeconomic factors with the non-performing loan. Castrén et al. (2010) describes the importance of the satellite approach because it isolates the credit risk indicator from the GVAR system.

**Table 2: Series of global, foreign and domestic variables and data sources**

Variables	Data source	
<b>Global and foreign variables</b>		
- Gross domestic products (GDP*)	International Financial Statistics (IFS) of IMF	
- Consumer price index (CPI*)		
- Exchange rate (E*)		
- Short term (R*)		
- Long term (LR*) interest rate		
- Oil price		
- Raw material price		
- Metal price		
<b>Domestic and exogenous variables</b>		
- Gross domestic products (GDP)		- National Statistic Office
- Consumer price index (CPI)	- National Statistic Office	
- Exchange rate (E)	- National Statistic Office	
- Short term (R)	- Statistical information bulletin of Central Bank of Madagascar	
- Long term (LR) interest rate	- Statistical information bulletin of Central Bank of Madagascar	
- Banking sector variables	- Central Bank of Madagascar	

Source: Author construction

### 3.4. The satellite equation

The satellite approach is performed to estimate separately the domestic macroeconomic factors in the GVAR model with the non-performing loan. Domestic macroeconomic factors which are endogenous in the GVAR model become exogenous in the satellite equation. The non-performing loan is used as a credit risk indicator, endogenous variable. Following Déés *et al.*(2007), the satellite equation takes the form below:

$$Y_{jt} = b_{j0} + b_{jt} X_t + \varepsilon_t \quad (2)$$

$$\text{for } j = 1, \dots, k$$

$j$  is the index of sectors

$X_t$  is a  $k \times T$  matrix of domestic exogenous variables, that are endogenous in the GVAR model

$b_{j0}$  is the intercept

$b_{jt}$  is a  $1 \times k$  vector of parameters

$\varepsilon$  is a  $1 \times T$  vector of residual

$Y_{jt}$  is a  $1 \times T$  vector of endogenous variables for sector  $j$ . In our case,  $Y$  stands for aggregate non-performing loan ratio.

In the satellite model, to be able to use non-performing loan as an indicator, we use the logit transformation of the credit risk indicator (Virolainen, 2004) below:

$$Y_{jt} = \frac{1 - npl_t}{npl_t}$$

### 3.5. Satellite GVAR model

The satellite GVAR model is the combination of the GVAR model (1) with the satellite equation (2). For this purpose, after having estimated the satellite equation, we integrated it into the GVAR model. The GVAR model was used to generate macroeconomic scenario through the generalized impulse response function. So, in the satellite GVAR model, the non-performing loan captures the conditional change of the domestic macroeconomic factors from the scenario generated by the GVAR model and the change of the global and foreign variables.

## 4. Results

The simulation results are as follow:

### 4.1. Unit root tests

Following PSW and DdPS, we performed the unit root test macroeconomic factors. For the foreign and global factors, we follow the integration test results of PSW (2004) and DdPS (2007) that show that global and foreign variables are weakly integrated order one  $I(1)$ .

For the credit risk indicator and macroeconomic domestic and exogenous variables cases, we used the Augmented Dickey-fuller test (ADF). The results show that all macroeconomic series in our model are integrated of order one  $I(1)$ . The results from the unit root test are in line with the economic theory because macroeconomic variables are generally integrated of order one.

## 4.2. Satellite GVAR estimation results

In principle, small open economy such as Madagascar is influenced by global economic evolution. So doing the GVAR estimation, we study particularly the impact of the international economies on Madagascar economy. In our case, we focus on Madagascar VECMX\* model in GVAR result, where the endogenous variables are Madagascar macroeconomic factors and exogenous variables are trading partner's macroeconomic variables and global variables. After estimating GVAR model, the generalized impulse response function (GIRFs) is performed to generate factors shocks as scenarios in the satellite model. In other words, dynamic relation results are used to simulate the effect on the credit risk indicator in the satellite GVAR model.

For the satellite model, we estimate the non-performing loan ratio and the domestic macroeconomic factors as exogenous variables. These macroeconomic factors are endogenous in the GVAR model. Equations and results are presented below:

$$npl = \alpha_1 GDP + \alpha_2 CPI + \alpha_3 E + \alpha_4 R + \alpha_5 LR + \beta$$

Where  $npl$  the non-performing loan ratio and the right-side variables are the gross domestic products (GDP), the consumer price index (CPI), the real effective exchange rate (E), the short-term interest rate (R) and the long-term interests rate (LR).  $\alpha$  and  $\beta$  are the parameters.

In the satellite model, the unit root test of domestic factors and the non-performing loan ratio indicate that all series are integrated in order one  $I(1)$ , so we can try and test the possibilities of a long-run equilibrium relation. We employ Johansen Cointegration techniques. The test shows that the NPL ratio and the factors are cointegrated. Trace and Maximum Eigen value statistics both indicate one cointegration equation.

The estimated coefficients of the long run relationship and the short-run dynamic of the satellite equation are presented below. The cointegrating equation  $ect_{t-1}$  or the long run model result takes the following forms:

$$ect_{t-1} = 1,00 npl_{t-1} - 3,00 GDP_{t-1} + 0,77 CPI_{t-1} + 1,22E_{t-1} - 0,83R_{t-1} - 3,95LR_{t-1} - 7.24$$

[-11.82]            [8.28]            [9.71]            [-0.39]            [-1.73]

The endogenous variable is the aggregate non-performing loan. All variables are given in logarithms as given in the GVAR model. In the long run relation, all coefficients except short-term interest rate are significant at the 5% level. The result of the dynamic short run is summarized in the table below:

**Table 3: Short run dynamics of satellite model**

	<i>CE</i>	<i>Const</i>	$\Delta GDP_{t-1}$	$\Delta IPC_{t-1}$	$\Delta E_{t-1}$	$\Delta R_{t-1}$	$\Delta LR_{t-1}$
$\Delta npl$	-1.019	0.019	-1.889	-0.420	-0.249	-2.817	-5.535
T statistic	[-8.1216]	[ 1.8750]	[-1.6837]	[-0.0119]	[ 0.9954]	[-2.4838]	[-0.6775]
Adjusted R <sup>2</sup>	0.530408						
F-statistic	6.970246						

Source: Authors calculation

In the short run dynamics, recall force must be strictly negative and significant to have an economic interpretation of VEC model, which is verified in our case. All coefficients are significant in the short run despite the IPC and the long-term interest rate. Coefficients in the model have also the expected sign.

The relation between GDP and NPL follow the cyclical theory. The growth of GDP decreases the share of non-performing loan ratio in short run and in the long run. The long-term interest rate growth decreases the NPL ratio in the long run and in the short run. The short-term interest rate is also correlated negatively with the NPL ratio but the coefficient is not significant in the long term. Inflation is positively correlated at a significant degree with the NPL ratio in the long run. But in the short run, the coefficient is not significant. The growth of real exchange rate decreases the NPL ratio in the short run but it increases this ratio in the long run.

Residual diagnostic tests have also been performed in order to verify the estimation result and the satellite model specification. First, for the normality test, Jacques Bera statistics are lower than the critical value, so the null hypothesis of the residual normality cannot be rejected. Then, the LM non-autocorrelation statistic indicates the value inferior of LM critical value, in fact, the null hypothesis of non-autocorrelation of the residual series is accepted, so the result shows the absence of serial correlated error terms. Finally, the absence of heteroscedasticity test was examined by using White statistics; the statistic value is lower than the critical value, so the residual series are homoscedastic. We can conclude that our satellite model is best specified.

### 4.3. Impacts of scenario in the NPL ratio

In this paragraph, we discuss the impact of one standard error of selected domestic, foreign and global macroeconomic variables shocks on the aggregate NPL ra-

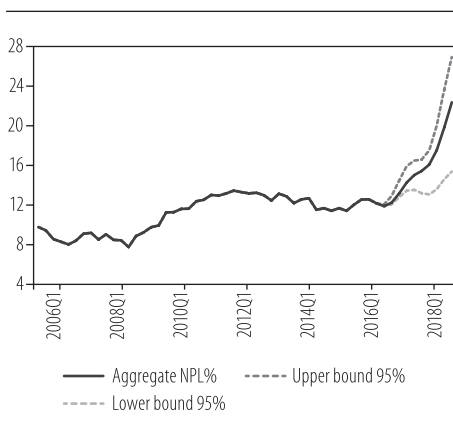
tio over four quarters horizon. We report in this paper the main following shocks as stress scenarios which affect the most the risk indicator: negative Madagascar GDP shocks, a positive shock of euro exchange rate and positive shock of oil price. All figures give a measurement of the reactions compared with the baseline. A bootstrap experiment analysis was performed for producing the lower and upper bounds of the NPL ratio reaction to the satellite GVAR model. The bootstrap results of all conditional shocks show that the aggregate NPL reactions are inside the confidence interval between 5% and 95 %.

Results of satellite GVAR simulation reveal the importance of the impacts on aggregate non-performing loan ratio against negative GDP shock, foreign positive Euro shock, and global oil shock. By the way, signs of the impacts on aggregate NPL are expected and fit the economic business cycle theory.

A negative standard error shock of the Madagascar GDP leads to an increase of non-performing loan ratio during the forecast horizon, it means a deterioration of banks loan portfolios quality (graph 1).

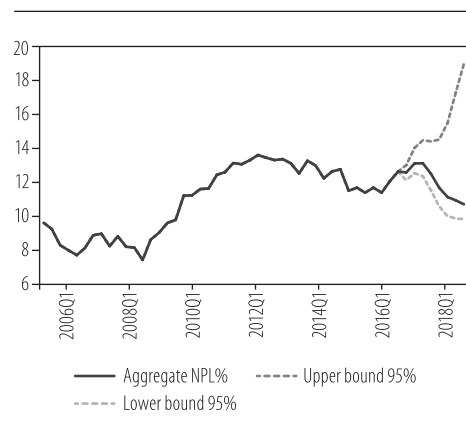
Positive one standard error shocks of the Euro real exchange rate (depreciation) which implies an increase of domestic real effective exchange rate implies an increase of NPL ratio until the value of +4.1% for the five first quarters (graph 2) and after that the NPL decreases.

**Graph 1: NPL reaction to one negative standard deviation of Madagascar GDP shock**



Source: Authors calculation

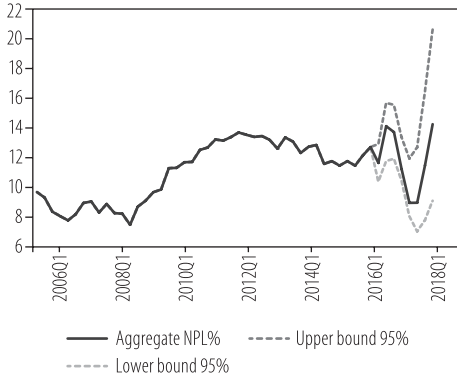
**Graph 2: NPL reaction to one positive standard deviation of Euro exchange rate shock (ie depreciation)**



Source: Authors calculation



**Graph 3: NPL reaction to one positive standard deviation of global oil price shock**



Source: Authors calculation

The positive one standard deviation of oil price shock increases the NPL ratio after the second quarter. Then, it decreases for a period of three quarters before finally increasing again. The growth of oil price deteriorates the economic situation and that could have a considerable consequence on the advance of credit portfolios quality.

#### 4.4. Capital calculation

The last step in the implementation of the macroeconomic stress test is the measurement of the impacts of different scenarios on the banking sector. We use the Capital Adequacy Ratio (CAR) defined as capital on risk-weighted assets to capture bank's capitalization under macroeconomic stress conditions. The out of sample forecast of non-performing loan ratios obtained in the previous section is used for this section to obtain the CAR projections. The CAR forecast is to be determined over an eight-quarter horizon after 2015Q2, the last quarter in our sample.

The calculation of aggregate banking sector CAR ratio under different shocks uses Vuković (2014) approach and considers several assumptions, as in all previous macroeconomic stress test works. The difference in the NPL ratio before and after the stress test is transformed into a loss in capital. The profit of the sector for the forecast horizon is assumed as zero, so that the equity capital is not increased by the amount of profit. Risk-weighted assets, total assets and total loans are kept constant at their starting values of the projections; these assumptions are consistent with the idea that banks should be able to cope with the adverse scenario without unduly reducing their balance sheets, cutting thus the supply of credit to businesses and households (Covas *et al.*, 2014). In the second case, apart from the macroeconomic shocks and all the assumptions cited above, we simulate the CAR under an assumption that the RWA increases by 16%. This variation

is based on the average of credit growth during the past five years. This purpose attempts is to evaluate the simultaneous effects of risk-weighted asset growth and adverse macroeconomic scenarios.

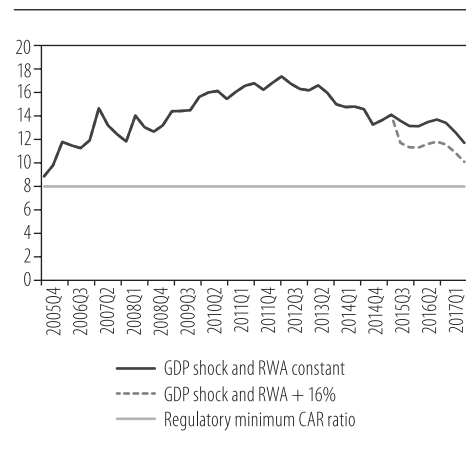
**Table 4: Banking sector capital under macroeconomic scenarios**

	Adverse macroeconomic scenarios (one standard error deviation)					
	Negative GDP shock		Positive Exchange rate Euro/Dollar shock		Positive Oil price shock	
	RWA constant	RWA increases by 16%	RWA constant	RWA increases by 16%	RWA constant	RWA increases by 16%
Baseline CAR 2015Q2	14,11		14,11		14,11	
Horizon						
1	13,13	11,32	13,17	11,36	13,96	12,04
2	13,47	11,61	12,77	11,01	12,06	10,39
3	13,69	11,81	12,76	11,00	12,37	10,66
4	13,41	11,56	13,24	11,42	14,30	12,32
5	12,63	10,88	13,88	11,97	16,04	13,83
6	11,70	10,09	14,30	12,33	16,03	13,82

Source: Authors calculation

As shown in the table above, the capital ratios of the system decrease under all scenarios. The capital is more sensitive by the change of exchange rate and the oil price shock during the three first quarters horizon but through the projection CAR is more sensitive by the GDP shock. These results are in line with the empirical evidence on the relationship between the CAR and the business cycle (such as Hirtle *et al.* (2016) and Topbaş (2018)). Assuming an increase in risk-weighted assets of 16%, CAR ratios dropped significantly in the adverse scenarios. Therefore, under all scenarios, the capital ratios of the banking sector decrease but are still above the regulatory minimum of 8%. The figure below illustrates the GDP shock effect on aggregate banking sector capital ratio.

**Figure 1: Aggregate CAR under GDP shock**



Source: Authors calculation

## 5. Conclusion

This paper develops a macro stress testing in order to assess banking sector credit risk under global macroeconomic factors and to predict the banking sector capitalization below adverse scenarios. A GVAR model specific for Madagascar has been constructed as a tool for generating scenario which allows international interaction between dynamic, foreign and global macroeconomic variables. To evaluate the impacts on NPL ratio to different conditional shocks we have estimated the satellite equation which assigns separately the NPL and domestic macroeconomic variables that would be afterwards combined into GVAR model.

The results suggest negative correlation between aggregate NPL and GDP shock which fits the cyclical pattern. The macroeconomic environment is a source of influence for banks' activities. The change in capital adequacy ratio against macroeconomic stressed conditions shows the deterioration of banking sector CAR under all adverse scenarios. The horizon of capital prediction shows that banking sector reacts most to a GDP shock. Through these outcomes, Madagascar banking sector is quite resilient to credit risk and remains sufficiently capitalized with a solvency ratio higher than 8%.

Therefore, this study encounters some limits. As well as this study is focused on the aggregate banking sector, a bank by bank analysis is needed in order to support and refine the results. This can allow a deeper analysis of credit risk portfolio situation under stress scenario. Also, the size of our data is very limited and the precision degree of our results depends on the availability of a consistent data. However, the long serial of financial indicator data problem is met by almost all the studies in macro stress testing.

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