ABSTRACT

This paper is inspired and based on Complexity Economics as developed by the Santa Fe Institute.

The paper is divided into three parts. The first part is an approach to risk control in finance, emphasizing measurable risk and uncertainty as two different ways to deal with risk; this part must be considered as the historical perspective. In the second part we maintain that today financial risk management is a more complex subject after the crisis, identifying the main issues in post-crisis risk management for financial institutions. In the third part we present a new methodology called Risk Dynamics into the Future (RDF), which is able to correct the biases implied in traditional methods: uncertainty, not-symmetrical interactions, not observable correlations, missing significant risk, lack of scalability and integration, poor estimation of the diversification effects. RDF it is a bridge between the current economic thought on financial risk management represented by the Value at Risk (VaR), a methodology based on historical data, and a model of scenarios to identify risk into the future.
FINANCIAL CRISIS AND RISK MEASUREMENT. THE HISTORICAL PERSPECTIVE AND A NEW METHODOLOGY

“The revolutionary idea that defines the boundary between modern times and the past is the mastery of risk: the notion that the future is more than a whim of the gods and that men and women are not passive before nature. Until humans being discovered a way across that boundary, the future was a mirror of the past or the murky domain of oracles and soothsayers who held a monopoly over knowledge of anticipated events”. Peter L. Bernstein (1996), page 1.

RISK CONTROL IN FINANCE: A RECENT HISTORY

In his book: “Against the gods: a remarkable story of risk”, Peter L. Bernstein (1966) does a thorough historical analysis of the concept of risk. He starts from the development of the laws of probability and the pretension of having statistical rules which allow the decision making process, and goes up to the 20th century to make a distinction between risk and uncertainty, being the former valuable and measurable while the last is not.

In Economics the concept of risk management as a practical technique, together with the use of statistical methods under certain theoretical assumptions, was introduced by Kenneth Arrow (1951, 1971) who was conscious of the impossibility of predicting the future and the contingencies associated with it. Therefore he developed a whole theory of diversification and insurance. The relevance of its thoughts lays in the fact that it considers the differences between the quantifiable and the non-quantifiable. That is the reason for us to establish him as a reference of global risk management as a theory and as a practical application to assure, diversify and control.

In an economic system, given long term equilibrium, time being the main variable, the probabilities of unexpected events are compensated during this long period. This could be the stock exchange case in which bull and bear periods produce in average a positive result, provide that we can remain invested in the long run. But uncertainty means that these regularities do not exist, and past data are by no means useful to predict any outcome. For that reason John Maynard Keynes after analysing uncertainty, design an economic policy model, with targets and instruments, trying to control the future and avoid risks.

The next step in the history of risk is to take into account the economic behaviour (Karl-Erik Warneryd (2001)). Game theory shows us that uncertainty depends on the behaviour of other players. Here we have strategies, formal and informal contracts, deals and herd behaviour. Diversification is a game theory strategy which seeks to maximize probabilities of surviving in case of big failures in risk calculations. These developments were loaded with quantitative techniques: the theory of probabilities, sample techniques, spreads around an average, the trade off between risk and profitability and the expected utility for investors. In G. Ruiz, J.L. Jimenez, J.J. Torres (2000) we analyse market, credit, operational, technological, liquidity, and legal risks. In a complex approach we can identify risk, to measure and manage it, and to value the managers according to their long run performance. In theory any aspect of risk could be considered but in practice some risks are not taken into account, or are approached only through probabilistic methods.

As a theoretical and practical subject risk management deals with risk valuation as well as with uncertainty, that is, situations that can be completely unknown to us. The following are three characteristics of uncertainty. Economic agents do not have enough information and understanding
for decision making, and their economic models do not catch with the complexity of economic reality. The historical view does not provide tools for a proper risk management, i.e., sound analytical methods with predictive power. Correlations between financial markets (bonds, commodities, equities, private equity, emergent countries, rate of exchange) that have been studied and established can change from positive to negative and the opposite, with devastating consequences for a portfolio aiming to diversification.

George A. Akerlof and Robert J. Shiller (2009) went back to a human behaviour analysis of risk taking. This methodology has deep roots in the history of financial risk thought, but lacks the tools for implementing his main ideas and principles. As we know there are not predictive models for herd behaviour considered a non-efficient market hypothesis, neither for extreme risk aversion nor for risk appetite. Nevertheless their hindsight is worth to take into account for financial risk analysis.

In the eighties Banker Trust tried to calculate a profit-capital ratio in terms of risk. The cost of the capital related to specific business and its profits was the implicit cost of risk taken to obtain these profits. The method was called “Risk Adjusted Return on Capital” (RAROC). As an example sales of options on equities could deliver high premium profits, but the risk of strong losses is also very high. The need of capital to match these losses is bigger in the options business than in others as simple trading with no risk retained. Both are bank activities but their profitability should be weighted by the risk that they take by the theoretical capital that each one requires. This policy was extended to every kind of business in the bank, such as the wage and bonuses policy for high level employees, considering the amount of capital that everyone “used”.

Risk analysis requires an operational data basis. The easiest risk to monitor is the more frequent, and it is very difficult to extend risk management to unforeseen risk events, with a low probability to happen. But we can not demise the basic idea that some factor of risk could be hidden in a good performance. That is true for the huge benefits of leverage in the years before the 2008 crisis that had an implicit risk of illiquidity.

In the late eighties J.P. Morgan (1997) developed a methodology for risk management. Riskmetrics is a data basis to calculate “value at risk” (VaR) a matrix of volatility correlations. Historical data of correlations and volatilities provides the maximum expected loss for a portfolio, for a period of time (say a day, a week, a month). The VaR calculation failed in the recent crisis due to the strong deviations in correlations and volatilities. New methods to measure risks are required. In this paper we introduce RDF as an alternative methodology to VaR.

During the late nineties Coopers & Lybrand, an audit and consulting firm that merged with Pricewaterhouse, developed a system called: “General Accepted Risk Principles” (GARP) which tried to deal with almost every situation of risk, encouraging the creation of independent departments for risk control and risk management, and clear definitions of responsibilities in the firms. These departments they were not only compliance and procedures reviewers but real risk control departments looking to establish limits to every line of products and business.

In the late nineties as well Goldman Sachs and Swiss Bank Corporations developed the concept of “stress testing” as a practical methodology for risk management. This idea was not new but at the time hardware and software facilities allowed to work with statistical methods and picture different scenarios for risk. But the “worst case scenario” is a concept that belongs in the realm of uncertainty as shown by the Long Term Capital Management (a huge investment fund that needs to be rescued by a group of investment banks). New methods combining macroeconomics and scenarios for specific asset portfolios, were needed.

The following are new data and issues in the recent history of financial risk that must be consider as a short-list of sources of troubles in the present crisis.

- Securitisation was a technique favoured as a way to spread risk and obtain liquidity. However there was a lack of responsibility in both the origination and structuring: on the left side of the balance sheet of the securitization vehicles, because of he poor quality of the assets, and in the right side due to an excess of leverage.

- There were imperfections in credit rating, and illiquidity problems for high rated assets were not considered.
-Capital requirements boost and shrink the balances of financial institutions in the high and low phases of the economic cycle. This fact accentuates GDP growth and employment deviations from potential growth and natural rate of employment.

-Regulators allowed big banks to have lower capital requirements if they had sophisticated risk models, but these models had produced ambiguous measures of risk.

-Large international banks so as local financial institutions push in the same direction, developing to better financial technology and models rather than basic credit and risk assessment.

We learn from the crisis that risk changes depending on who is holding it. Increase capital buffers at financial institutions, making them countercyclical, focusing in loans as basic measures of risk, are important issues but not enough to avoid liquidity troubles in the future. One main idea surging from the crisis is that liquidity risk is best held by institutions that do not require liquidity as pension funds, life insurance or private equity firms. On the other hand credit risk is best held by institutions that have plenty of credit risk to diversify such as retail banks and hedge funds.

These ideas are intended for the long run as a way to change behaviour when dealing with risk. They are a kind of consensus in today financial thought, but we need to go from consensus to action. We propose a methodology to test stress scenarios called: “Risk Dynamics into the Future” (RDF). RDF allows to asses the risk in different situations and we consider it as an ordinary method in modern financial thought.

**RISK MANAGEMENT AFTER THE CRISIS**

The following are some of the main issues in post-crisis risk management for financial institution:

- The need for stronger regulatory core capital.
- To take into account that high rated assets could be illiquid
- To gain more transparency in transactions.
- Improvements in risk control, governance and compliance.
- Inappropriate policies related to appointment of directors, bonus and payment systems have been identify as causes of poor risk management.
- Off-balance sheet operations deserve more attention as they constitute a new form of risk.
- Profits and dividends should be approached in a long run context.

Risk management is a more complex subject than in the past and an agreement should be reached around the following principles:

- The increase of core capital should be related to trading operation more than to stable positions.
- Its absolutely necessary to avoid the full business cycle impact on the needs of capital.
- Bank reserves against credit default must be anti-cyclical, that means more and less relative reserves in both the lower and higher phases of the cycle.
- The effects of asset valuation in the balance sheet need to be diminished looking for more stable long run valuations. Mark to market valuations provides very good information, but the specific role of each kind of asset in a business must be taken into account to determine their valuations.
- A limit to leverage will avoid the excess of credit that come with optimistic expectations about the economy.

- Liquidity deserves more regulation and supervision. The more long term investment are matched with short term liquidity positions, the more is the systemic risk for the financial system.

- Supervision needs to be extended to credit rating agencies. A discussion must be open regarding rating agencies criteria for valuation.

- Regulatory codes for director payments and bonuses must be implemented. The point here is to know how a payment system can introduce a bias in the management of the firm.

- Changes are necessaries in regulation and supervision to analyse business plans and risk taking strategies.

- More international coordination in regulation and supervision is needed.

At the beginning of the crisis there was a movement against financial complexity, but new financial instruments as securitisation remains the only way to provide liquidity to the real economy. Securitization, previously blamed for the present financial problems is today a solution for private, financial and non-financial, and public liquidity problems.

Robert J. Shiller (2008) went back to the ideas of Kenneth Arrow to insure against an unexpected increase (or decrease) in the price of assets. Insurance was the field explored by Arrow as a way to deal with uncertainty. Schiller suggest that in the case of mortgages an index can be used to adjust the payment of mortgages to the cycle, while the risk of undesirable volatility in houses and mortgages can be covered by derivatives. Some of these ideas are theoretical and do not have a real market to be implemented. Furthermore, insurance in finance lacks the stability familiar to life, houses, or car insurance; the volatility of the credit derivative swaps (CDS), or derivative on commodities are good examples. Only a good system for monitoring credit and loans can establish a healthy basis for risk management.

A lesson learned from the crisis is the need to emphasis risk control in everything that can makes us more vulnerable, as basic risks in loans and mortgages and liquidity. Risk should be analysed and valued in-house with the specific knowledge owned by each financial institution. External valuations by rating agencies are an input for risk management but not a substitute for internal valuations because they lack business experience and relevant local information. Size and risk concentration matters. Business strategies that focuso on a very profitable market can be profitable in the short run but a big source of risk for the future. And last but not least macroeconomic scenarios deserve more attention that they had received in the past.

How have we arrived to the present situation? There is a tradition in financial risk thought about how to identify, to measure and manage risk. In G. Ruiz (2008) we present the case of a financial entity with a sound financial risk management that was unable to avoid liquidity and credit problems in the crisis.

From a theoretical point of view every issue about risk was taken into account, market illiquidity included. They were able to see the extremely narrow spreads in debt credit and the abnormal prices in the real estate market. They did also conduct stress test for liquidity. Loans and risky assets were continuously monitored and valued mark to market, however complex structures were not. Rating agencies provided the value for collaterals and they accepted them. From a risk management point of view complex structures were in a no man land between loans and tradable assets.

But the main source of troubles came from the sales departments, because incentives to sell created a bias on the whole organization in favour of sales and against risk control. Risk control department was strongly regulated and internal control and compliance were well implemented. But in practice and from the point of view of the whole organization these department were considered just a necessary inconvenience for business. Financial deals were carefully prepared by the back office and sales departments, and risk control departments did not have the time to study in depth these complex operations. Almost every deal was in a rush in a world plentiful of opportunities and hopeful about the future. In this situation it was very difficult to properly discuss each operation. A
sound methodology was needed to halt from the very beginning this movement in sales and leverage. Our point in this paper is that a model of scenarios can provide a wide consensus aiding to implement a culture for the long run and for a steady rise in business.

Considering risk scenarios is an important change in financial behaviour. Historical analysis is relevant but just a piece of a more complex analysis. Risk spread and insurance cannot cover every kind of risk because there is not a true market to cover them. After the crisis, diversification is not the solution anymore. When different markets move in the same direction, as happened in this crisis, we have illiquid markets for assets that historically were not synchronised. VaR methodology and historical data are useful as inputs into the analysis to avoid risk concentration, but we should be able to design and build complex scenarios where different risks could materialize. We propose a methodology for risk management that takes into account the historical perspective for predictions putting together the macroeconomic historical approach, a model for plausible scenarios, and the specific circumstances of a portfolio, business or firm.
In this part we will show an approach to the credit risk measurement which is able to correct the biases implied in currently used methods:

- Not-measurable uncertainty components
- Not-symmetrical interactions among risks
- Not observable correlations
- Missing significant idiosyncratic risk
- Lack of scalability and integration
- Poor estimation of the diversification effects

Following the analysis of risk in G.Ruiz, (2000), we will show how the measurable risk can be integrated with uncertainty (not measurable) using a method that combines econometric models and expert economic scenes. This method, initially designed to forecast capital needs under stress situations, has become a tool useful to help analysts and managers to make decisions either strategic or operational. It has already been tested on the real arena as a risk management tool for several financial institutions.

The measurable risk is controlled by means of macroeconomic models that not only allow the forecast of the significant variables in its expected values, but they also estimate the joint probability distribution function of these outcomes. Afterwards it is integrated with uncertainty by means of the instantiation of some of the variables defining a macroeconomic scene; as a consequence, we will have a reduced space of that probability distribution function, with the marginal probability distribution function with equivalent statistical proprieties.

We propose a new scope over the current risk concepts -Value at Risk (VaR), Expected and Unexpected Risk (UR), Shortfall...- extending them to a “Risk conditioned to an economic scenario”, improving the “What-if” method, traditionally limited to the “Expected Value if a certain condition is met”.

The importance of these procedures derives from the need of a better measurement of the performance of the financial institutions as intermediaries between savings and investment. The control of risk and uncertainty is essential in this activity and it is performed by financial institutions applying two basic concepts, selection and diversification.

In both concepts, the information, frequently very asymmetrical, is strongly relevant, in the first case for the expected loss estimation, and in the second case for the decrease of variability and the control of extreme portfolio loses at crisis situations. The early applications of these analysis were carried out by big investment banks taking advantage of an almost continue flow of information. The most appropriate method was an extension of methods to analyse bonds portfolios. However, when these concepts had to be calculated for the portfolio of a retail bank it was necessary to redesign the way it was calculated.

In the credit paradox, the quality of risk usually moves in an opposed way to diversification. If a bank becomes a specialist in a particular class of credit (sector, product, etc) it usually results in a better expected risk for the portfolio of this particular class of credit. But, under this assumption, the same specialized position will cause the bank to be in a weaker position if a crisis beats the sector were it has accumulated a high concentration of risk.

When the real credit portfolios are valued using the common formulae (Vasicek, Basel II), a frequent problem arises: some of the hypothesis issued to justify their validity should not be taken into account. The one which introduces more bias is the hypothesis of infinite granularity; if this hypothesis is accepted, it is assumed that the portfolio is composed of an (almost) infinite number of loans, each of them with an (almost) infinitesimal amount. The existence of singular investments of great volume sharing A&L with portfolios composed of small or medium loans invalidates this
hypothesis. Our RDF method described in this proposal, corrects these biases in the last phase of the calculation, avoiding the omission of the so-called “heavy ties” of the probability distribution of losses.

**RDF OVERVIEW**

The method, known as RDF (Risk Dynamics into the Future), aims to become a new standard in stress testing in the risk management area (See AIS in Bibliography).

Stress testing consists of a set of analyses, techniques and actions aimed at measuring the vulnerability of entities, systems and models in the event of exceptional circumstances. The sensitivity of the financial sector to the effects of economic recession, means this tool is essential for both entities and regulators in the sector.

RDF combines a set of models allowing, by way of sophisticated econometric models, the simulation of unfavourable economic scenarios, and the calculation of the distribution of losses in these scenarios, providing support for strategic planning and business development.


**RDF METHOD QUALITY AND METHODOLOGICAL CRITERIA**

Two main quality criteria have been followed in the development of the methodology.

First, it should adapt perfectly to the Basel II agreements. In this sense, the development of RDF has used the same elements which define the concept of expected loss (PD, LGD, EAD), only using plausible hypotheses and models in a credit risk context. Even, being RDF compared with the “Supervisory Capital Assessment Program” (SCAP) issued by the Federal Reserve System in April 2009, RDF can be considered more coherent with the current risk concepts, as it does not use the “ceteris paribus” principle and it takes into account the residual noise composed by non-instanciated variables. However, it has to be pointed out that the uncertainty is managed on both cases with economic scenarios.

Second, the method must be useful for the development of the financial entity business. In this sense we have aimed to provide a global vision of the risk assumed through the complete calculation of the distribution of losses, in order to achieve directly applicable risk measures (VaR, shortfall). We have also strived to make RDF both simple in the exploration of stress scenarios through economic indicators using the common language of economists, risk executives and general managers (GDP, CPI, unemployment, Euribor, etc) and speedy in the obtaining of risk reports to facilitate the scenario exploration stage.

The main criteria used in the construction of RDF are:

- The sources of variability which produce the risk arise essentially from the macroeconomic situation. An econometric or macro model allows this domain to be governed. VARMA type models have been chosen for this method.
- Depending on the severity of a possible crisis, the companies and retail exposures of the portfolio will be able or not to cope whit it. Modelling their response capacity requires to combine the macroeconomic variables and the characteristics of the instrument and of the specific data of each sub-portfolio, in the so-called micro models. The model could be developed at an aggregated level, although the treatment of sub-portfolios seems most suitable.
The micro models which relate the macroeconomic situation to the losses in each sub-portfolio have their own residual variables. These random variables will be categorised as risk drivers, linking a single multivariate distribution (in this case as independent variables) integrated into the macroeconomic model.

The macroeconomic model (macro model) enriched with the residual variables of the models, optionally multi period, is integrated in a single dimension multivariate distribution (number of periods multiplied by the number of macro and micro variables). The indirect effect and the interactions are thus controlled.

The risk measurements incorporate the distribution of the losses from the micro and macro models through the indicated multi variable distribution. VaR, Shortfall or unexpected loss can be calculated in a conditioned scenario.

We understand definition of scenarios as being the instantiation of some variables in some periods. The system must be capable of calculating the probability of occurrence of this instantiation and of generating the resulting marginal distribution.

The method includes an innovative analytical solution for the integration of the loss function, which complements the more traditional Monte Carlo solution.
**RDF Method Modules**

The RDF method is made up of the following modules:

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**RDF Inputs and Outputs**

The model **inputs** are:

- A segmentation of the credit portfolios
- Series of probabilities of default (PD) and historical losses given default (LGDs) per segment
- The expected exposures for the period analysed per segment
- The scenarios to simulate

and the **outputs** are:

- The distribution of losses of a scenario-conditioned portfolio (current and extreme)
- Expected loss
- Economic capital
- Projection of the extreme scenario-conditioned economic indicators
CONFIGURATION OF PORTFOLIOS, SCENARIOS, MICRO AND MACRO MODELS

The segmentation of the portfolios is made ad hoc in line with the credit portfolios of each bank. The implementation stage includes a preliminary segmentation study of the portfolios of the financial entity. This segmentation should fulfil two goals. First, it should separate the portfolios with a low correlation of losses, in order to minimise the final economic capital. Secondly, it should coincide with the business units for regulatory capital calculation purposes.

The models of the components of the expected loss (PD and LGD) must be “ad hoc” for the entity. The implementation stage must include the development of the PD and LGD prediction models, using the economic indicators from the VARMA model. We can then project these components and incorporate their fluctuations into the distribution of losses.

Stress scenarios are plausible states of the future that identify extreme situations of the economy. They are defined using macroeconomic variables values for a future period. The impact of these scenarios on the risk measurements can then be analysed.

Different types of scenarios can be defined: historical, hypothetical or systematic.

All the scenarios are calculated by way of a single general VARMA model of the macroeconomic environment. This model is common for the entire country banking system, making future projections for the selected economic indicators and calculating their joint distribution in these future periods.

The future values of the economic indicators introduced by the analyst will condition the VARMA model, because the new projections of the indicators and their distribution. This system breaks away from the classical hypotheses of ceteris paribus, and its limitations calculating the direct and indirect effects of hypothetical yet plausible scenarios.

Changes in the measurements of interest risk for each scenario depend on the model which relates the credit risk measurements to the macroeconomic variables. This requires us to identify the macroeconomic variables which influence the behavioural structure of the credit risk of each portfolio, and to incorporate these variables in the measurement of risk on these portfolios.

This is carried out using econometric models such as regression, which relates the macroeconomic variables to a risk measurement of each portfolio, such as probability of default (PD) and LGD. The models should take into account the complexity of the concentration and the correlation, in the integration of the risk measurements of several portfolios.

JOINT DISTRIBUTION OF VARIABLES, THE CONDITIONED EXPECTED LOSS FUNCTION AND LOSS FUNCTION

Once the scenarios have been defined using the Multi Normal distribution of transformed macroeconomic variables along with the random variables of micro models, we can generate the residual distribution conditioned to the instantiation of one or some of the variables at specific moments in time.

As a consequence, we shall have a marginal distribution, also Multi Normal, with a smaller dimension than that of the original VARMA model. By applying the Schur complement matrix calculation, we can determine the conditioned covariance matrix at the instantiation of the variables which define a scenario.

This new scenario concept has two fundamental advantages: first, it reduces the limitations of ceteris paribus, so the indirect effects are also taken into account; and second, it is not limited to
the expected value conditioned to certain values, but rather operates on the marginal distribution of losses conditioned to these values.

The distribution of losses is calculated using the estimation of the probability of losses, expressed as a surface integral:

\[
P(Y = y) = \int \int \cdots \int \frac{\Omega(X)}{\nabla L(x)} \delta(y - L(x)) d^nX = \int \int \cdots \int \frac{\Omega(X)}{\nabla L(x)} \delta^{(n-1)}X
\]

This multiple integral is resolved by way of numerical approximation through an original method of asymptotic expansions in stationary points.

Given a series of macroeconomic variable values we obtain the PD and LGD associated to each segment/portfolio, which, in turn, give us the losses, multiplying these values by exposure. The total losses conditioned to these values will be calculated by adding the losses associated to each segment/portfolio.

**SOME NOTES FOR IMPLEMENTATION**

In order to implement RDF we need to define three main elements: tests, scenarios and portfolios.

The test is the main analysis unit. A test calculates the distribution of losses of the portfolios conditioned to an economic stress scenario. The test can be used to obtain reports containing loss indicators (expected loss, VaR, economic capital, expected shortfall…).

In order to define a scenario, it is first necessary to set the time period for the calculation of the distribution of losses (e.g. the next year). Then we project the non-conditioned economic indicators (GDP, CPI, unemployment, Euribor, etc). After this, the analyst can create a stress scenario by modifying or fixing these indicators in one or more periods, or by specifying a historical stress scenario pattern (e.g. the crisis of ’93). Finally, the application should show the projection of the economic indicators conditioned to the hypothetical values of the specified scenario.
Finally, the configuration of portfolios will involve selecting the portfolios to be tested and, in the opinion of the analyst, the level of Exposure at Default (EAD) to be assumed in each portfolio. In this way, the analyst can carry out different tests and define the envisaged level of exposure in all the business units.
The application requires the loading every quarter of the series of economic indicators (GDP, CPI, Euribor, unemployment…). This allows the forecasts to be updated in line with the current situation.

There should also be yearly monitoring of the internal models (VAR, PD, LGD). This segment will involve analysing the stability of the parameters and their prediction level. This analysis will determine the validity or the need to re-estimate each model. The application should be organised so as to allow easy replacement of new and old models.
**GLOSSARY**

*Basel II:* International regulation approved in 2004, drawn up by the Basel Committee on Banking Supervision over recent years in order to guarantee international convergence in the review process of supervisory rules for capital sufficiency in banks with international activity. The Basel II document contains the framework passed to estimate capital sufficiency, along with the minimum standards to be reached, which the supervising authorities in the countries represented on the Committee are presenting for implementation in their respective countries. The Committee counted on the backing of the Governors of the Central Banks and of the Heads of Banking Supervision of the Group of Ten.

*Distribution of losses:* This indicates the probability of a given level of losses being incurred.

*EAD (Exposure at Default):* This is the total amount estimated at the moment of default on a credit or loan.

*Economic Capital:* This is the capital level above the expected loss which a financial entity must have in order to guarantee solvency. It is often expressed as the difference between VaR and expected loss.

*EL (Expected Loss):* This is the measurement of the distribution of losses and gains, in other words it indicates how much can be lost on average, and is normally associated to the preventative reserves policy which the institution should have against credit risks. It is estimated as the product of the probability of default (PD), exposure at default (EAD) and loss given default (LGD) of debtors.

*Expected Shortfall:* This is defined as the expected value of the losses beyond a specified percentile of the distribution. Measuring the lower part of the distribution tail, expected shortfall provides a good measurement of the extreme losses which may come about.

*GNU:* The General Public License, often referred to by its acronym GNU GPL, is a licence created by the Free Software Foundation in the mid-1980s, and is orientated to protect free distribution, modification and use of software. Its goal is to declare that the software covered by this licence is free, protecting it from attempts to appropriate it and restrict the freedoms of users.
Historical scenarios: These are past events, normally of crises which may significantly affect the entity. This type of analysis is based on the supposition that the past may repeat itself. The limitation is that the future may be very different.

Hypothetical scenarios: These cover situations which have not occurred in the past. The goal is to draw up possible future events which may cause important losses in the portfolio of the entity. For example, in the case of credit risk, we could consider the effect of a hypothetical political crisis in a specific country, the modification of the currency exchange system or the simulation of the effects of changes involving interest rates or other prices on the credit quality of counterparts.

LGD (Losses Given Default): This is the percentage of losses in the event of default on a credit or loan. It is measured as a proportion of exposure. This represents the net cost of the default of the debtor, i.e. the unrecovered part once the costs involved in recovery have been taken into account.

Loss function: This quantifies the level of losses for the following year. This function is not usually dealt with directly, but rather its distribution and other summary statistics are considered.

PD (Probability of Default): This is the probability of a portfolio loan ending in default within a period of one year, i.e. the total defaults per “good” client, measured in line with the equivalent life involved.

Systematic scenarios: These involve selecting a wide range of scenarios which envisage a series of variations in the risk factors, in order to assess their impact. The largest number of possible scenarios is envisaged, regardless of their probability of occurring, in order to determine the main risk factors the entity is exposed to.

Stress testing: This designates the different techniques to assess vulnerability to exceptional yet possible events in a plausible timeframe for the financial institutions. Stress testing involves specifying a series of scenarios of extreme yet plausible movements in the macroeconomic environment which may affect the risk of a portfolio, and then to analyse the expected performance of the portfolio.

Unexpected Loss. This is the loss above that expected, measured as the VaR – EL, which the creditor may incur through default of its debtors. It can be expressed as a multiple of the standard deviation of the distribution of probabilities of losses and gains. These losses determine the economic capital required by the creditor in order to face unenvisaged losses.

Value at Risk (VaR): This is a loss level such that probability “α” of the loss exceeding this amount in a period of time corresponds to a certain level of confidence chosen by the analyst. The analyst thus establishes the level of confidence with which to work and the time period in which the loss of the financial assets whose risk is to be measured may come about. Based on these two parameters, VaR corresponds to the percentile associated to the established level of confidence, the distribution of loss probabilities within the given timeframe, considering the conditions of uncertainty of the market.

VARMA (Vector Autoregressive Moving Average): A multiequational model which models the evolution of a vector of variables over time, estimating the parameters based on historical data. It is presented in two ways: structural and reduced. In the structural model, an endogenous variable depends on the contemporary values of the other exogenous variables, and depends also on values of the past, of itself and of other variables. In the reduced model, each variable depends only on past values of the other endogenous variables.
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