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The Impact of the Basel Accord on Greek Banks: A Stress Test Study

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Abstract: In this paper, we study the impact of extreme events on the loan portfolios of the Greek banking system. These portfolios are grouped into three separate groups based on the size of the bank to which they belong, in particular, large, medium, and small size. A series of extreme scenarios was performed and the increase in capital requirements was calculated for each scenario based on the standardized and internal ratings approach of the Basel II accord. The results obtained show an increase of credit risk during the crisis periods, and the differentiation of risk depending on the size of the banking organization as well as the added capital that will be needed in order to hedge that risk. The execution of the scenarios aims at studying the effects which may be brought about on the capital of the three representative banks by the appearance of adverse events.

Keywords: banking regulation; credit risk; stress test

JEL Classification: G21, G32

1. Introduction

Banks must uphold the appropriate level of equity capital in order to be in a position to deal sufficiently and effectively with the risks they take. The level of these capital requirements is mainly

determined by the size and structure of the bank portfolio whose quality is quantified by certain parameters (probability of default, exposure at default, *etc.*) as stipulated by the calculation method chosen, based on the Basel I and II accords [1–3]. Of particular importance, for an integrated approach of the capital requirements each bank must uphold, is the development of extreme events simulation scenarios, which not only follow the requirements set by the supervision framework but also the hypotheses of sound and integrated risk management conduct.

The financial state analysis, which can be conducted at the bank or bank sector level, has particular value since it provides substantial information about the credit provision policy followed but also, in general, about the path which is expected to be followed (e.g., equity capital, total assets, claims on clients, *etc.*). However, it is not a reliable tool for determining the degree of coverage of the risks taken with respect to the exposure that has been made. This weakness is dealt with by using the capital adequacy index which, as defined by the two Basel accords, links these two elements and forms a reliable valuation measure of the capital requirements that need to be upheld in order to cover the bank against risks. Indeed, the capital adequacy index is defined as a ratio whose numerator includes the set of supervisory capital (basic and supplementary), and the denominator includes all asset exposures weighted with respect to the risks they contain (with the new accord, it includes credit market and operational risks). Other information is also included in calculating the denominator (delinquencies, collaterals, *etc.*) that is not contained in the financial statements and the annual reports because they are viewed as concerning confidential data whose publication is not allowed. In calculating the capital adequacy index, other capital requirements are also taken into account with respect to market risk and operational risk. It is noted that in the first Basel accord, the risks taken into account were credit risk and market risk, while in the second Basel accord, the operational risk is also included. While risk calculation based on the first accord uses predetermined coefficients that correspond to each exposure, the second accord develops a more elaborate methodology which takes into account the factors that determine the degree (high or low risk) and, analogously, the level of exposure. In particular, Basel II suggests the use of two approaches (standardized approach (RW), internal ratings approach (RWIRB)) [1,4]. The application of the first approach (standardized approach) presents similarities with the respective approach of Basel I (calculation of risks based on supervision coefficients) but includes added factors for computing the total result (delinquencies, collaterals, credit ratings, *etc.*). The second approach (internal ratings approach) allows the development and use of models measuring the three risks (credit, market, and operational) after their approval and acceptance by the central bank.

Basel II is a more risk-sensitive approach compared to Basel I. In this respect, Basel II penalises bad portfolios or rewards good portfolios much more effectively than Basel I. Additionally, there are more risk parameters to stress in the Basel II case. Therefore, one must expect that the results of Basel II represent more reliably the adverse economic effects that a stress test is required to portray.

Undoubtedly, the systematic and scientific listing of the estimation of the effects that will be brought upon by the implementation of the Basel II proposals on credit portfolios is considered particularly important. However, up to now, the effects that will be brought upon the capital requirements of the Greek banking system, the reserved capital for hedging the risks undertaken that have been calculated by the application of the standardized approach and the internal ratings approach, have not yet been fully evaluated as to the existence, the extent, and the magnitude of the changes. The Basel committee monitors and evaluates the implementation of the Basel II IRB approach for credit

risk in order to assess possible future policy options [5]. Important issues, like which categories of banks will be most affected, which parts of the portfolios will have the greatest changes, as to their size and extent, what will be their degree of impact, *etc.*, which do not only concern issues of a qualitative character, have not had the necessary quantitative corroboration.

The Basel committee has taken care when conducting studies that simulate extreme events in which a large number of banks from the member states of the committee take part, in order to form reliable risk management strategies and create a framework of preventive supervision of credit institutions [2,6–8]. There have also been a number of works published that examine issues related to dealing with, or avoiding, extreme adverse situations [9–11].

In this paper, an attempt is made to examine, for extreme or stress conditions, the effect of the Basel II accords on Greek banks, which are active in Greece, listed on the Greek stock market, and supervised by the central bank of Greece. In particular, after conducting a series of alternative adverse scenarios for various factors, the new capital requirements were estimated according to the Basel I approach and both Basel II approaches. In addition, the convergence or divergence of each approach for both accords was evaluated with regards to the evaluation of three "representative banks," each of which forms a "synthesis" of three categories of banks (small, medium, and large) to which the set of the main Greek banks was partitioned and which form the sample selected. Mainly, there was a model developed based on the alternative approaches for computing capital requirements (standardized approach and internal ratings approach), introduced by the Basel I and II accords, and we applied a series of simulation scenarios for extreme adverse conditions. The execution of the scenarios aims at studying the effects which may be brought about on the capital of the three representative banks by the appearance of adverse events. In this research, an adverse event was considered to be the increase of defaults on the portfolios of the banks which affects the levels of risk tolerance of the bank and, hence, its survival or collapse.

2. Data and Model Development

2.1. General

In the empirical study conducted, taking into account the requirements laid out by the second Basel accord in combination with the principles that the international accounting standards pose and the operational structure of Greek banks, it was considered that it is particularly important to create a model that will be in a position to estimate credit risk based on the supervision framework. During the development of the model, it was taken into account that each bank is characterized by particularities which concern the type and range of its functions, the bank risks taken, and the efficiency of the policy that sets the amount of demanded equity capital, which requires specialized investigation and evaluation. The development of the model is based on the application of the procedures and approaches introduced by the two existing accords and analysis of the total level of supervisory and economic capital. In particular, for the Basel II accord, two approaches were followed: the standardized approach and the internal ratings approach. The model accepts elements which characterize the type of credit exposures, *i.e.*, the product type, the remainder of the exposure, the current delay, the level or type of collateral, the provision on risks taken, the probability of default, the loss given default, and the

exposure at default. Hence, the model is in a position to estimate the risk of bank portfolios, since it accounts for the risk from lending, in order to determine the respective capital requirements against credit risk and the capital adequacy of banks. In particular, the model formed provides important information to analysts so that they can come up with immediate results concerning the change in capital requirements of a bank during the transition from one methodology to the other. It will mainly provide information, either for supervisory reasons or internal information of the level of capital maintained depending on the nature of activities and the risks which are taken by a bank, based on the methodology followed. In this way, it will contribute: (a) In the evaluation of the financial earnings of a bank; (b) In the evaluation of the marginal contribution of each element to the total risk of the bank's portfolio; (c) In the more accurate pricing of a loan, where the risk of the loan will appear more correctly; (d) In the creation of an alternative form of pricing the safety of a deposit as opposed to those based on the option pricing models [12]. Finally, each bank, through making the proper calculations, will be in a position to know the effects on its capital requirements by making the decision to move from one methodology for calculating its capital requirements to another, what investment opportunities there will be, and what capital relief it will have based on the structure and quality of its portfolios as well as the insurances it has registered.

2.2. Sample, Model, and Analysis of Bank Financial Data

The model accepts aggregate data per product type, risk category, type of collateral, *etc.* The data that feed the model come from balance sheets, yearly reports, and supervisory reports for the year 2007. The data collected concern financial data, current and overdue loans appearing in the portfolios of Greek banks, provisions, and the values of the parameters which the Basel accords and, hence, the Bank of Greece imposes for estimating the credit and operational risk as well as the calculation of the banking institutions' capital adequacy. Supervisory data were provided by the Bank of Greece for the time period of 2007 and consisted of supervisory confidential data per the Bank for:

1. Balances of current, in arrears and non-performing loans (the Bank of Greece
   Governor's Act 2442/99) with a breakdown by:
   - Consumer loans
   - Mortgage loans
   - Business loans (SMEs and Corporate)
2. Supervisory provisioning requirements (banks provisions) according to the Bank of
   Greece Governor's Act 2442/1999

Initially, a grouping of the banks' samples, containing the main Greek banks, into three separate groups, was attempted based on the size of the assets. The sample taken consists of the financial data of 18 Greek banks doing business in Greece, listed on the Greek stock exchange supervised by the Bank of Greece and whose total assets correspond to about 80%–90% of the assets of the entire banking sector in Greece. The application of the methodology developed [13,14] led us into grouping the banks in the following categories: (a) The category of the large banks which includes the four largest banks (Bank 1); (b) The category of medium size banks which includes the next four banks based on size (Bank 2); (c) The small banks category which includes ten banks (Bank 3). During the

development of the model, the risk-weighted assets for each case were calculated. Following that, there were various scenarios applied in which the risk elements change such as the level of exposure, the probability of default and the loss given default. After that, the new capital requirements were calculated based on the new conditions (whether the results were worse or not).

It's worth noting that 2007 was a crucial period for Greek banks since, starting from August 2007, the financial crisis began to exert upward pressure on bank interest rates in the money markets of developed economies while the monetary and credit magnitudes kept on exhibiting large increases. The three banks that came out as a result of these groupings possess the following financial data appearing in Table 1.

Table 1. Basic Indicators Analysis by Bank.

	Banks	Bank 1	Bank 2	Bank 3
	Assets (in EUR)	235,713,397,000	76,312,377,172	24,824,817,920
	Capital (in EUR)	16,907,423,000	3,816,164,278	2,149,518,304
Profitability	**Profit/Capital**	17.72%	12.17%	9.47%
	Profit/Risk Weighted Assets	1.95%	1.03%	1.14%
	Net Interest Margin	3.04%	3.08%	2.63%
	Net Interest Income/Risk Weighted Assets	3.39%	4.00%	3.17%
Risk-Capital Adequacy	**Risk Weighted Assets/Total Assets**	65.21%	59.16%	72.24%
	Core Equity Ratio	9.67%	8.43%	10.86%
	Capital Adequacy Ratio	13.77%	9.31%	12.91%
Provisions Adequacy	**Annual Provisions/Net Interest Income**	16.24%	20.46%	20.94%
	Accounting Provisions/Regulatory Provisions	65.73%	96.74%	76.84%
	Non-Performing Loans Net of Provisions/Regulatory Capital	14.62%	46.07%	24.91%
	Regulatory Provisions Shortfall/Regulatory Capital	4.51%	3.65%	10.67%

Data covers one year (2007) and the first two lines are aggregates (sums) for that year per bank group (Bank 1, 2 and 3), whereas the rest of the lines are financial ratios calculated on the aggregated financial elements for each bank group. From the analysis of the above indices and magnitudes for the set of the three banks the following are implied:

Bank 1 exhibits the greatest capital return (17.72%) and the strongest capital adequacy (13.77%). Furthermore, it has taken satisfactory low risks (mean RW 65.21%). Its provisions, based on the International Accounting Standards (IAS), are much lower compared to supervisory provisions, but this difference is very small relative to its supervisory capital and cannot effect its strong capital adequacy index. The small magnitude, computed based on the provisioning policy followed, is likely to be due to the advanced risk management systems which allow the ability of a more accurate risk measurement. Possible improvements can be: (a) Improvement of loan pricing since the index of net interest revenue to risk-weighted assets could reach 4% of Bank 2; (b) Increasing the level of risk since its capital adequacy index is very high (13.77%) and could easily reach 11.5% and, from that, expect higher returns.

Bank 2 has a medium capital return (12.17%) but the lowest capital adequacy (9.31%). Although its provisions are judged as satisfactory, in comparison with the supervision provisions, and the mean RW (59.16%) is the lowest out of all three banks, the capital efficiency index is low due to the small

(in comparison) size of its capital. The bank has a more effective pricing of loans (and deposits), where the index of net interest income to risk-weighted assets is equal to 4% but lags behind on all other sources of revenue. Therefore, the overall index of efficiency is much smaller compared to that of Bank 1. Possible improvements are capital increase, revenue increase from other sources other than interest and introduction of risk measurement systems and a more accurate and effective provisions policy. Bank 3 has the lowest capital return (9.47%) and takes the highest risks (RW = 72.24%). Its capital is sufficient at present with a capital adequacy index of 12.91%, but the lack of provisions relative to supervision provisions can mean that the capital adequacy index is really at 11.5%. This bank may be in danger due to defaults since it is taking more risks (relatively). It looks likely that it will need a capital boost in the medium run and that it is necessary to improve the pricing of its deposits-loans as well as increase its revenue from other sources.

2.3. Application of Basel Accords Approaches

2.3.1. Standardized Approach

In order to compute the capital requirements based on the standardized approach, the various exposures were classified into categories according to their supervisory handling, *i.e.*, (a) Exposure to small business credit (Small Enterprises); (b) Exposure to large business credit (Large Corporate); (c) Exposure to mortgage loans whose loan to value (LTV) is greater than 75%; (d) Exposure to mortgage loans whose loan to value is less than 75%; (e) Consumer credit and credit card exposure (Retail); (f) Loans in default for all the above categories of loans. Following this, all loans in default are grouped in two categories: those that are sufficiently covered with an element which includes supervision relief (defaulted (Provisions > 20%)) and those insufficiently covered (defaulted (Provisions < 20%)). The distribution of provisions depends on the cover percentage which is a model parameter. The provisions are then calculated and subtracted from the exposures thus generating the net exposures. Finally, for the calculation of the risk-weighted assets, the provision coefficients are applied to the net exposures. The final values of the distributions of exposures to third party non-payment were regulated in such a way so that the total provision for all products agrees with the total provision of the scenario, which in turn is set by the user. The provisions for the various products were set such that they are in agreement, as an order of magnitude, with those that result from the Act 2442/1999 of the Governor of the Bank of Greece [11] and the conditions of the market.

Following this, the respective capital requirements were calculated and interpreted for each one of the three representative banks and for alternative scenarios simulating extreme events based on risk increase. The application of the standardized approach leads to a different change of the capital adequacy index (Y) for each bank with respect to the increase of loan payment defaults (X). This is due to the different risks and assets structures corresponding to each bank. However, it is evident that the increase in loan defaults will affect the provisions and, hence, the profitability and capital. Secondly, it will increase the risk-weighted assets. As a whole, the above consequences are put forth as a reduction in the capital adequacy index. In particular, for Banks 1, 2, and 3, the estimated capital adequacy functions are the following:

$$\hat{Y} = -0.0191X + 0.1596, R^2 = 0.9961 \tag{1}$$

$$\hat{Y} = -0.0413X + 0.0107, R^2 = 0.9958 \tag{2}$$

$$\hat{Y} = -0.0346X + 0.1388, R^2 = 0.9960 \tag{3}$$

The Regressions (1–3) relate the capital adequacy index (Y) for each bank with respect to the increase of loan payment defaults (X). The observations are not time series but nine outcomes of stress scenarios.

Bank 2 appears to be worse than the other two, with regard to its performance, since the regression line of Function (2) starts from lower levels, whereas its slope is the greatest (0.0143). This is so because the capital adequacy of Bank 2 is at the borderline. Furthermore, its profitability cannot compensate appropriately for the defaults that come up in the extreme events simulation scenarios. Indeed, an increase in defaults by one percentage point will bring about a reduction in the capital adequacy index equal to 0.0413 percentage points while the capital adequacy index is equal to 6.7%.

Bank 3 presents a medium situation relative to Banks 1 and 2. An increase in defaults by one percentage point will bring about a reduction in the capital adequacy index equal to 0.0346 percentage units while the capital adequacy index will be equal to 10.4%. The slope of defaults is greater, relative to Bank 1, and lower relative to Bank 2. This implies that changes in defaults affect the capital requirements of Bank 3 more intensely, relative to Bank 1, while this degree of effect is lower compared to Bank 2.

Hence, of the three banks, Bank 1 has a better head start with respect to the capital adequacy index, *i.e.*, for zero defaults the level of its capital requirements is 16%. The slope of the corresponding line is also smoother since Bank 1 is larger than the other two banks. Both of these factors (the index head starts and line slopes) take on satisfactory values, as expected, since the capital efficiency of this bank is more powerful with respect to the others, while the capital efficiency index, which states the profitability level of the bank with respect to the risks it takes, is better.

2.3.2. Internal Ratings Approach

In order to compute the capital requirements using the internal ratings approach, the various exposures were categorized in the same pools for the standardized approach. Following this, the actuarial method was applied, *i.e.*, the division of exposures into pools of similar loans with respect to the level of risk. The risk is determined based on the probability of default and the loss given default of each pool of non-defaults.

Initially, using the internal ratings approach, an effort was made to examine if the changes introduced by Basel II lead to a reduction or an increase of the capital requirements and an effort was made to estimate this change. For each bank, three scenarios were applied based on the degree of default loan coverage by provisions. In particular, the first scenario concerns a low coverage of default loans by provisions (0%), *i.e.*, all default loans are either not covered or are covered with provisions below 20%. The second scenario concerns the intermediate cover (50%), *i.e.*, 50% of default loans are covered by a provision higher than 20%. The third scenario concerns a great (full) cover (100%), *i.e.*, 100% of default loans are covered with a provision higher than 20%. The coverage percentage of defaults by provisions is a basic parameter for the final calculation of the capital requirements that

banks will uphold. In particular, greater coverage of defaults by provision will lead to the upholding of lower capital requirements. This percentage, however, depends on the size of the bank as well as the efficiency of its provisions.

The effect on the capital requirements brought about by the application of the Basel II internal ratings approach depends on many factors. The most important of these factors are the exposures and the respective probabilities of default, loss given default, and exposure at default which concerns all the exposures of the loan provision portfolio. These three parameters are simultaneously found for the first time in the capital requirements calculation. For this reason, the capital requirements calculation made is differentiated from the framework set by Basel I as well as the standardized approach of Basel II. The probability of default (PD) and the loss given default (LGD) were computed in such a way so that the provisions made through them are equal to the IAS provisions (Scenario 3) as well as an intermediate scenario (Scenario 2). In the present study, the application of PD and LGD in Scenario 1 was chosen, which is pessimistic but also particularly realistic in crisis periods, since the total capital requirements are increased. In this case, there is a reduction in capital requirements for credit risk but an increase in capital requirements due to operational risk and lack of provisions. The total result is the increase of capital requirements. For this scenario, considered realistic, the following can be observed: the greater reduction in risk-weighted assets (RWA) is observed in mortgage and retail loans as far as Bank 1 is concerned. With respect to Bank 2, besides the two cases mentioned, there is also a reduction in retail banking business loans. Also, for Bank 3 there is a reduction appearing in mortgage and retail loans while small enterprises loans also exhibit a reduction which is, however, smaller. For Bank 1 and the first scenario defined as the strict version, *i.e.*, risk indices are stressed and the provisions calculated surpass those in the books, we noted an increase in risk-weighted assets by 6.8%. For the second scenario, defined as the intermediate state between the first and third scenarios, we noted a decrease of the risk-weighted assets on the order of 22.6%. Finally, for the third scenario in which the provisions calculated approach the supervision provisions, we noted a reduction of the order of 53.9%. For Bank 2, there was only one scenario developed in which there is a decrease of risk-weighted assets by 12.5%. For Bank 3 and the strict scenario, we have a worsening of 7.8%. For the intermediate scenario, we have a reduction by 24%. We note that the deviation of the capital requirements in the case of the internal ratings approach is much more prone to changes, with respect to Basel I, and, in essence, depends on the values of the risk parameters as these appear in the scenarios. A change in these parameters can bring about an important reduction of capital requirements.

Following that, the capital requirements were calculated with the internal ratings approach for the three banks using alternative values for the risk parameters. In the six tables that follow, the results are given from the various scenarios applied on each bank. In the first five columns of Tables 2, 4 and 6 the results under normal conditions, *i.e.*, for the no extreme case scenarios appear. The next two columns of these tables show the results produced by the conduct of the extreme events scenario for each bank (Bank 1, Bank 2, and Bank 3). In particular, in the extreme event scenario, we examine the effect of increasing the probability of default by +100% on the capital requirements held by Bank 1 in the case where the internal ratings approach has been adopted.

In the following Table 2, the first column concerns the kinds of bank portfolios. The next three columns concern the portfolios balance as well as the risk weights as defined by the Basel I (RW Basel I) and Basel II (RW IRB) approaches for each exposure. The expected loss (EL) is the sum identified by

Bank 1 as the exposure's expected value. It is defined as the product of probability of default (PD), the loss given default, and the exposure at default (EAD). In this case, the percentage mentioned in Table 2 is the probability of default times loss in the case of loss. It is an indication of the risk each exposure contains. The sixth and seventh columns representing the results of the extreme case scenario for the bank are defined in a similar manner. For exposures at default, the probability of default has been set at 100% and, as a result, the percentages appearing are very high and are due to loss in case of default. As a consequence, the banks have identified a very large expected loss for exposures of this kind.

Table 2. Bank 1: RW analysis per portfolio for normal conditions and extreme scenarios.

Portfolio Type	Balance in th. EUR	RW Basel I	Normal Conditions		Extreme Scenarios	
			RW IRB	EL	RW IRB	EL
Small Enterprises (non-defaulted)	20,317,708.53	100%	94.57%	1.52%	120.65%	3.03%
Small Enterprises (defaulted)	882,523.47	100%	0.00%	45.10%	0.00%	45.10%
Large Corporate (non-defaulted)	63,693,041.47	100%	101.56%	0.74%	132.06%	1.48%
Large Corporate (defaulted)	2,719,584.53	100%	0.00%	52.01%	0.00%	52.01%
Mortgage LTV < 75% (non-defaulted)	30,035,466.00	50%	24.44%	0.17%	38.88%	0.34%
Mortgage LTV < 75% (defaulted)	1,093,453.00	50%	0.00%	30.00%	0.00%	30.00%
Mortgage LTV > 75% (non-defaulted)	3,397,417.00	50%	40.73%	0.29%	64.80%	0.57%
Mortgage LTV > 75% (defaulted)	152,839.00	50%	0.00%	50.00%	0.00%	50.00%
Retail (non-defaulted)	19,329,601.00	100%	55.10%	2.02%	86.83%	4.04%
Retail (defaulted)	901,719.00	100%	0.00%	65.54%	0.00%	65.54%

With the application of the coefficients set by the Basel accord, the risk-weighted assets will be equal to 125.2 billion euros, while with the internal ratings approach, it will be equal to 103.2 billion euros. After conducting a study of the extreme event scenario, the capital requirements that Bank 1 must uphold will be equal to 11 billion euros. As was expected, the capital requirements increased in order for the bank to meet its defaults increase without burdening its depositors and, at the same time, maintain the required stability of its activities and ensure its solvency to depositors and investors. The development of such a scenario consists of a very extreme assumption that there is a 100% increase on current defaults. Due to its size, Bank 1 seems to be able to cope since the withheld capital continues to lag behind the level of the total provisions portfolio (3.2 billion euros). Table 3 of the extreme probability default increase realized for Bank 1 is included below.

Regarding Table 3, it is noted that: (a) The first column (% increase of PD) concerns all the probability of default scenarios executed, with the most favorable the increase in probability by +0% and most unfavorable the increase in probability by 160%; (b) The second column (RWA AIRB credit) is the risk-weighted assets of Bank 1 for all the gamut of scenarios concerning the increase in the

probability of default in order to deal with the credit risk; (c) The third column (RWA operational) is the contribution of the risk-weighted assets due to operational risk; (d) The fourth column (RWA provision shortfall) corresponds to the contribution to the risk-weighted assets due to a shortfall in provisions made, since the likelihood of this state being realized is an extreme expression which was unexpected by Bank 1. As the probability of default increases, the shortfall in provisions will increase similarly; (e) The fifth column (total RWA (excluding market risk)) represents the final set of RWA which corresponds to each scenario of probability of default increase. In these risk-weighted assets, the capital requirements against market risk are not included since this risk is not an issue of examination in the current work; (f) The sixth column (% increase in RWA) represents the percentage expression of the change in added RWA upheld, depending on the scenario of probability of default increase. An increase in probability, as expected, will lead to an increase of that percentage. The synthesis of the various scenarios developed leads to the following estimated regression function for risk-weighted assets (Y):

$$\hat{Y} = 0.3605 \, PD - 0.3411, \, R^2 = 0.9967 \tag{4}$$

The slope of Function (4) is equal to 0.36, *i.e.*, an increase in the probability of default by *x*% causes an increase of the risk weighted assets by 0.36 × *x*%. Similarly, for Bank 2, there are a series of simulations scenarios conducted. The methodology followed is the same as in Bank 1.

Table 3. Bank 1: stress scenarios for different levels of PD increases (th. EUR).

% Increase of PD	RWA AIRB Credit	RWA Operational	RWA Provisions Shortfall	Total RWA (Excluding Market Risk)	% Increase in RWA
0%	103,276,900	11,738,372	17,298,780	132,314,053	
20%	111,967,114	11,738,372	20,376,918	144,082,404	8.89%
40%	119,705,155	11,738,372	23,455,055	154,898,583	17.07%
60%	126,738,816	11,738,372	26,533,192	165,010,382	24.71%
80%	133,230,889	11,738,372	29,611,329	174,580,592	31.94%
100%	139,292,584	11,738,372	32,689,466	183,720,424	38.85%
120%	145,002,340	11,738,372	35,767,603	192,508,317	45.49%
140%	150,416,993	11,738,372	38,845,741	201,001,108	51.91%
160%	155,578,701	11,738,372	41,923,878	209,240,953	58.14%

Table 4. Bank 2: RW analysis per portfolio for normal and extreme scenarios.

Portfolio Type	Balance in th. EUR	RW Basel I	Normal Conditions		Extreme Scenarios	
			RW IRB	EL	RW IRB	EL
Small Enterprises (non-defaulted)	6,784,562.74	100%	88.95%	1.32%	113.0%	2.6%
Small Enterprises (defaulted)	541,833.26	100%	0.00%	41.09%	0.0%	41.1%
Large Corporate (non-defaulted)	12,787,654.26	100%	109.37%	0.95%	141.1%	1.9%
Large Corporate (defaulted)	2,004,114.74	100%	0.00%	47.63%	0.0%	47.6%
Mortgage LTV < 75% (non-defaulted)	15,065,652.00	50%	15.38%	0.10%	24.6%	0.2%

Table 4. *Cont.*

Portfolio Type	Balance in th. EUR	RW Basel I	Normal Conditions		Extreme Scenarios	
			RW IRB	EL	RW IRB	EL
Mortgage LTV < 75% (defaulted)	826,638.00	50%	0.00%	20.80%	0.0%	20.8%
Mortgage LTV > 75% (non-defaulted)	1,380,297.00	50%	33.28%	0.22%	53.3%	0.4%
Mortgage LTV > 75% (defaulted)	86,289.00	50%	0.00%	45.00%	0.0%	45.0%
Retail (non-defaulted)	5,891,266.00	100%	68.88%	2.78%	106.0%	5.6%
Retail (defaulted)	617,096.00	100%	0.00%	70.00%	0.0%	70.0%

With the application of the coefficients set out by the first accord (Basel I), the capital requirements will be equal to 3 billion euros, while with the internal ratings approach, these will be equal to 2 billion euros. After conducting the extreme events scenario analysis, the capital requirements the bank will have to uphold will be equal to 3 billion euros. The capital requirements increased so that the bank will be able to cope with the defaults increase without burdening the depositors and for the required stability of its activities to be maintained and, at the same time, ensuring its depositors and investors. The development of such a scenario contains a very extreme assumption, the increase of defaults by +100% on their current level. Due to its size, the bank seems to be able to cope since the capital withheld continues to fall short of its supervision capital. The following is Table 5 for all extreme event scenarios concerning an increase in the probability of default conducted for Bank 2.

Table 5. Bank 2: stress scenarios for different levels of PD increases (th. EUR).

% increase of PD	RWA AIRB Credit	RWA Operational	RWA Provisions Shortfall	Total RWA (Excluding Market Risk)	% Increase in RWA
0%	26,855,534	4,049,827	896,262	31,801,624	
20%	29,126,924	4,049,827	1,879,899	35,056,652	10.24%
40%	31,166,858	4,049,827	2,863,537	38,080,223	19.74%
60%	33,035,450	4,049,827	3,847,174	40,932,452	28.71%
80%	34,771,310	4,049,827	4,830,811	43,651,950	37.26%
100%	36,400,240	4,049,827	5,814,449	46,264,517	45.48%
120%	37,940,052	4,049,827	6,798,086	48,787,967	53.41%
140%	39,403,402	4,049,827	7,781,723	51,234,955	61.11%
160%	40,799,518	4,049,827	8,765,361	53,614,708	68.59%

As in the previous cases, the scenarios conducted regarding an increase in the probability of default appear as well as the effects brought about on the capital requirements of the bank. In all cases, the change in capital requirements is positive since the final level for all of these cases increase in order for the specific risk parameter (PD) to be covered. The estimated regression function of the risk weighted assets (Y) for the various scenarios applied is the following:

$$\hat{Y} = 0.4250PD - 0.4060, R^2 = 0.9975 \tag{5}$$

Hence, an increase of the probability of default by *x*% causes an increase in risk-weighted assets by 0.425 × *x*%. Similarly, for Bank 3, there is a series of simulation scenarios conducted. The methodology followed is the same as with Bank 1 and Bank 2.

With the application of the coefficients set out by Basel I, the capital requirements will be equal to 1.4 billion euros, while with the internal ratings approach, it will be equal to 1.1 billion euros. After conducting the extreme event scenario, the capital requirements that the bank will have to uphold are equal to 1.5 billion euros. Due to its size, Bank 3 seems to be just able to cope since the reserved capital continues to fall short of the level of the total provisions portfolio. Table 7 for all extreme event scenarios regarding the increase in the probability of default conducted on Bank 3 is included below.

Table 6. Bank 3: RW analysis per portfolio for normal and extreme scenarios.

Portfolio Type	Balance in th. EUR	RW Basel I	Normal Conditions		Extreme Scenarios	
			RW IRB	EL	RW IRB	EL
Small Enterprises (non-defaulted)	3,029,998.20	100%	92.72%	1.41%	117.92%	2.81%
Small Enterprises (defaulted)	133,887.90	100%	0.00%	43.64%	0.00%	43.64%
Large Corporate (non-defaulted)	8,787,838.80	100%	102.32%	0.89%	132.03%	1.77%
Large Corporate (defaulted)	562,380.10	100%	0.00%	44.60%	0.00%	44.60%
Mortgage LTV < 75% (non-defaulted)	2,707,838.00	50%	14.79%	0.10%	23.67%	0.20%
Mortgage LTV < 75% (defaulted)	96,409.00	50%	0.00%	20.00%	0.00%	20.00%
Mortgage LTV > 75% (non-defaulted)	1,227,767.00	50%	33.28%	0.22%	53.25%	0.45%
Mortgage LTV > 75% (defaulted)	86,822.00	50%	0.00%	45.00%	0.00%	45.00%
Retail (non-defaulted)	2,007,165.00	100%	75.77%	3.06%	116.58%	6.12%
Retail (defaulted)	301,757.00	100%	0.00%	77.00%	0.00%	77.00%

Table 7. Bank 3: stress scenarios for different levels of PD increases (th. EUR).

% increase of PD	RWA AIRB Credit	RWA Operational	RWA Provisions Shortfall	Total RWA (Excluding Market Risk)	% Increase in RWA
0%	14,130,925	1,470,158	2,278,487	17,879,571	-
20%	15,256,094	1,470,158	2,746,897	19,473,151	8.91%
40%	16,258,985	1,470,158	3,215,307	20,944,452	17.14%
60%	17,172,713	1,470,158	3,683,717	22,326,590	24.87%
80%	18,018,469	1,470,158	4,152,127	23,640,757	32.22%
100%	18,810,337	1,470,158	4,620,537	24,901,035	39.27%
120%	19,557,971	1,470,158	5,088,948	26,117,079	46.07%
140%	20,268,164	1,470,158	5,557,358	27,295,682	52.66%
160%	20,945,811	1,470,158	6,025,768	28,441,740	59.07%

As in the previous cases, all the scenarios of probability of default increase are shown, together with the effects on the capital requirements of banks. In all cases, the change in capital requirements is positive since, for all of these, their final level is increased in order to cover the risk parameters (PD). The estimated regression function of risk-weighted assets (Y) for the scenarios applied is the following:

$$\hat{Y} = 0.3665PD - 0.3483, R^2 = 0.9963 \tag{6}$$

i.e., an increase of the probability of default (PD) by *x*% causes an increase of risk weighted assets by 0.3665 × *x*%.

The Regressions (4–6) relate the percentage increase of PD to the percentage increase of risk-weighted assets RWA (Y) for each bank. The observations are nine outcomes of simulated stress scenarios. In this respect, we could have followed a simple straight line fitting (interpolation) method to our data and not statistical regression.

Regarding the high *R* square in all six regressions, it is worth noting that regressions are not spurious as our data were not time series but a comparatively small number of outcomes of stress scenarios that a statistical regression is not applicable. In this case, a linear model fitting or interpolation to apparently linear data would have been more appropriate. The methodology that we have applied is in accordance with the methodology applied by the European Banking Authority (EBA) in 2011 and 2014 EU-wide stress testing [15,16].

3. Conclusions

The role of simulation scenarios of extreme events lies in exhibiting the effects of extreme market events on the financial state of the bank. In this case, we examined the effects of an increase in loans at default on the capital adequacy index. The increase of loans at default will affect primarily the provisions made and, hence, the profitability and capital and, secondly, it will increase the risk-weighted assets. As a whole, their effects will be demonstrated by a reduction in the capital adequacy index.

Applying the standardized approach, we conducted extreme event simulation scenarios in the form of multiple trials increasing the defaults by varying percentages, starting with a 50% increase and ending up at a 170% increase of loans about to come under default. The result is that, per 100 basis units increase in defaults, there is a fall in the capital adequacy index by 2 basis points for Bank 1, 4 basis points for Bank 2, and 3.5 basis points for Bank 3. The aforementioned values are formed by two parameters. The percent of current loans at default in the portfolio is considered as the first parameter. The current profitability and capital is considered as the second parameter, since these constitute the factors that will absorb the added provisions that result based on the simulation scenario. The results show that Bank 1 coped without problems against all of the extreme event simulation scenarios conducted. This is due to its high capital adequacy as well as its high profitability. Bank 2 has a very slight capital adequacy, and its profitability is such that it will just be able to withstand an increase of up to 60% of its portfolio defaults. An increase of 100% on its defaults will lead to a reduction of its capital adequacy index below 7%, a percentage smaller than that defined by Basel but also what the Bank of Greece views as acceptable. Bank 3 can absorb the extreme event simulation scenarios to up to a 170% increase in defaults. As a consequence, this bank can also be considered as strong, capital-wise, but not as much as Bank 1. Given that the provisions made, however, are likely to be insufficient, the above threshold of the simulation scenarios it can absorb will be much lower than the initial estimate of 170% and will lie at just 100%. In conclusion, the application of the standardized approach based on Basel II will lead to a new evaluation of the capital adequacy index for all three banks. With regards to the static value of the index, this will not change compared to the value that would have resulted based on the Basel I accord. The reduction in capital requirements against credit

risk will be compensated by the added capital requirements against operational risk. This element will not change the final decisions that have been taken by the banks relative to the configuration of their capital level (whether they increased or not). The dynamic picture, *i.e.*, the way in which the capital adequacy index will evolve in the future for each bank, will be different from what it would be based on the Basel I accord. From the analysis conducted, it seems that this new methodology introduced by Basel II favors both the retail portfolio as well as the mortgage loans. Furthermore, the standardized approach favors secured loans while it "punishes" delinquencies. Bank 1, although it looks to be strong capital-wise, has a capital adequacy that may be drastically reduced with the appearance of delinquencies. In spite of this, due to the fact that it appeared to be robust in the scenario of the extreme event simulation conducted, it could take more risks compared to the other two banks. Bank 2 needs a capital increase, since, for an intermediate extreme event scenario, the capital adequacy index would collapse. With the present situation, this bank could expand to provisions of very low risks and sufficient coverage, e.g., by certain mortgage loans. For Bank 3, the capital adequacy index could easily collapse. Furthermore, since it does not have the ability to expand into big business loans, its expansion can be based on small loans with greater dispersion. The risk it can take involves the provision of retail banking loans with a relatively high spread (consumer, small enterprises) but up to only a given percentage of exposure on the total of its provisions portfolio. For all three banks, the conclusion is drawn that they must modify the pricing of their loans and their credit provision policy so that they are in a position to correspond sufficiently to the new rules of capital adequacy defined by the framework of Basel II [2].

In order to examine the effects from the internal ratings approach, there was a series of scenarios of extreme events with a uniform increase in the probability of default for all portfolios starting from 20% up to 160%. Such an increase affects the capital requirements by increasing the provisions and the risk-weighted ratios. It also affects both the numerator and denominator of the capital adequacy index. In order for there to be a unified approach, these two effects were put forward as an increase of risk-weighted assets (denominator). The results obtained are the following: the risk weighted assets increase almost linearly with respect to the probability of default. In particular, every 10% increase of PD causes an increase of risk-weighted assets by 3.6%, 4.3%, and 3.7% for Bank 1, Bank 2, and Bank 3, respectively. This means that, as in the standardized approach, Bank 2 is more sensitive compared to the other two to extreme event tests. However, in this case, both the PD and LGD of the exposures are important. In all banks, based on the scenarios conducted, there is a drop in the capital adequacy index observed. This means that, in all banks, the growth possibility is limited and there is a need for more effective risk management. In particular, for Bank 2, where the capital adequacy index was barely sufficient, there will have to be a capital increase. Bank 1 seems to be the strongest bank having the most capital and a higher index. The internal ratings approach can adversely affect its capital adequacy if it takes more risks that it can stand. It seems that, given its portfolio, retail banking loans are favored. In spite of this, this bank could also take on good quality large business loans. Bank 3 is the second strongest, but, due to its small size as well as its capital, it wouldn't be able to take risks against large business loans. Finally, Bank 2 needs to increase its capital. Its index based on the internal ratings approach is below 8%, which means that it doesn't have any growth prospects. It could be in the interest of the bank to apply the standardized approach and not the internal ratings approach. In a crisis period, the capital requirements will be doubly hurt both from the increase of defaults as well as the

probability of defaults. This means that the banks must take timely measures in order to compensate this risk. In the internal ratings approach, this is feasible since the tools exist as well as the models for measuring and managing credit risk. The credit policy can be defined appropriately through the system of provision grading, collaterals, appropriate pricing, and risk management, both at the client level as well as the portfolio level.

Comparing the quantitative results regarding extreme event scenarios for both approaches, there are small changes observed to the capital requirements for the standardized approach in the various scenarios examined, while there were much larger changes in the calculation of the capital requirements with the internal ratings approach. The choice of the internal ratings approach can bring about important capital relief when the portfolio is of good quality. The bank, in this particular case, will have the benefit of low capital requirements in good periods while it will take the risk of having high capital requirements in bad periods. The bank, in such a case, will either have to tighten its credit provisions policy, so that it avoids the worsening of its portfolio (which means that there are appropriate credit and risk management mechanisms) or, in the worst case, it must have the ability to be backed up in terms of capital. This seems realistic for bigger banks which have the ability to invest in skilled personnel, necessary procedures, and more effective risk management but also have the capital to absorb the risk when it surpasses some limits. The smaller banks, in our opinion, and according to the results that emanate from our study, will have to adopt the standardized method. The only case for transferring to the internal ratings approach is by investing in products of low credit risk such as loans to high quality credit receivers, large dispersion, and good quality collateral. However, the return on such a portfolio will be very low. It is worth noting that a bigger bank would run a risk from adopting the internal ratings approach if it is not in a position to sufficiently control credit risk. A bad portfolio could lead to the collapse of capital adequacy. The internal ratings approach forces the bank, independently of its size, to develop a more accountable stand towards credit risk control and focus its attention on measuring, managing, and compensating it.

If we compare the stress test of our paper (exercised on data from the 2007 period) to the information we currently have regarding the state of the Greek banks during the Greek Crisis, we can make the following comments:

- The capital needs of the banks suggested by this current study are of the order of magnitude of 50% of the existing capital, whereas the corresponding capital needs (credit loss projections minus (−) loan loss reserves) for the period December 2011–2014 were of the order of magnitude of 100% [17] of the core tier 1 capital at that time.
- If we compare however the capital needs suggested in our study to those of the period after the peak of the crises (2013–2016) are of the same order of magnitude [18].

This means that our stress study before the crises did not capture the totality of the magnitude of credit losses appearing at the peak of the crisis, as probably the majority of stress tests did at that time. Recent experience helped the policy makers and risk managers to shape more reliable stress tests that can capture a larger variety of extreme events.

Finally, a more general policy regarding stress tests of financial institutions in Greece can be aided by the introduction of IRB in all banks for stress test purposes, as it is a much more reliable method for demonstrating the effects and the changes in risk. Additionally, the difference between the results of

the stress test of the current study and what actually happened at the peak of this crisis suggests that subsequent stress test approaches have to incorporate relative or larger macroeconomic shocks in the study of the effects of adverse economic events.

Regarding Basel III [19], the banks will face increased capital requirements and increased cost of funding, which will put pressure on margins and, in adverse economic conditions, the weaker banks will find it more difficult to raise the required capital. Increased capital and liquidity requirements may lead to a reduction of banking activity; however, the increased capital buffers will reduce the risk of individual banking failures.

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Author Contributions

Both authors contributed extensively to the work presented in this paper. J.L. and A.D. are equally contributing first authors.

Acronyms

RW Basel I: Risk Weight Basel I
EL: Expected Loss
PD: Probability of Default
LTV: Loan to Value
RWA: Risk Weight Assets
RW: Risk Weight
IRB: Internal Ratings Approach
AIRB: Advanced Internal Ratings Approach

Conflicts of Interest

The authors declare no conflict of interest.

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