

Stress Testing the Greek Banking System

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Abstract

The financial stability and smooth function of the financial system constitute issues of high interest, particularly after the outbreak of financial crises. The current crisis generally proved that dysfunctions in the banking system cause systemic risk and turbulence in the economic environment and vice versa; the deterioration of the macroeconomic environment affects financial institutions. Our study has two objectives: the first is to identify the effects of the macroeconomic environment on the smooth functioning of the Greek banking system and, specifically, to what extent the deterioration of economic conditions affects the credit risk of Greek banks. The second objective is to develop a macro stress-testing framework to assess the stability of the Greek banking system and the credit risk of Greek banks in particular in the context of a hypothetical deterioration of the macroeconomic environment.

JEL Classifications: G01, G17, G20, C15

Keywords: stress testing, credit risk, financial stability

1. Introduction

The recent financial crisis has forced central banks, supervisory authorities and the management of financial institutions to review more closely all aspects of the financial stability issue. It has been proved that financial stability can evolve into a fragile economic situation and that a failure to take preventive measures can easily lead to financial instability. A transition in conditions of financial instability can cause large losses on the constitutive parts of the financial system and real economy.

In the framework of the globalized economy, the intense interdependence between national economies operates as a channel of transmission of crises and consequently creates a ‘domino effect’. Therefore, the formation of financial stability conditions and the smooth function of the financial system constitute issues of high interest for supervisory authorities. The ensuring of proper functioning of the banking system is a basic priority because the banking system represents the largest percentage of total assets in national financial systems.

The relationship between the macroeconomic environment and the banking system is an issue that has been investigated extensively. It is related to the resilience of banking institutions to deterioration of macroeconomic conditions. The aim of these investigations is to examine how the banking sector is affected by fluctuations in the macroeconomic environment.

Due to instability of the macroeconomic environment, an assessment of the financial system is considered imperative. A useful tool for the assessment and the identification of vulnerabilities

within the financial system is stress testing. Stress testing includes a range of techniques used to assess the vulnerability of a portfolio to major changes in the macroeconomic environment and exceptional but plausible events (Blaschke, Jones, Majnoni, & Martinez Peria, 2001). Macro stress testing refers to methods that analyze the effects of adverse macroeconomic conditions on an individual financial institution or a group of financial institutions (Virolainen, 2004).

Stress testing has become a widely used tool to assess potential vulnerabilities in a financial system. In individual financial institutions, the term describes a range of methods that attempt to measure the sensitivity of a portfolio to a set of extreme but plausible shocks, and it is a means of revaluing a portfolio using a different set of assumptions (Jones, Hilbers, & Slack, 2004). Stress-testing programs include a variety of techniques that are applied to assess the importance of assumptions that underlie economic models and forecasts (Van Lelyveld, 2007). Stress testing is applied either at portfolio level of financial institutions or at the financial system level (system-focused level). The system-focused stress test was conducted by the supervisory authorities of the countries and was intended to identify hazards that may cause instability in the financial system. The process of stress testing at the system level includes two approaches: (i) the top-down approach and (ii) the bottom-up approach. In the top-down approach, the stress test is conducted on an aggregated representative portfolio, whereas the bottom-up approach is performed by aggregating the results of stress tests on individual portfolios.

The development of the methodology of stress testing was specifically encouraged by the International Monetary Fund (IMF) and the World Bank through the Financial Sector Assessment Program (FSAP). The FSAP was established in 1999 with the aim of assessing the financial stability and financial development of developing and emerging markets.

Our research has two objectives: the first is the identification of the effect of specific macroeconomic variables on the loan portfolio quality of Greek banks. The quality of a loan portfolio is associated with credit risk and is measured by loan loss provisions. Based on the existing methodologies of selected authorities who conducted macro stress tests in their countries, we select the following macroeconomic variables: annual growth of gross domestic product (GDP), inflation (as expressed by the consumer price index), the industrial production index, the unemployment rate and the economic sentiment indicator.

First, we estimate the overall relationship between the macroeconomic variables and the loan loss provisions for the Greek banking system to examine the effect on the credit risk ratio. The second objective of the research is the development of a macro stress-testing framework to assess the stability of the Greek banking system and the credit risk of Greek banks in particular in the context of a deterioration of the macroeconomic environment, which is based on a historical approach.

The paper is organized as follows: the second part includes a review of related studies, and the third a description of the Greek banking system and an outline of the macroeconomic environment in which the banks operate. In the fourth part, we describe the model specification and the interpretation of the results. The fifth section is related to the implementation of the macro stress test and the analysis of the outcomes. Finally, the sixth section presents the concluding remarks of this study.

2. Review of Related Studies

The macroeconomic determinants of aggregate defaults in the economies of the U.S. and Australia were investigated by Ali and Daly (2010). In particular, this research refers to macroeconomic determinants of aggregate default risk and the impact of macroeconomic shocks. The results of the research suggest that GDP, short-term interest rates and total debt are meaningful indicators for aggregate default when the level of industrial activity does not signal the default.

Based on VAR analysis, Dovern, Meier, and Vilsmeier (2010) model the interaction between the write-off ratio and return of equity (ROE) of the German banking system and macroeconomic developments. Based on their results, the German banking system is affected by macroeconomic conditions and specifically by fluctuations in GDP, consumer price index (CPI), the 3-month interest rates and the U.S. GDP. Louzis, Vouldis, and Metaxas (2012), in their research on the macroeconomic and bank-specific determinants of non-performing loans in Greece found that GDP growth, the unemployment rate and lending rates affect non-performing loans.

Akhter and Daly (2009) examine the health of financial intermediaries in varying macroeconomic conditions. The research, which was conducted across more than 50 countries, describes how financial soundness indicators (FSIs) change due to alteration of the macroeconomic environment. FSIs consist of the core and the encouraged set, reflect the robustness of financial intermediaries, and are associated with the capital adequacy and profitability. The results show that business cycle, inflation, real effective exchange rates and size of the industry affect FSIs. A similar study, which was conducted by Babihuga (2007), finds that business cycle, inflation rate, short interest rates and real exchange rate have a strong relationship with the behavior of FSIs.

Jakubik and Schmieder (2008) conducted a comparison of two different types of economies: the transitional economy of the Czech Republic and the developed economy of Germany. The aim of their research was to identify which macroeconomic variables might affect credit risk. They also investigated the effect of the business cycle's fluctuations on the aggregate default rate of corporations and households. Their research included two credit risk models for each country. The first credit risk model was developed with the aim of describing the behavior of the corporate default rate. For the Czech Republic, the model included as independent variables real exchange rate, inflation, GDP and indebtedness of the corporate sector as a portion of GDP with time lags. The outcomes showed that the effect of the real exchange rate was significant and that the negative effect of inflation was at lower levels. The corresponding German model included the following macroeconomic variables: nominal interest rate, GDP, industrial production and debt-to-GDP ratio. The results suggested that the nominal interest rate and GDP affect the default rate. For the household sector, the Czech credit risk model included unemployment rate and real interest rate, both of which had a positive effect on household default rates. The German credit risk model involved household income, which had a negative effect on household default rate, and the household-debt-to-GDP ratio, which had a positive effect.

The relationship between business cycle factors and the loan losses of Polish commercial banks was examined by Glogowski (2008). The results suggest that GDP growth; changes in real interest rates, unemployment rate and exchange rate have a significant influence on loan losses. Moreover, a rapid growth of lending in combination with an increase in property prices may cause financial instability.

Filosa (2007) investigates the sensitivity of the Italian banking system to macroeconomic shocks through an application of macro stress testing. This research models the interactions between macroeconomic and financial variables and indicators of banks' soundness. According to the study, the banks' soundness is expressed by the ratios of flow to outstanding loans, and the stock of non-performing loans to outstanding loans. The macroeconomic and financial variables consist of output gap, inflation and the short-term ECB rate.

Through a comparative analysis of macro stress-testing methodologies with application to Finland, Sorge and Virolainen (2006) found a significant relationship between industry-specific default rates and GDP, interest rates and corporate sector indebtedness. Moreover, they found that developments in the economic environment affected banks' loan-loss provisions.

Jiménez and Saurina (2006) find a negative effect of lagged GDP and a positive effect of real interest rates on NPLs of Spanish banks. Based on their outcomes, they also suggest that loan

quality depends on loan growth with a four-year lag. Moreover, the authors find an interaction between the phase of the lending cycle and the quality of the loans.

Evjen, Lund, Morka, Nordal, and Svendsen (2005) apply a macro stress test that includes a demand and a supply shock to the Norwegian financial sector. The application of the shocks related to the effect of rapid changes on the level of banks' provisioning. The study suggests that provisions constitute an indicator of financial stability. Moreover, the authors suggest that the conditions of the macroeconomic environment are very important for debt servicing capacity. The macroeconomic indicators used as independent variables are GDP, unemployment rate, wages and CPI.

In the context of macro stress testing for Finland, Virolainen (2004) found that GDP, interest rates, industrial production, real wages, the stock index and oil prices had an effect on credit risk related to the corporate sector. Similarly, the unemployment rate and interest affected the default rate of the household sector. Additionally, Delgado and Saurina (2004) examined the influence of a set of macroeconomic indicators on LLPs and NPLs and found that GDP growth has a negative influence and interest rates a positive effect.

The effects of the macroeconomic environment on loan loss provisions, non-performing loans and return on assets, and on the identification of cyclical patterns, were investigated by Quagliariello (2004) for a large sample of Italian intermediaries. The results show that new bad debts and loan loss provisions against loan losses have an increased effect, as does the deterioration of the economic environment.

The relationship between the loan-loss provisions of major UK banks and the macroeconomic environment is investigated by Pain (2003). Specifically, this research suggests that the economic cycle and fluctuations in asset prices affect the level of banks' loan loss provisions because they relate to the ability of borrowers to serve their obligations. Moreover, low GDP growth, high real interest rates and faster lagged growth in aggregate lending lead to an increase of bank provisioning.

The evidence of preliminary macroeconomic stress testing of the Austrian banking sector shows a relationship between banks' loan loss provisions (LLPs) and specific macroeconomic variables (Kalirai & Scheicher 2002). The outcomes of this study suggest that loan loss provisions relate negatively with GDP growth and positively with interest rates. More specifically, a rise in the short rate, a fall in business confidence, a decline in the stock market and a decline in industrial production affect the level of LLPs. Pesola (2001) describes the relationship between macroeconomic factors, banks' losses and non-performing loans (NPLs) for the Nordic countries in periods of crises. In this study, the dependent variables were the ratios of banks' loan losses to lending and enterprise bankruptcies to population. The independent variables were lagged GDP percentage change, income surprise variable combined with lagged indebtedness and a regulatory dummy. In the same context, Pesola (2005) expanded his research to include Germany, Greece, Spain, Belgium and the UK. The outcomes show that high customer indebtednesses are associated with adverse macroeconomic shocks.

3. The Greek Banking System

3.1. Description of the Greek Banking System: Evolution and Structure

The consecutive internationalization of financial transactions in combination with rapid technological developments have converted the international banking system and strengthened its role in the modern financial environment. The liberalization of capital and money markets in combination with the abolition of barriers to cross-border financial services has widened significantly the interconnection of national banking systems. On the one hand, these changes have resulted in the reduction of the costs of offered banking services. On the other hand, this situation has increased the potential for the transmission of problems or crises from one country to another.

These developments directly affect the operations of banking institutions. The increase in intensity of banking competition leads the banking institutions to adopt complicated and risky strategies to maintain their profitability. Moreover, within the European Union, monetary integration and the adoption of the euro strengthen the competition and accelerate the process of forming a single market of financial services. In parallel, the modern international financial environment is dominated by acquisitions and mergers that create large financial groups.

In the highly interdependent financial environment, financial stability is connected with the development of internationally harmonized rules for banking supervision. In particular, the Second Bank Directive (Basel Committee on Banking Supervision, 2003; 2005) plays an important role in the establishment, operation and supervision of credit institutions, setting out the principles of banking in the single European financial market and providing equal competitive conditions for all European banking institution (including banks that operate in Greece).

The Greek banking system experienced a radical transformation in the last twenty years. The changes marked an era that included the liberalization of interest rate determination, free movement of capital and increased competition. Additionally, the banks were allowed to configure their own investment policies without the restriction of investing a certain percentage in government bonds. Moreover, allocation inefficiencies and the initiation of the process for financial integration within the European Union contributed to the modernization of the Greek financial system.

In particular, until the mid-1980s, the Greek banking system operated in an environment characterized by selective controls and regulations. In the 1990s, a period characterized by an acceleration of liberalization and deregulation of the financial system, efforts were initiated toward the deregulation of the domestic banking system. In parallel, a process of gradual and extensive liberalization of the market was motivated by international developments and the need for participation in the Single European Market for financial services.

Banking activity in Greece was significantly affected by the harmonization of national regulations within the European Union, particularly with the enactment of the Second Banking Directive concerning the establishment, operation and supervision of credit institutions (Tsionas, Lolos, & Christopoulos, 2003). Additionally, consistent macroeconomic and structural policies were adopted because the country joined the Economic Monetary Union (EMU), policies that gradually reduced inflation and interest rates. The EMU affects the Greek banking system by increasing cross-country competition. Moreover, the intensification of competition in the domestic market has put pressure on bank profitability and led to a reduction in the interest rate margin. The liquidity of banks increased due to the abolition of the banks' obligation to keep a high proportion of their portfolio in government securities to finance public deficits.

At present, the Greek banking system is characterized by increased competition, internationalization and disintermediation. These factors reduce the cost of banking services and help the banking system to increase its efficiency. Currently, all deposit rates and almost all lending rates are freely determined, and banks are allowed to extend credit on their own terms and to provide new financial products and services. Additionally, investment requirements imposed on commercial banks for the financing of small and medium size enterprises and public enterprises are gradually being abolished.

The global financial crisis and adverse macroeconomic conditions affected the Greek economy, which suffered from important structural weaknesses and high levels of fiscal deficit and public debt. One of the most important consequences of the financial crisis related to the financial stability of the Greek banking system was the failure of international money and capital markets¹. The main

¹ Annual Report of the Bank of Greece, 2008

effect of the malfunctioning of the markets was the high cost and gradual increase in inadequacy of funding sources, which deteriorated the liquidity situation of Greek banks. To enhance the liquidity and the capital adequacy ratios of the Greek banking system, the Greek government developed a liquidity support plan (Law 3723/2008) which included (i) a recapitalization scheme of up to €5 billion, (ii) a guarantee scheme of up to €15 billion, and (iii) a securities scheme of special government bonds of up to €8 billion.

Additionally, Greek banks suffered significant losses in their portfolios due to the Private Sector Involvement (PSI) program, which was associated with the restructuring of the Greek sovereign debt². The liquidity crisis evolved in the solvency crisis in 2012; the banks were forced to resort to the Bank of Greece for Emergency Liquidity Assistance (ELA). In 2012, the resolution, restructuring and recapitalization, was considered necessary for the financial stability of the country.

4. Method

4.1. Data

The first step of our study is the identification of the relationship between the macroeconomic environment and the asset quality of the Greek banking system to identify the impact of macroeconomic variables on the credit risk indicator. For this reason, we have selected the four systemic commercial banks of the Greek banking system (National Bank of Greece, Piraeus Bank, EFG Eurobank Ergasias and Alpha Bank), which represent 98.69% of the entire financial system of Greece in terms of total assets. Table 1 presents the commercial banks included in our dataset. The time horizon of our research covers the period from 2001Q1 to 2013Q4 and includes the eras before and after the financial crisis.

Table 1. Commercial banks

Commercial banks	Total Assets (th EUR, 2014Q3)	Percentage (in terms of total assets)
NATIONAL BANK OF GREECE SA	80.758.000	27.00%
PIRAEUS BANK SA	80.089.000	26.77%
EFG EUROBANK ERGASIAS SA	67.496.000	22.56%
ALPHA BANK SA	66.869.000	22.35%
BANK OF ATTICA SA	3.925.000	1.31%
	299.137.000	100%

Source: Hellenic Bank Association

The financial data of the banking institutions of our sample are drawn from Bureau van Dijk's Bankscope Database and from published annual reports and info memorandums. Data for the macroeconomic variables include the following: annual growth of gross domestic product (GDP), inflation (INF) (as expressed by the consumer price index), industrial production index (INPRO), unemployment rate (UNEMP) and economic sentiment indicator (SENTI). Data sources include the World Bank, the OECD and reports of the Bank of Greece (table 2, Appendix: table A1, A2).

² Annual Report of the Bank of Greece, 2012

Table 2. Variable description, notation, and the expected effect of the explanatory variables

Variables	Notation	Expected effect	Description
<i>Dependent</i>			
Loan-Loss Provisions	LLPS		Under IAS 39 loan loss provisions are determined based on an incurred loss model, supported by objective evidence of impairment. This includes observable data indicating that there is a measurable decrease in the estimated future cash flows from a group of financial assets since the initial recognition of those assets, although the decrease cannot yet be identified with the individual financial assets in the group. IAS 39 states that loan loss provisions cannot reflect losses based on expected future events.
<i>Independent (macroeconomic variables)</i>			
Gross Domestic Product growth (annual %)	GDP	Negative	Annual percentage growth rate of GDP at market prices based on constant local currency.
Inflation, consumer prices (annual %)	INF	Negative or positive	Inflation as measured by the consumer price index reflects the annual percentage change in the cost to the average consumer of acquiring a basket of goods and services.
Industrial Production Index	INDPRO	Negative	Industrial production index is an index covering production in mining, manufacturing and public utilities (electricity, gas and water), but excluding construction.
Unemployment, total (% of total labor force)	UNEMP	Positive	Unemployment refers to the share of the labor force that is without work but available for and seeking employment.
Economic sentiment indicator	ESI	Negative	The Economic Sentiment Indicator is a composite indicator made up of five sectoral confidence indicators with different weights which show how a group feels about market and business environment.

Notes: the definitions of the independent variables were obtained from World Bank, OECD and IMF

4.2. Methodology and Model Estimation

For the model specification, we perform panel data analysis for the period from 2001Q1 to 2013Q4. The dependent variable of the model is the logit transformation of loan loss provisions (LLPS). We have selected the following as the independent macroeconomic variables: GDP growth, inflation (INF) as measured by the consumer price index, industrial production index (INPRO), unemployment rate (UNEMP) and economic sentiment indicator (ESI).

Loan loss provisions describe the credit quality of the banks and reflect the rates of arrears and defaults on loans (Kearns, 2004). In accordance with the Basel Committee on Banking Supervision

(1999), when a loan is recognized as impaired, a banking institution must charge the respective loan loss provision to counterbalance the expected credit loss. Therefore, an increase (decrease) of the level of loan loss provisions implies deterioration (improvement) of the loan quality.

The model, which estimates the credit risk in the Greek banking system and the effects of macroeconomic conditions, has the following form:

$$LLPS_{i,t} = a_{i,t} + \beta_{1i,t}GDP + \beta_{2i,t}INF + \beta_{3i,t}IND + \beta_{4i,t}UNEMP + \beta_{5i,t}ESI + \varepsilon_{i,t}$$

where LLPS represents the log of loan loss provisions, i refers to an individual bank, t refers to year, GDP is the GDP growth, INF is inflation as measured by the consumer price index, IND is the Industrial Production Index, UNEMP is the total unemployment rate and ESI is the Economic Sentiment Indicator in Greece, and ε is an error term.

The econometric methodology includes a choice between a fixed effects (FE) model and a random effects (RE) model. For this reason, we employ the Hausman test, which indicates that a random effects model is more appropriate for the analysis ($p\text{-value} > 0.05$). Thereafter, we perform diagnostic tests for heteroskedasticity and serial correlation in the panel data. A Breusch and Pagan Lagrange multiplier (LM) test for random effects indicates that there is heteroskedasticity in the panel data ($p\text{-value} < 0.05$). Based on the Wooldridge test, we reject the null hypothesis of no first-order autocorrelation in the panel data of banking institutions banks (table 3). To have reliable and consistent results, we perform panel regression with Driscoll-Kraay robust standard errors estimators. Driscoll and Kraay (1998) propose a nonparametric covariance matrix estimator that yields heteroskedasticity and autocorrelation consistent standard errors. Additionally, the Hausman test indicates that an FE model with Driscoll-Kraay robust standard errors is more appropriate.

4.3. Results

The results from the panel regression analysis can be summarized as follows (table 3). Our research confirms that macroeconomic conditions affect loan quality and therefore the credit risk of banking institutions. First, the annual percentage growth rate of GDP is related negatively as we expected, and it is statistically important as other studies have indicated (Ali & Daly, 2010; Akhter & Daly, 2009; Jakubík & Schmieder, 2008; Pain, 2003; Sorge & Virolainen, 2006; Evjen *et al.*, 2005; Virolainen, 2004; Kalirai & Scheicher, 2002). The negative relationship between GDP growth and loan loss provisions indicates that when macroeconomic conditions become adverse, the loan quality of Greek banks deteriorates. This situation is related to the fact that when an economy is in recession, the ability of companies and households to repay their obligations is decreased. The effect of the relationship between inflation and credit quality may be positive or negative (Akhter & Daly, 2009; Jakubík & Schmieder, 2008; Filosa, 2007). According to the results, inflation seems to be significant, and its sign is negative. The negative relationship indicates that an increase of inflation leads to a more competitive national economy, with more profits and improvement in the payment capacity of borrowers and particularly companies. The results concerning the unemployment rate are consistent with those of other studies (Glogowski, 2008; Evjen *et al.*, 2005; Dovern *et al.*, 2010); it has a significant effect on credit risk because it is related to the ability of households and individuals to repay their debts. Moreover, a negative relationship is proved between loan loss provisions and the Economic Sentiment Indicator. It is confirmed that when macroeconomic conditions and the business environment experience ‘bad’ economic conditions, the behavior of borrowers is affected. In this case, the increase in credit risk when the Economic Sentiment indicator becomes worse is the fact that individuals and businesses are reluctant to repay their debt obligations when there is a feeling of uncertainty and insecurity about the future of the economy. Finally, the level of industrial production does not exert a significant effect on the credit risk of the Greek banking system.

Table 3. Panel regression results. Dependent variable: Loan Loss Provisions (LLPS)

	FE model	RE model	Pooled OLS model with Driscoll-Kraay robust standard errors	FE model with Driscoll-Kraay robust standard errors
GDP growth (GDP)	-0.0777 (0.000)***	-0.0782 (0.000)***	-0.0782 (0.018)***	-0.0777 (0.017)***
Inflation (INF)	-0.0986 (0.010)***	-0.0994 (0.018)**	-0.0994 (0.035)**	-0.0986 (0.033)**
Ind. Production Index (IND)	-0.0045 (0.708)	-0.0038(0.777)	-0.0038 (0.785)	-0.0045 (0.744)
Unemployment rate (UNEMP)	0.0439 (0.001)***	0.0433 (0.002)***	0.0433 (0.007)***	0.0439 (0.005)***
Economic Sentiment Ind. (ESI)	-0.0294 (0.000)***	-0.0297 (0.001)***	-0.0297 (0.000)***	-0.0294 (0.040)**
Constant term	20.9585 (0.000)***	20.9994 (0.000)***	20.9994 (0.000)***	20.9585 (0.000)***
R-squared	0.7568	0.7568	0.7107	0.7586
Wald test Prob (F statistic)	(0.000)***	(0.000)***	(0.000)***	(0.000)***
Hausman test		(1.000)	(0.000)***	(0.000)***
Wooldridge test for autocorrelation		(0.5707)		
Modified Wooldridge test for heteroskedasticity	(0.000)***	(0.000)***		
Number of obs.	195	195	195	195

Notes: *p*-values in parentheses. Significance levels are indicated by */**/** on the 10%/5%/1% level.

^a Estimations are performed using the pooled OLS estimators

5. Stress Testing

For the assessment of the Greek banking system, we apply stress testing that focuses on the evolution of loan-loss provisions under deteriorated macroeconomic conditions. The methodology followed for the conduct of the stress test is a sensitivity analysis in combination with hypothetical economic shocks. The methodology of sensitivity analysis describes the shift of risk factors when an adverse but plausible shock happened to a macroeconomic variable. The most important aspects of the issue of stress tests' validity and credibility are the objectivity and plausibility of stress scenarios. Referring to the scenarios, the hypothesis is flexible in the formulation of potential events and provides information about the sensitivity of the selected risk factor to different crucial variables. The main disadvantage of the hypothetical form of stress scenarios is the difficulty of determining the likelihood of the event occurring.

5.1 Scenario and Shock Calibration

Scenario construction constitutes one of the basic components of the stress-testing process. A definition of stress scenario describes it as a 'simultaneous relative changes of multiple risk factors

from the current condition to the stressed condition, which is translated into a numerical plausibility based on a multivariate distribution assumption of risk factors' (Breuer & Krenn, 1999). The aim of stress testing is to evaluate the vulnerability of the Greek banking system in macroeconomic shocks. In this research, we develop two types of scenarios: baseline and adverse scenario. The baseline scenario includes the values of the macroeconomic variables according to projections³; the adverse scenario includes historical adverse values in the period from 2001Q1 to 2013Q4. The historical scenarios replicate historical episodes of stress. The types of scenarios that are usually adopted by supervisory authorities or by banking institutions are the historical and hypothetical scenarios. The historical is easier to plan and apply, and they are based on the concept that certain extreme and unfavorable economic incidents are likely to be repeated. Moreover, the historical scenarios are based on the assumption that future crises will be similar to past ones (Breuer & Krenn, 1999). Table 4 presents the macroeconomic variables of the credit risk model for the actual, baseline and adverse scenarios.

Table 4. Macroeconomic variables: actual, baseline and adverse scenario

Macroeconomic variable	Actual (2013Q4)	Baseline (2014Q4)	Adverse (historical approach)
GDP growth	-3.1%	1.2%	-10.4%
Inflation, consumer prices	-1.7%	-1.13%	-1.7%
Unemployment rate	27.3%	26.1%	28%
Industrial Production Index	-1.3	-5.1	-12.8
Economic sentiment indicator	91.4	99.10	74.8

5.2. Credit Risk Stress-Testing Results

Following the macroeconomic credit risk model (1) that we developed in the previous section, we apply the baseline and adverse scenarios based on the coefficients of macroeconomic variables that we obtained from panel data analysis. In this step, we employ the projected values from the scenarios to quantitate the impact of the macroeconomic shocks on loan loss provisions. Both scenarios assume simultaneous deterioration of the selected macroeconomic variables.

In the case of the adverse scenario, which includes a projection of the level of loan loss provisions in which the macroeconomic variables take the worst values in the period from 2001Q1 to 2013Q4, the stress-testing results show that the credit risk faced by the Greek banking system as expressed by loan loss provisions increases by 9.32% (Table 5). Although stress testing is a forward-looking risk management tool and historical scenarios include economic situations that have occurred in the past, the results of our research provide useful information for the Greek banking system and the four systemic banks. The increase in loan loss provisions at 9.32% in probable deterioration of the macroeconomic environment suggests that the credit risk faced by banks is quite elevated.

Additionally, we demonstrated that the macroeconomic environment greatly affects the credit risk of banks and, in combination with the increase in non-performing loans, limited liquidity and

³ The projections for the values of the macroeconomic variables are derived from Hellenic Statistical Authority (EL.STAT.), OECD and Eurostat.

the overall economic instability in Greece, plays an important role in the financial stability and smooth operation of Greek banks. The fact that the increase in loan loss provision leads to an increase in capital buffers has a significant effect on economic growth and the real economy because the additional funds held by the banks could be channeled to the financing of the economy.

Table 5. Level of loan loss provisions under different type of scenarios

Type of scenario	Loan loss provisions	Change
Actual	19.88	
Baseline	19.23	-3.28%
Adverse	21.02	9.32%

6. Discussion

The financial stability and smooth function of the financial system constitute issues of high interest for supervisory authorities, particularly after the outbreak of financial crises. The current crisis generally proved that dysfunctions in the banking system could cause systemic risks and turbulence in the broader economic environment and vice versa; the deterioration of the macroeconomic environment negatively affects financial institutions. Therefore, an assessment of the financial system has become a cornerstone of an efficient economic policy with the aim of identifying potential vulnerabilities at the macro level.

The objectives of our research were as follows: first, an examination of the effect of specific macroeconomic variables on the Greek banking system. Enriching the existing methodologies of selected authorities who conducted macro stress tests in their countries, we selected the following macroeconomic variables: annual growth of gross domestic product (GDP), inflation (as expressed by the consumer price index), industrial production index, unemployment rate and economic sentiment indicator. We estimated the relationship between these macroeconomic variables and the level of loan loss provisions (LLPs) for each banking institution to examine the size of the effect on this credit risk measurement ratio. The interpretation of the results is based on two basic assumptions: first, that the macroeconomic condition has an effect on loan-loss provisions (LLPs) and, second, that a deterioration of economic conditions implies an increase in default probabilities from companies' point of view and a difficulty for borrowers to service their debts. Despite the simplicity of our model, we find some significant conclusions; one is that the macroeconomic environment affects the credit quality of the Greek banks as it is expressed by the loan-loss provisions. Specifically, we found that GDP growth, unemployment rate, inflation, and economic sentiment indicator affect the credit quality of the Greek banking system. The second objective of the research was the development of a macro stress-testing framework to assess the stability of the Greek banking system, and particularly the loan quality of Greek banks, in the context of a hypothetical deterioration of the macroeconomic environment. Based on the model that resulted from the panel data analysis, we applied shocks to the values of the macroeconomic variables and observed the change in the levels of loan-loss provisions.

For further research, an investigation of the relationships among the macroeconomic environment and other credit quality ratios and profitability and capital ratios is suggested. Moreover, we could examine the potential interdependencies among the macroeconomic variables to develop multifactor scenarios. Finally, we could include even more variables that describe the macroeconomic environment.

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Appendix

Table A1. Descriptive statistics of macroeconomic variables

Macroeconomic variables	Mean	Median	Std.dev.
GDP growth (GDP)	-0.0519	1.05	5.2856
Inflation (INF)	2.8345	3.0645	1.5507
Industrial Production Index (IND)	-2.2923	-1.75	4.7118
Unemployment rate (UNEMP)	13.1057	10.35	6.2446
Economic Sentiment Indicator (ESI)	95.9923	99.8	11.2305

Table A2. Descriptive statistics of Greek banks

Loan loss provisions (logit transformation)	Mean	Median	Std.dev.
NATIONAL BANK OF GREECE SA	18.639	18.258	1.044
PIRAEUS BANK SA	17.981	17.332	1.511
EFG EUROBANK ERGASIAS SA	18.698	18.660	1.032
ALPHA BANK SA	18.652	18.636	0.838

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