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**"STRESS TEST RESULTS AND EFFECTS ON BANKS'  
PERFORMANCE:  
AN EMPIRICAL ANALYSIS OF THE EUROPEAN MARKET"**

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Firma dello studente

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*To my sisters and my mum,  
For your unconditional support  
and all your sacrifices.  
Thank You.*



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## **Introductory Note**

In a globalized world, where people; goods and services are continuously flowing from side to side, banks have become the natural connector, being able to support and provide the required resources to corporate clients and private citizens as well. Of course, such a fundamental role presents numerous advantages in terms of profitability and prestige. Unfortunately, advantages do not come alone. Though the bright side seems to prevail over the negative one, as the banking sector is growing at a constant pace, we cannot neglect the fact that carrying out this kind of business implies unavoidably assuming many and different risks, which may grow as the banking activity itself swells. The first part of this work focuses just on this relationship. In particular, we describe how risk and profitability are intrinsically related one to the other and to what extent the risk management function has increased its importance as value management tool. Especially for the banking industry, risk management policies are revealing themselves as a value-adding activity that, on the one hand, may shelter from potential adverse impacts and, on the other, it can provide a concrete support to any other profitable, value-creating action. Specifically, the modern financial risk management attempts to handle all the possible threats that the financial institutions may face: from the typical financial risks to more operational and business-centered ones. Although we acknowledge the significance of the latter, herein we concentrate on the classic financial risks, given that they are still the most important ones for any financial entity. Chapter II provides a brief overview of the main financial risks, describing in general terms the key features and some of the most widespread measurement techniques. The main body of the project is represented by the final two chapters. Chapter III details the stress-testing framework. Namely, we detail all the peculiarities of stress test exercises: from possible categorizations to the current regulatory architecture. This chapter paves the way for the empirical analysis, which is included in chapter IV. The latter aims at underlining how crucial stress tests have become for regulatory authorities. In fact, the recent Financial Crisis has pointed out all the fragilities that characterize the financial system. Therefore, national and international supervisors have been constantly looking for methods, models, tools, such as stress tests, to cope with this increasing urge of restoring financial stability and providing right information to the market. Notwithstanding the enormous progresses that have been made in the last couple of years, there is still a long way to go. For this reason, the upcoming stress test will probably serve as a useful means through which regulatory authorities may figure out whether they are moving to the right direction or not.



# 1. Introduction to Financial Risk Management

## 1.1. Risk, Uncertainty and Risk Exposure

According to the Oxford Dictionary, risk may be defined as “A situation involving exposure to danger”. The word risk derives from the Latin *Risico* and has always had a prominent negative acceptance, being constantly employed as synonym of danger; harm, in other words, something to avoid. Notwithstanding, risk may be regarded an essential part of any business: from the very beginning, each action that companies undertake is characterized by risk and uncertainty. The latter concept is strictly related to the former and although sometimes they are used to express the same idea, failing to distinguish the actual difference might turn out to be misleading. *Uncertainty* might be defined as a condition that derives from the fact that companies are not the sole players in the environment they operate in. They cannot not control for all the factors that they require to carry out their business: both the external and internal worlds have their own functioning rules and mechanisms which are somehow independent and uncontrollable by companies themselves. *Risk*, on the other hand, refers more to an operational, managerial and manageable dimension. It may be what companies reasonably expect to face given the actions they strategically decide to implement. In this sense, risk depends directly on companies’ intentions, or with an appropriate word, on their *risk appetite*.

All businesses act trying to make profits, some of them succeed whereas other fail, but in any case, all of them take on risk, as, profit and loss themselves might be considered as outcomes of risk. In fact, for any business strategy, risk is the possible distortion from managers’ ideally-expected results in terms of efficiency, effectiveness and profitability given the uncertainty. If there were no uncertainty, risk would disappear in that all possible outcomes would be easily forecastable. Thus, we may regard uncertainty as a necessary condition of risk; the latter exists only as a consequence of the former. Managers and entrepreneurs may know exactly the importance of coping with uncertainty. At the same time, they recognize that without uncertainty there would be no room for risk and therefore no possibility to make any profit. Once all sources of uncertainty are identified, managers’ decisions must concentrate on how much risk to take on, the so-called *risk appetite* of the company. This might be persuasively summarized as the managerial decision regarding what and how much is worth for the company to craft. As a general rule, risk appetite should be set to the point where marginal benefits of taking additional risk are exactly compensated by marginal costs (Stulz, 1996). The appetite, furthermore, shall be developed on the company’s business strategy, not neglecting the actual competitive environment and stakeholders’ concerns.

Similarly, *risk tolerance* may represent the imaginary boundaries outside which no positive outcome is valuable enough for companies to justify the amount of risk that they intend to assume. From a very operational point of view, risk tolerance is the level above which the company may not be able to carry on its core business, since potential incremental losses would trigger irreversible damages: deciding to overstep this limit would stray into a pure hazard dimension.

The managerial act of deciding, selecting what specific risks to take on, and hence choosing to subject the company to risks, may be regarded as *risk exposure*. Horcher (2004) suggests an interesting clarification between risk and risk exposure. Accordingly, the former is deemed as the probability of loss, whereas the latter is the possibility of loss. Therefore, in the definition of risk exposure the subjective feature; the controllability and the key decisional role of the management are implicitly emphasized.

A conception of risk as exclusively negative would be without any doubt incompatible with the modern economy. Each individual business, from the smallest family-run bakery to the most sophisticated investment bank should firmly bear in mind that risk is an essential element not only from a profitability point of view but also for the simple existence and survival of the business itself. Therefore, the restricted definition of risk as a possible negative outcome, intended either as financial or reputational damage by Sharma (2003), among others, is necessarily overcome.

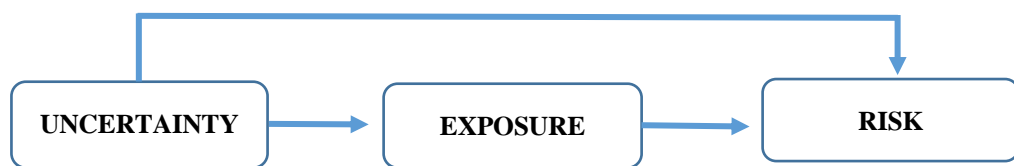


Figure 1.1. *The interaction between uncertainty, exposure and risk.* (Author's elaboration)

## **1.2 Financial Risk Management: A Value Management Tool**

Risk Management has acquired a key role not only in the financial sector but in all companies in general. Though risk is intrinsically neither negative nor positive, by definition, what characterizes risk management's basic priority is the downside part of risk, as, generally, the favorable side is already dealt with in the daily operative business activities. Even though a company might not adopt directly any risk-avoidance policy, it may not fade away the chance of losing customers to a new competitor or the possibility to face an increase in the cost of credit lines. This is what risk management is all about; hedging the company from hypothetical and rational adverse changes, that may undermine the core performance as well as the entire value of the company.

The general literature defines risk management as a standardized process, a step-by-step procedure, which may be universally applicable to both financial and non-financial companies. Of course, there is still no wholly-accepted methodology for assessing enterprise risk management procedures but independently from the field or from the number of steps, the main goal remains one: value management. The choice of using management instead of preservation, as one would normally expect, is voluntary. In fact, value management has a wider, more profound insight compared to the sole preservation. When we preserve something, such as a company, we attempt just to protect it from any eventual adverse change that may negatively impact on its value. On the other hand, when we manage something, we are trying to find solutions to contemporaneously maximize the upside and minimize the downside of it. Differently from the mere preservation, value management deals with a set of actions, programs, systems that clearly aim at taking advantage of possible positive effects of taking on risks, thus considering value as dynamically, actively adjustable and not as externally given and to be solely conserved as it is. Following the teachings of Koller *et al.* (2015), the market value of a company may be estimated as the sum of non-operating assets and the present value of all future cash flows deriving from core activities, discounted for an appropriate weighted average cost of capital (WACC), which should reflect individual capital structures. Thus, value mainly depends on the operating cash flows that the company may be able to reasonably produce during its own existence: actions that augment core inflows will also increase the enterprise value; conversely, anything that absorbs cash will erode it. Risk management practitioners seem to be well-aware of this fundamental concept. When it comes to value, any decision may have a relevant impact on it, and so are the risk management ones. In first instance, risk management shall focus on protecting cash flows from any inimical change, understanding and mitigating all possible threats that the enterprise might encounter throughout its business life. But a fully successful risk management may allow companies

also to significantly boost their current market value, by acting principally on three main areas (Stulz, 1996): financial distress and bankruptcy costs; payments and other outflows to shareholders and stakeholders and reduction of taxes. Financial distress costs may affect companies' value in a multitude of ways. In first instance, they may create difficulties from a funding, or more precisely, a debt capacity point of view, since companies in financial trouble may likely pay higher expenses for receiving endowments, shrinking therefore resources for core activities. Further, this situation may lead to reputational damages which may impact negatively on the operative performance and the utter value of the company. Strictly related to financial distress costs are payments to shareholders and other stakeholders. From a shareholder's perspective, when a firm reaches a distress phase, in their eyes, it is as if they implicitly assumed a covered position, consisting of a long call option for what concerns returns and long put option as regards their effective risk exposure: so long as the company will create profitable returns, they will be keen to risk as much as they can. But as soon as a critical, watershed point is reached they will be better off exercising their embedded put option, permitting creditors to take over. Hence, until this stage is reached, shareholders may have nothing to lose and for this reason they may be the first ones to pressure the board into high-risk and value-destroying opportunities. Naturally, this eventuality may persuade many stakeholders to react promptly. Let us consider employees for instance. Their choice to work for a specific company depends on various factors, among which reputation and salary surely play significant roles. In case of distress and reputational damages, it becomes extremely hard for any company to attract or even to merely retain employees, as they might likely demand consistent incremental monetary guarantees and other kind of benefits, thus contributing to add fuel to the fire. The same reasoning holds for suppliers, who, in a nutshell, may not be eager to carry on business with a company that faces financial and operative turbulence. Also in this case, supplementary warranty obligations might be needed and particularly, in the form of advance payments. This may ultimately affect adversely the company's working capital and liquidity necessities and hence, as a matter of fact, its actual survival. All the aforementioned cases might gradually and eventually lead the company to file for bankruptcy, which, needless to say, represents the worst outcome.

The final major benefit of risk management concerns corporate taxation. Differently from the previous two, the linkage between taxation and risk management is not intuitive at all. Smith and Stulz (1985) point out that an effective risk management may diminish the volatility of taxable income and, as a consequence, allow corporations to benefit from the tax function's convex shape, typical of most worldwide tax codes. The convexity of the tax function implies that companies may proactively manage their taxable income so that to make it fall within a

target and efficient taxation range. And any reduction in volatility would definitely permit them to achieve this outcome.

The conception of risk management as a value management tool has gained an increasing acceptance throughout the last few decades, since the role of the risk officers and risk management departments in general have been adopted increasingly by large companies. But with the last statement we do not regard risk management as a practice relegated to big corporations only, on the contrary, it is fundamental for all kind of businesses to have at least a minimum of risk management policy and a person, who is directly responsible of it. The overall complexity and number of people involved changes according to the size of the organization: an international investment bank may have an entire department dedicated, as strongly recommended by Basel II; whereas a small grocery shop is likely to rely on its owners to accomplish this task.

After portraying a general view of risk management, it is important to spend a couple of words also for a particular subcategory: the financial risk management. When dealing with financial risk management, all general principles of the risk management are concretely applied to financial institutions, paying due attention to their peculiarities and specific needs. What essentially distinguishes the banking risk management from others is not the procedure itself, which, as already stated, is quite standardized but rather the importance that risk managers and officers give to the upside part of risk. In financial risk management, negative outcomes and upside benefits are even more interconnected, since the risks of core activities and risk management coincide. Financially speaking, we might say that risk management for a financial intermediary corresponds to the purchase of a “well-out-of-money put option” (Stulz, 1996) with the clear scope of eliminating the downside and preserving the upside at the same time. Hence, risk management practices in this field weighs the negative and positive sides of risk even more, stressing once again, how they both are faces of the same coin and for this reason interdependent and equally important when drawing any business strategy.

### **1.3 Financial Risk Management: Step-by-Step Procedure**

Any company may have its own risk management procedure, modelled on its business necessities and financial means. Hence, as already stated previously, there may not be any commonly-accepted procedure, as well as some persistent and remarkable inconsistencies regarding steps definition. But nevertheless, we may still trace a simple and effective six-step procedure, which may serve to figure out how companies and especially financial institutions,

accomplish risk management practices. Nowadays, what stands out modern risk management processes is their circular (Williams, 2004) and dynamically-adjustable nature: new threats; system inefficiencies may be promptly individualized and solved, thanks to a horizontally and well-integrated flow of information.

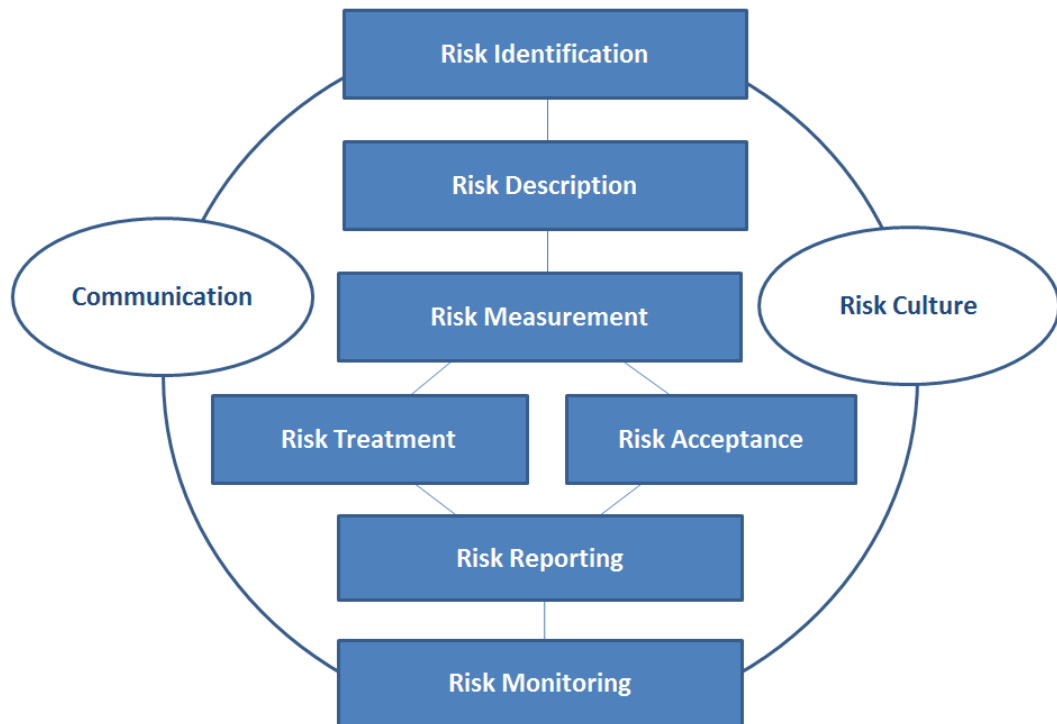


Figure 1.2. Risk Management step-by-step procedure. (Author's elaboration)

*Risk identification* basically consists of understanding what the possible threats that the company may face when accomplishing its business. A primary and general division of risks may suggest the distinction between generic or *systemic* and *business-specific risks*. The former characterize all companies, independently from the sector they operate in and hence, are extremely difficult to deal with. To such category belong, for instance political and macroeconomic risks. For this reason, what usually businesses, and in particular small-medium enterprises, tend to focus on are business-specific risks which relate more to an operative and manageable dimension. Within the latter side, business risks may be classified in a variety of ways, such as: strategical; operational; technological; financial; compliance-related and so on. Therefore, this first stage significantly differs depending on core businesses: a bank, for instance, is supposed to shelter itself primarily from credit and interest risk, which in a consumer staple firm would have only a marginal relevance. In general, it is the top management that performs this kind of analysis, by virtue of their deeper company

knowledge and should be reviewed periodically, particularly in case the company's portfolio is directly or indirectly subject to any significant changes, such as the entry in a completely new, disruptive sector or an unexpected poor performance. Identifying risks may not be as easy as it seems at the first sight, as companies are inclined to focus just on the main and obvious ones instead of carrying out a broader and more comprehensive analysis. In the previous section, it was strongly underlined that, basically, all corporate actions, required to deliver value to the final customer, are impregnated by uncertainty and risk and hence any management team should keep this in mind when taking decisions regarding what and how the organizational hedging programs are carried out.

This may not be the case of the banking and financial sector where, as detailed later, internationally-approved regulations require banks to specifically target and handle a significant number of potential risks that characterize their day-to-day activities. Nowadays banks play a key role world-widely and are directly connected with almost all types of business firms, so that greater regulatory obligations are not surprising at all. Let us consider, for instance, the bankruptcy of a grocery chain. This may rarely have any major relevant impact, whilst, as the recent Financial Crisis has proved, the failure of a large bank may endanger the entire economic and financial system.

Once risks are identified, the following stage requires their *description*, which basically means pointing out the peculiarities of each single risk and why it should be important to hedge it. Usually, to simplify the process, this phase may be included straightly in the first one, as the identification itself implies some descriptive analysis.

*Risk measurement* represents the next step. This phase may be extremely troublesome and quite subjective, in the sense that it varies a lot according to different factors which, most of the times, are not under direct control of the companies. Think for instance of the experience that risk managers may have: some could be more experienced and thus able to perform a more reliable and precise computation, whereas others may feel not at ease when measuring risks. Generally speaking, we may use either or both *qualitative* and *quantitative* assessments but given the need for straightforward and reliable indications, only the latter are employed in practice. Also, different methodologies may have relevant impact on the reported measurements themselves, hence posing a big challenge for what concerns precision and alignment of the results. A useful and plain measure, which may be utilized by all kind of companies, is suggested by Boehm (1989):

$$\text{Risk Exposure (RE)} = P \times C \quad (1.1)$$

Where  $P$  is the probability of occurrence for a specific risk and  $C$  is the expected loss deriving from that risk. Let us suppose that the probability for a risk, for instance the failure of a new production facility is 25% and the related expected loss is 100.000 euro. The risk exposure in this case is 25.000 euro. As risks are many and different, each of them should be evaluated separately, hence who is in charge of risk management should in first instance assess a likelihood of occurrence scale, deciding the range and meaningful intervals: from 0 % for unrealistic threats to 100% for certain losses. In between, the management shall decide how to properly distribute the percentage scale based on the level of details aimed and information possessed. Afterwards, realistic loss forecasts are required for each risk. Also these predictions, like the probabilities, are completely arbitrary and subjective values but nevertheless they are indeed helpful to obtain at least a raw estimate of the impact of risks.

In the financial sector, the aforementioned problem is partially mitigated by the adoption of common rules which encourage the implementation of specific, alternative techniques. Additionally, the presence of many practices to evaluate the same thing might be considered as an inestimable resource as well, incentivizing and accenting the debate within the top management.

One comprehensive and widespread measure is the *Value at Risk (VaR)*. Although a deeper insight will be provided later, we believe that it is inevitable to spend a few introductory words regarding this methodology. What is value at risk and why it is so important? Value at Risk, or VaR, is a risk measurement introduced by JP Morgan during the late 1980s which has gained increasing popularity among practitioners due to its simplicity and extreme versatility: from portfolio analysis to firm-wide risk evaluation, this technique applies indistinctly to a multitude of concrete cases. The VaR measure has positively impacted on the financial world thanks to the striking and concise significance that it can convey with just one single value. Originally presented to the JP Morgan senior management on a daily basis, the VaR summarizes, using statistical principles, the entire risk exposure of the company within a precise timespan and confidence interval. Along with VaR, other methods have recently gained unprecedented attention. Tools such as stress testing; Cash Flow at Risk (CFaR) and Monte Carlo simulations may be indicated as compelling successors of VaR. As all of them focus primarily on total exposure, a comparative and integrated usage might be immensely beneficial, on the one hand; while on the other, specific risk indicators and individual estimates shall be still required, in order to obtain a meaningful and comprehensive enterprise risk exposure.



After measuring each risk, a set of potential losses is obtained. The next stage is simply ranking them from the riskiest to the least one. Once reached an acceptable standing order, the management should decide which exposure to prioritize and treat. Obviously, with the help of a classification, it becomes way easier to decide which risks need to be picked up first and treated, but nevertheless, many times it is not as easy as it sounds. For instance, it may happen that the highest-ranked risk for a company derives from a possible change in the accounting rules, in which case any specific risk avoidance measure would have no impact at all. Although this is an extreme case, it appears clear what the main task of the management in this phase is: deciding whether to accept (*Risk acceptance*) or to treat (*Risk treatment*). Either circumstance depends directly on the company's risk tolerance and appetite, besides, of course, on the controllability of the risk by the management team. Risk acceptance might be improperly addressed as risk ignorance, which indeed on surface may look quite similar but nonetheless, the acceptance assumes an initial acknowledgement and a following careful judgement by the responsible team, whilst the ignorance does not. Additionally, the latter would pose many concerns regarding the actual competence and adequateness of the risk management group. In case of treatment, conversely, all efforts will necessarily focus on how to efficiently and effectively manage the risk. The objectives may be fundamentally two: *risk avoidance*, on the one side, *risk protection*, on the other. Albeit substitutable in many other contexts, the former may be referred to as the situation whereby the management may face the concrete chance to avert the risk, whereas, in the latter case, little can be done to avoid it and therefore mitigating responses may be required. The final ambition is to reach a solution which balances benefits, in terms of reduction of risk exposure, and costs, conceived as monetary expenses as well as opportunity costs. An insightful and straightforward formula is represented by Pfleeger's Risk Leverage (1998):

$$Risk\ Leverage = \frac{Risk\ Exposure_{Before\ Reduction} - Risk\ Exposure_{After\ reduction}}{Cost\ of\ Reduction} \quad (1.2)$$

This ratio is a very helpful measure for the entire management team: each member in fact, with a trivial calculation, could achieve an immediate understanding of the efficacy and convenience of any risk treatment proposals, providing also the opportunity for an objective comparison between different measures that aim at judging the same risk. Needless to say, it is up to the management to decide what level of threshold should be acceptable. Moreover, since this is a general and approximate measure or, in other words, a mere starting point, other more specialized techniques and measures will be required to evaluate single risks. Risk

treatment for a financial intermediary is unarguably more challenging. For a bank, in particular, risk treatment concerns, three dimensions<sup>1</sup>: policy decisions, cash market transactions and derivatives. The order in which they have been enunciated is not casual but should be considered as a sort of three-leveled and cascade-shaped tank from which to pick solutions anytime the previous ones are exhausted or ineffective.

*Policy decisions* relate to the pure core business of financial institutions, they contribute to define the corporate positioning in terms of profitability and corporate strategies. Belonging to this category are decision such as the spread to apply on mortgage interest, as well as the banking fees for accounts and credit lines. As the financial market has become increasingly competitive, decisions related to this first set of activities may have a circumscribed utility.

More useful to this purpose are the *cash market transactions*. These are substantially all those standardized operations utilized to manage the bank's balance sheet, such as fixed-income and mortgage-backed transactions. Though strongly regulated by the competent authorities, this category guarantees more space to move in and more instruments to choose between, giving therefore more discretionary decision power to the responsible team.

When it comes to treating banking and financial risks, *derivatives* are surely a key part to be considered in order to understand how risk management policies function in this sector. But notwithstanding, they should be used as residual protecting means and not as primary vehicles upon which to plan a structural hedging policy. Derivatives are financial instruments that derive their value from an underlying asset's actual performance, such as bonds; stocks and commodities. Throughout the last decades, their application has tremendously surged thanks to the usefulness of their ultimate scope, that is, risk transfer. As the topic is extremely articulated, for simplicity's sake it may be more practical to spend just few introductory words regarding classification and main typologies. Generally speaking, derivatives may be divided into two main categories: Exchange-Traded Derivatives (ETDs) and Over-The-Counter (OTCs), with the former characterized by high degree of liquidity and standardization and the latter employed as bespoke agreements, ideal to satisfy specific needs of the counterparties. The most commonly-used instruments are: options; futures; forwards; swaps and swaptions. But independently from the individual preference, it shall be borne in mind that their usage ought to be circumscribed to the residual risk only and not utilized as primary strategical tools, as stated earlier, since the overall complexity and volatility of these instruments may remain excessively soaring, even for the most experienced professionals. Following risk treatment are results *reporting* and *monitoring*. They should be accomplished diligently on

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<sup>1</sup> Strategies and Tactics, 2006. *Risk Management Programs & The Use of Derivatives*.

regular basis so as to allow all responsible members to be well-informed about the performance and efficacy of the selected treatment techniques. This will eventually allow companies to identify other sophisticated solutions or even new emerging threats: with the reporting and monitoring stage, risk management procedure may start to realize its intrinsically-circular nature. As shown in exhibit 1.2, two additional horizontally-integrated elements are necessary for a fruitful risk management practice: *communication* and *risk culture*. Communication within a company includes all information inflows and outflows. Culture, on the other hand, may be defined in a variety of ways. Schien (1990) delineates it as a dynamic learning process, whereby organization members acquire the knowledge to solve internal and external problems: in other words, they learn how to survive. Regarding risk culture, that is to say a particular subcategory of organizational culture, there is no point against which the previous definition might not be extended also to the latter, as it concerns company survival as well. As a consequence, risk culture should guide employees in their daily decision-making habits, helping to reckon tradeoffs between risk benefits and harms. Concerning risk management, communication and risk culture are somehow heavily interrelated and interdependent one with the other: thanks to a meaningful and explicit communication, a strong and shared risk culture may be built, at the same time; this can be used to encourage and improve communication and risk reporting. It is crucial to highlight once more that communication and risk culture must flow horizontally in any organization and not vertically. Why? As one would imagine, simply giving instructions and receiving feedbacks might be much easier to manage but nevertheless, in the long run, it may turn out to be unproductive and somewhat superficial, as it would alienate the individual, personal commitment towards the organization's values and goals. In fact, culture may be considered as a control mechanism for companies and self-regulation tool for individual members. As far as risk management is concerned, individuals shall comprehend the importance of their roles and tasks so that to be incentivized to point out anomalies as soon as they come to know and to express proactively their opinions and suggestions, allowing in turn the organization to enhance dynamically and continuously its risk management practices. This, as time goes by, will eventually build up a solid risk management culture. Without a horizontal flow across the organization, this would be clearly very tough, if not impossible.

## 2. Introduction to Banking Financial Risks

Nowadays financial institutions have become an essential part of everyone's life. In a dynamic and globalized environment, banks have been playing a key adhesive role, being able to connect successfully people and businesses and contributing to develop and modernize the economy. But nevertheless, just because of their roles as all-around entities, they have been subject to many threats which in some cases may turn out to be extremely harmful. Therefore, Banking risk management has always been one of the most complicated yet fascinating topic for scholars and risk managers, who throughout the years have been constantly looking for models and answers to address such a crucial matter. Risks that banks face on a daily basis are many and various but for simplicity's sake what are introduced in this section are the sole financial risks, i.e. the risks that relate primarily to the core banking activities. Specifically, the table below:



Figure 2.1. *Banking Financial Risks.* (Author's elaboration)

## 2.1 Introduction Interest rate risk

Many financial risk management handbooks and scientific papers do not deal directly with interest rate risk. What is usually done is including the latter in the broader market risk, as, correctly, interest risk may also be deemed as a consistent component of the market risk, in the sense that large amount of interest rate changes may be triggered by market operations that banks carry out in their daily activities. Despite the validity of this conception, a relevant part of interest risk may be still not covered. In fact, what has been introduced so far is the interest component related to the sole trading book, that is, associated with the current trading transactions, which basically constitute the short-term capital gains and liquidity management. Interest rate risk does not involve only the trading book but concerns the entire banking book: all assets and liabilities are somehow affected by possible changes in the market interest rate. Moreover, an additional indirect effect concerns the volumes negotiated by the bank (Resti, Sironi 2007). Generally speaking, this implicit effect may follow the universal law of supply-demand. In fact, an increase in market interest rates may not only trigger higher interests expensed and earned by the bank but it may also lead to additional volume-related impacts. For instance, a decline in credit line demand: since it becomes more expensive, many customers may reduce the demand for that service, affecting, as a consequence, the overall profitability of the bank. Taking into account all the aforementioned characteristics of the interest rate risk, we may broadly define it as the risk that unexpected movements in market interest rates may affect both the profitability and value of a bank. The *profit* dimension relates primarily to the bank's income statement and describes the short-term effect. Conversely, the value, or better, the *economic value* component represents more a balance sheet or assets and liabilities perspective, which is, needless to say, a long-term view.

Practitioners and financial experts are keen to divide interest rate risk into four main subcategories, each of them accenting a specific interest component: the *repricing risk* (1), which focuses on potential maturity mismatches; the *yield curve risk* (2), which deals with adverse movements of interest rates of fixed income instruments; the *basis risk* (3), which basically is the risk associated with imperfect hedging policies and the *optionality risk* (4), that refers to price movements deriving from automated or behavioral changes in interest. In details:

(1) The *repricing risk* represents the main type of interest rate risk, since, most of the times, when outsiders of the banking sector are asked to describe, in general terms, the interest rate risk, they uniquely refer to the repricing and not to any of the remaining risks. Interest rate risk may derive from the maturity mismatch between assets and liabilities. During the accomplishment of core activities, it may happen that assets have longer maturity than

liabilities. In this case, from the moment in between the end of the former and the end of the latter a “gap” is formed, whereby the bank is not covered from possible fluctuations in the market interest rates. Therefore, if, for some reasons, the market rate varies, a *refinancing risk* arises, that is, the financial institution shall require to find further funds to balance the longer asset maturity. Practically, it is the risk that derives from an upsurge of costs associated with financing an interest-gaining position of the bank. Conversely, when liabilities have longer maturity, banks may incur in *reinvestment risk*: new investing opportunities shall be identified, but this may be costly, particularly if market interests fell: a bank, in that case, would have to reinvest at lower rate and report lower income.

(2) The *yield curve risk*, or *non-parallel gap risk* affects primarily investments in fixed maturities, such as bonds. Let us consider the simplest case, whereby the bank holds just a single bond with maturity of one year. If the yield curve shifts, movements are straightforwardly reflected in the yield curve. In a more realistic scenario, though, a bank holds different instruments with different maturities and any of them may shift the yield curve unevenly. For instance, assuming for simplicity’s sake, that a bank possesses only a 15-years-mortgage with interest earnings at 5% financed through a one-year-deposit at 2%. The gap is a plus 3% in the first year. But if we expect a sharper rise in the second year of the short-term rate, this would unsymmetrically reduce the positive gap, affecting the net income of the bank: for example, the long-term rate rises by 1% but the short-term rate increases of 2%, the gap would be just one percent. This may also be the result anytime, in a floating interest scenario, banks use different benchmarks, i.e., call market rates, treasury bills’ yields etc., to price assets and liabilities: any non-parallel movements in the yield curves, which is rather frequent, might alter the net interest income.

(3) The *basis risk* is a particular threat which derives basically from the ineffectiveness of hedging policies. It may happen that two investments may have an imperfect negative correlation and thus, price changes of one of them are not fully compensated by the other position. This may increase the possibility of unexpected gains as well as the chance of unforeseen losses, incrementing, as a result, the total volatility of the bank’s portfolio. Let us suppose that a bank possesses only two instruments: a 6-month treasury-based loan and a 6-month LIBOR-based borrowing. If the 6-month treasury increases by 2% but the LIBOR surges of 3%, the net interest spread reduces, resulting in a lower income for the bank. Many variants may be included in the basis risk such as: locational basis risk; product or quality basis risk and calendar basis risk. But regardless of the subcategory, the underlying functioning mechanism remains the same.

(4) The *optionality risk* is the last component of interest rate risk. It is the risk embedded in many assets and liabilities. In general, an option provides the right but not the obligation to buy, sell or, in some cases, to alter the cash flows of a financial instrument. Options may be stand-alone instruments, such as exchange-traded options and Over-The-Counter contracts, or they may be implicitly embedded within other instruments. In the former case, they can be used both in the trading and non-trading account, while the latter are more properly implemented in the non-trading account. Classical examples are customer loans with the right to prepay or refinance or the many different forms of non-maturity deposit instruments which give depositors the right to withdraw funds at any time without any penalties. Let us consider a simple case, for clarity's sake, of a bank holding only two instruments: a 20-year mortgage and a 5-year time deposit. Assuming a decrease of 2% in the mortgage interest rate and that the customer decides consequently to refinance his mortgage, this would lead to a drop in the interest spread earned by the bank.

### 2.1.1 Gap Models and the Earnings-Based Approach

Interest rate risk models divide themselves into two macro-categories: the earnings-based models and the equity-based methods. Among the earnings-based approach, certainly repricing gap models play the starring role. Three main variants have been conceived: the repricing gap, which focuses just on net interest income changes; the maturity-adjusted gap, that poses the accent on equity value changes but ignores cash flow timing and the duration gap on equity value, which, differently from the previous one, includes cash flow timing as well.

When dealing with the interest rate risk, regardless of the particular risk or the specific repricing model adopted, it is crucial to point out the importance of the concept of *gap*. Banks may have many assets and liabilities with different maturities. For a determined period, i.e. the gapping period  $t$ , interest rate risk may be regarded as the risk that assets and liabilities that mature or are subject to repricing during that period, namely, sensitive assets and liabilities, may be affected by unexpected changes in market interest rates and thus, resulting in a negative effect on the net interest income.

$$G_t = SA_t - SL_t = \sum_j sa_{t,j} - \sum_j sl_{t,j} \quad (2.1)$$

Assuming, for simplicity's sake, that banks earn a net profit computed as the difference between interest-earning financial assets (FA), intended as both sensitive and non-sensitive assets, and interest-bearing financial liabilities (FL), comprehending sensitive and non-sensitive liabilities, we may state that the net income for a gapping period  $t$  is:

$$NII = II - IE = r_A \times F_A - r_L \times F_L = r_A \times (SA + NSA) - r_L \times (SL + NSL) \quad (2.2)$$

As non-sensitive assets and liabilities are not, by definition, affected by unexpected changes in market interest rates, they do not lead to potentially adverse impacts on the net interest income. Therefore, the latter may depend only on unforeseen fluctuations of sensitive assets and liabilities.

$$NII = r_A \times SA - r_L \times SL \quad (2.3)$$

To further simplify,  $\Delta r_A = \Delta r_L = \Delta r$ , which leads to the following conclusion

$$\Delta NII = \Delta r \times (SA - SL) = \Delta r \sum_j sa_{t,j} - \sum_j sl_{t,j} = \Delta r \times G \quad (2.4)$$

The gap  $G$  is the essential element that connects the changes in market interest rates to the corresponding variation in net interest income. If the gap is positive, that is, sensitive assets exceed sensitive liabilities; a rise in market rates generates a positive flow. Conversely, if rates shrink, a negative impact is recorded. Obviously, the other way around holds analogously: in case of a negative gap, a rise in interest rate produces a decline in income while a decrease a favorable inflow.

The previous framework represents the basic repricing gap model, which, needless to say, has many limitations. But nonetheless, it may be use as an introduction to pave the way towards more sophisticated gap models, such as the maturity-adjusted gap and the duration gap. The former represents a huge step forward in terms of realism compared to the simple repricing gap model, whereas the latter surely is the most advanced of the three.

The maturity-adjusted model follows the same mechanism and considerations of its predecessor but completely eliminates a non-realistic assumption, which is though critical for the validity of the repricing gap model: the instantaneous interest change of sensitive assets and liabilities following a variation in market interest rate. The reasoning behind is quite trivial: when market rates changes, its effects are not immediately propagated to the bank's assets and liabilities but only restricted to the period from maturity (or repricing) of the instrument to the end of the established gapping period. Let us consider a 5- month customer credit and a gapping period of one year. According to the repricing gap model, we would require to pool this asset in its entirety along with other sensitive assets. Conversely, the maturity-adjusted gap suggests, correctly, that only those non-covered months, that is, from the sixth to the end, expose the bank to interest rate risk, as in the prior five months, the asset, and therefore, its funds are fully employed.

In general, in case we may consider a rate-sensitive asset  $j$  and its yield  $r_j$ , the interest income deriving may be calculated as:

$$ii_j = sa_j \times r_j \times p_j + sa_j \times (r_j + \Delta r_j) \times (1 - p_j) \quad (2.5)$$

whereby  $p$  stands for the fraction of year from today until the maturity or repricing date of the aforementioned asset  $j$ . The interest income is therefore a sum of two components: a known



one, represented by the first addendum of the previous equation and an unknown element represented by the remaining part. The change in interest income depends solely on the unknown part and thus:

$$\Delta ii_j = sa_j \times (1 - p_j) \times \Delta r_j \quad (2.6)$$

The overall change in interest income may be defined as the sum of all  $n$  rate sensitive assets of the bank:

$$\Delta II = \sum_{j=1}^n sa_j \times \Delta r_j \times (1 - p_j) \quad (2.7)$$

Assuming in first instance that the same logic may be applied to compute the interest expenses, and additionally that changes in interest rates of assets and liabilities are uniform, we may derive the change in total interest income as:

$$\Delta NI = \Delta II - \Delta IE = \left( \sum_{j=1}^n sa_j (1 - p_j) - \sum_{j=1}^n sl_j (1 - p_j) \right) \Delta r_j \equiv G^{MA} \times \Delta i \quad (2.8)$$

Where  $G^{MA}$  is the maturity gap, calculated as the difference between a firm's weighted average asset maturity (MA) and weighted average liability maturity (ML).

$$G^{MA} = (MA - ML) \quad (2.9)$$

With:

$$MA = W_{A1}M_{A1} + W_{A2}M_{A2} + W_{A3}M_{A3} + \dots + W_{An}M_{An}$$

$$ML = W_{L1}M_{L1} + W_{L2}M_{L2} + W_{L3}M_{L3} + \dots + W_{Ln}M_{Ln}$$

$$W_{Ai} = (\text{market value of asset } i) / (\text{market value of total assets}).$$

$$W_{Li} = (\text{market value of liability } j) / (\text{market value of total liab.})$$

$$M_{Ai} \text{ is the maturity of asset } i.$$

$$M_{Li} \text{ is the maturity of liability } j.$$

When  $(MA - ML) > 0$  then an increase (decrease) in interest rates is expected to decrease (increase) a financial firm's equity. The other way around also holds.

Both the models presented so far may fare quite well on paper but they do present challenging limitations when performed concretely (Sironi, Resti, 2007). Firstly, changes in interest rates of assets and liabilities may not be uniform for different maturities. This, in particular, is exacerbated if the sensitivity of assets and liabilities to interest rates varies consistently. Secondly, demand loans and deposits and in general all instruments without a fixed maturity do not reflect immediately, for various reasons, the change in market interest rates. Another major problem is represented by the fact that repricing models, as presented so far, deals only with flows, i.e. interest expenses and income therefore, neglecting potential impacts on assets and liabilities. Lastly, effects deriving from changes in market values of assets and liabilities are completely ignored.

### 2.1.2 The Duration Gap Model

To the aforementioned problems, practitioners and experts have designated the standardized gap model as one possible solution or at least, to the first three points. In a nutshell, this further evolution introduces the concept of *adjusted gap*, which basically, is a repricing gap that considers also the difference in sensitivity of assets and liabilities and the price-quantity interactions. Despite the big step forward, still, the effects deriving from changes in market value of assets liabilities are not taken into account. As a result, another more comprehensive measure has gained increasing acceptance: the duration gap model. The main difference is represented by the variable of interest: in the former two cases, a flow variable, the net interest income whereas in the latter, a stock, equity-based variable is adopted.

The duration of an instrument may be calculated as the average of cash-flow maturities associated with the instrument itself, whereby every maturity is weighted according to the ratio between the present value of cash-flow for a given maturity and the market price of the instrument.

$$D = \sum_{t=1}^T t \times \frac{\frac{CF_t}{(1+r)^t}}{P} \quad (2.10)$$

where:

$D$  = duration

$t$  = maturity of individual cash flows expressed in years

$CF_t$  = t-th cash flow

$r$  = effective yield to maturity requested by the market for maturity  $T$

$P$  = price or market value of the instrument concerned

$T$  = maturity of the asset, namely, of the final cash flow

In practice, the duration is a measure that considers both the instrument's residual life and the amount of intermediate flows, in addition to considering the sensitiveness of the instrument's after a change in the market interest rates. For the interest rate risk purpose, duration as it is may not be useful. Thus, a variant is required, that is, the modified duration:  $-\frac{D}{1+r}$ . The modified duration gives the possibility to quantify percentage change in prices deriving from extremely small change in market yield.

$$\frac{\Delta P}{P} \cong -\frac{D}{1+r} * \Delta r \quad (2.11)$$

As stated earlier, the duration may allow us to estimate the sensitivity of market value to changes in market interest rate:

$$\frac{\Delta MV}{MV} \cong -\frac{D}{(1+r)} \times \Delta r = -MD \times \Delta r \quad (2.12)$$

From which:

$$\Delta MV \cong -MV \times MD \times \Delta r \quad (2.13)$$

The latter equations may refer indistinctly to either assets or liabilities. In case of assets, we would have  $MV_A$  and  $r_A$  instead of  $MV$  and  $r$ . The same holds for liabilities. Following the calculations of Sironi and Resti (2007), we may arrive to the following point:

$$\Delta MB_B \cong -(MDA - MDL) \times \Delta MVA \times \Delta r = -DG \times \Delta MVA \times \Delta r \quad (2.14)$$

With  $L$  representing the bank's financial leverage ( $MV_L/MV_A$ ) and  $DG$  as the duration gap. The equation points out that the change in the market value of a bank's equity following a change in interest rate is a direct function of three factors: the intermediation activity undertaken by the bank ( $MVA$ ); the size of the interest rate change and the difference between the modified duration of assets and liabilities adjusted by the bank's financial leverage. Interest rate changes are neutralized in case  $MDA = MDL$ , that is, sensitivity of assets and liabilities are identical. But in reality, what happens is that assets have larger value than liabilities. In that case, we would require a  $DG$  equal to zero for the immunization to work efficiently and, as a consequence, the modified duration for assets must be lower than liabilities' one. Conversely, when  $DG$  is not zero the former equation allows us to calculate the impact of changes in equity value due to a change in market interest rates.

Although the duration gap model represents a milestone when it comes to interest rate risk, it still far from being unbiased and blindly-adopted. Four main problems are stressed out (Sironi & Resti, 2007). The first issue regards the dynamic nature of immunization policies which leads to short-lasting hedging effects. A second problem concerns costs of immunization policies: in practice, many strategies may turn out to be extremely expensive for banks. Thirdly, the duration gap is a linear approximation model, and as such, it may lead to larger error estimate, the greater the change in interest rates. Finally, the duration gap suffers the same unrealistic limitation of its predecessors, i.e. uniform interest changes. Similarly, the threat is resolved with the concept of modified duration gap, which takes into account also different degree of sensitivity of assets and liabilities.

### **2.1.3 The Basel Committee Model for Interest rate risk**

Uniform changes in interest rate may be deemed as the greatest limitation of all gap models. And though concrete solutions, such as modified duration, have been introduced, they are still far from being flawless. For this reason, other cash-flow based techniques have gained extraordinary success: it is no coincidence that even the Basel Committee opted for a cash

flow model instead of the repricing ones. These models are generally referred to as Cash-flow Mapping and may be applied to manage many different risks other than the interest rate one. The underlying functioning concept is quite trivial: single bank positions, typical of gap models, are transformed into value at risk, that is, in other words, from the yield curve the focus now shifts towards zero-coupon or term-structure rate curves. Banks' exposures are basically decomposed into unitary cash flows and grouped, for simplicity's sake, into a limited number of *buckets*. Obviously, the number of buckets may vary consistently from institution to institution. On the one hand, a reduced number, i.e. three or lower, would not capture significant changes, conversely, a large number, i.e. more than fifteen, would cause too much of a noise in the curve. As a result, an optimal number may be around twelve, which may permit to carefully capture relevant shifts while properly neglecting uninfluential movements. Consequently, in a general mapping procedure, cash flows whose maturity does not match a precise bucket may be either accurately divided into two distinct flows and assigned to the closest couple buckets, trying to preserve the characteristics of the original flow, or assigned to one single node, as in the Basel Committee model.

A proper way to “map” banks assets and liabilities into a fixed number of buckets or nodes is represented by residual life of single exposures: all the assets and liabilities with similar repricing maturity are grouped together into discrete intervals and the central midpoint amount of the flows is designated as the value of the bucket in the term structure.

The Basel Committee identifies additional criteria to properly manage interest rate risk. In particular, financial institutions are required to reveal a terse indicator, which shall represent straightforwardly the overall exposure to interest rate risk. These include the division of bank's assets and liabilities into thirteen layers, each of them with a specific duration interval. The cash flow mapping, in this case, does not explicitly consider intermediate flows, such as coupons, in the sense that their presence may only influence the assignation to one interval rather than another: the higher the intermediate coupons, the greater the likelihood to be grouped with positions with lower residual life. Every bracket shall be reported at its net position, taking as such the difference between assets and liabilities for all the intervals. Further, to compute the overall risk exposure, each of the thirteen brackets is then weighted for the relative average modified duration and for a possible range change  $\Delta r_i$ , which naturally is greater for short-term maturities, as volatility in the long run tends to decrease. The result is a simple value similar to the previous duration gap computation of changes in market value of assets and liabilities. The sole difference is that in the latter case, we are dealing with market values of balance sheet while in the former with book values.

$$\Delta NP_i \cong NP_i \times MD_i \times \Delta r_i \quad (2.15)$$

Needless to say, interest impacts may have different effects depending on the net position  $NP$ : in case of a positive (negative)  $NP$ , an increase in interest may trigger a loss (profit). The other way around works symmetrically for interest rate drops. One pivotal remark of the Basel Committee's methodology is the fact that it does not allow to completely compensate positive and negative net positions, as, correctly, this would implicitly imply the existence of sole parallel shifts of the yield curve, which of course is far distant from reality.

The scope of the entire process is to obtain a sound and easily-comparable estimate. Thus, following the indications of the Committee, summing up the absolute values of the thirteen intervals and dividing for the regulatory capital, we may come up to a ratio which concisely represents the bank total exposure to interest rate risk and might be easily evaluated in relation to the average of the sector.

$$\frac{\sum_{j=1}^{n+1} |\sum_{i=1}^{13} \Delta NP_{ij}|}{RC} \quad (2.16)$$

As presented so far, the Basel Committee model would find in the simplicity its greatest advantage. But simplicity more than a sole advantage may be regarded as a double-edged sword: it is no coincidence that one of the main criticism of the model is that it tends to improperly oversimplify the banking reality. Moreover, the usage of book values instead of market values may also be deemed as a relevant limitation, as, the former ones are in general much farther from fundamental values than the latter. The criticism has clearly underlined the evident limits of the model, nonetheless, the Basel Committee model does not aim at becoming the internal technique of excellence, which, given the low rate of adoption, might be almost impossible, but rather to give a simple and straightforward comparison opportunity for the sole regulatory purpose.

## 2.2 Introduction to Banking Market Risk

Market risk arises from fluctuations of assets and liabilities' market values, which may result, at least in the short-term, in potential losses for banks. When accomplishing daily activities, in fact, banks are exposed to a lot of volatility, which in some cases may not be directly governable, posing consequently, hard times to banks' risk management policies. For instance, let us assume, realistically, that a bank holds equity investments as assets. In general, banks may control for some business-related issues, such as remuneration policies or business plan approvals but may encounter more challenges when stock prices widely fluctuate due to uncontrollable factors. And differently from the interest rate risk, market risk's components are various and different. According to the classical division, in fact, five main risks may be identified within the market risk:

- 1) *Interest rate risk*. In the banking language, management of interest rate risk may be also deemed as asset-liability management (ALM). In the section related to the interest risk, it was stated that the many practitioners tend to deem the interest risk just as a part of market risk. But as already explained earlier, this specific risk relates to the only trading book of the bank and not to the entire balance sheet as the broader understanding would suggest. This implies that the interest risk component belonging to the market risk has a specific short-term and investment-related feature.
- 2) *Exchange rate risk*. The exchange rate risk may be defined as the adverse impact that exchange rate movements may have on the banks' cash flows, assets and liabilities, resulting in a loss. Madura (1989) more broadly defines it as the effects that negative unexpected changes in exchange rate may have on the value of firms. Three main risks may be grouped into the category (Papaioannou, 2006): the *transaction risk*, which arises for account payables, receivables and repatriation of dividends; the *translation risk*, that may be normally faced during the consolidation of foreign subsidiaries, that is, typical of parent-subsidiary relationship, and finally, the *economic risk*, which basically is the threat of changes in present value of future operating cash flows due to moves in the exchange rate. Essentially, the economic risk mirrors the changes in revenues and operating expenses.
- 3) *Equity risk*. The equity risk represents the threat deriving from unexpected stock price movements. A bank may carry out equity investments as part of its non-operating activities or as main core business as for investment banks. But the equity risk may also derive in case the bank accepts stocks as collateral thus, not necessarily linked to any direct investment.
- 4) *Commodity risk*. It is the risk associated to market values of positions, which may be sensitive to changes in commodity prices, such as commodity futures or commodity swaps.

5) *Volatility risk*. The volatility risk simply derives from sensitivity changes from one or more precedent risks' volatility.

### 2.2.1 Market Risk Measurement: The Value at Risk Approach

Among the different models to calculate VaR and SVaR the Variance-Covariance is surely one of the most well-known. This technique, which sometimes is called delta-normal method, assumes that all bank's portfolio exposures are linear and that risk factors are both normally and independent and identically distributed (i.i.d. hypothesis). As a result, portfolio returns are linear combinations of normal variables and thus normally distributed as well. The greatest benefit of the Variance-Covariance approach is its simplicity. But this may also be regarded as its biggest drawback as, for instance, it may not be able to capture the effects of embedded options or in general of instruments with no linear patterns. Additionally, empirical researches (Huisman *et al.*, 1998) have clearly pointed out that the normal distribution assumption does not fare well in reality, as tails, and specifically the left tail, may be in general fatter (*leptokurtosis*).

Practically, assuming for simplicity's sake that the bank's portfolio is composed by one instrument, the value at risk may be conceived as the difference between the expected value of the portfolio in the chosen time horizon  $t$  with a certain likelihood  $p$  and the lowest value of the portfolio, at the same time horizon and with the same probability:

$$VaR = MV_m - MV_L = V_0 (1 + R_m) - MV_0 (1 + R_L) = V_0 (R_m - R_L) \quad (2.17)$$

where:

$MV_0$  = the current market value of portfolio;

$MV_m$  = expected value of the portfolio on the time horizon  $t$

$MV_L$  = the lowest value that a portfolio can record (level) on the chosen time horizon, corresponding with the confidence interval;

$R_m$  = the portfolio's average yield on the time  $h$

$R_L$  = yield corresponding level

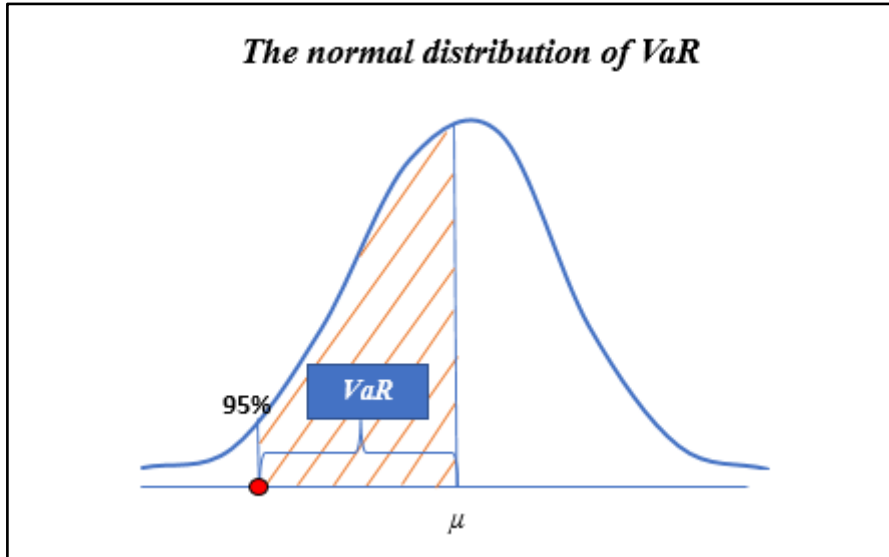


Figure 2.2. An example of VaR Probability Distribution. (Author's elaboration)

The lowest value  $MV_L$  is determined as a distribution function depending on the time span  $t$  and on the likelihood of occurrence, that is, the confidence interval  $\alpha$ :

$$1 - \alpha = P(x < R_L) = \int_{-\infty}^{R_L} f(x)dx \quad (2.18)$$

Moreover, as the VaR is based on the cumulative normal distribution assumption, the variable we are looking for  $R_L$  may be determined as follows:

$$RL = \alpha \times \sigma + R_m \quad (2.19)$$

With  $\alpha$  being the confidence interval and  $\sigma$  the market volatility of the portfolio. Therefore the value at risk may be rearranged as:

$$VaR = MV_m - MV_L = MV_0 \times [(R_m - (\alpha \times \sigma + R_m))] = -MV_0 \times \alpha \times \sigma \quad (2.20)$$

As the value at risk represents a potential loss for the institution, the minus symbol might be omitted, as it would somehow be redundant or confusing.

$$VaR = MV \times \alpha \times \sigma \quad (2.21)$$

To implement the variance covariance approach to a position, we need first to define three elements. First the market value, which is easily obtainable. Secondly, a scaling factor  $\alpha$  which ponders the risk measure into a determined interval of confidence, which is an arbitrary factor, and lastly the market volatility of the returns. The  $\alpha$  represents the confidence probability or percentage of risk tolerance ( $1 - \alpha$ ) of the VaR. Of course, a higher value of  $\alpha$  would imply higher level of protection against unexpected losses and is typical of banks with high risk aversion. A simple way to choose the adequate confidence interval is suggested by Zaik *et al.* (1996). They noticed that customers and shareholders in particular are worried about banks' creditworthiness and credit ratings and thus banks try as much as they can, in terms of equity capital, in order to preserve a high, investment-grade rating. Notably, rating



agencies associate to each rating a specific probability to default. For instance, Moody's for an investment grade company Aa3, predicts a probability to default of 0.03%. According to Zaik *et al.*, starting from that probability of default we may derive a confidence interval as a simple subtraction of the former from the unit, in this case as  $1 - 0.03\% = 99.97\%$ .

<i>Moody's Rating Class</i>	<i>1-Year Probability of Insolvency</i>	<i>Confidence Level</i>
<i>Aaa</i>	0.001%	99.999%
<i>Aa1</i>	0.01%	99.99%
<i>Aa2</i>	0.02%	99.98%
<i>Aa3</i>	0.03%	99.97%
<i>A1</i>	0.05%	99.95%
<i>A2</i>	0.06%	99.94%
<i>A3</i>	0.09%	99.91%

Table 2.1. *Rating Classes and Confidence Levels* (Resti, Sironi, 2007)

Another crucial point is to decide the time span over which to forecast potential losses. To this purpose, three main considerations need to be addressed (Resti & Sironi, 2007). First, the degree of liquidity of single positions. The easier the winding up of a position, the lower the time horizon should be and the lesser the further losses. Secondly, another relevant factor is size of the positions, as intuitively, larger investments may require more time to be liquidated. Last but not least, the intention of the financial institution is also deemed as equally important. Accordingly, we may distinguish a position whether it is held as investment and thus for longer periods or whether it is speculative one and as such, to be divested soon.

Strictly related to the issue of time horizon is the assumption about volatility. In fact, the latter is directly proportional to the time horizon: the volatility of single position or of an entire portfolio may augment unpredictably as time horizon increases. But to circumvent this problem we may rely on the normality assumption of the Variance Covariance approach and, in particular, on the i.i.d. hypothesis which guarantees the possibility to calculate any time-span volatility using the daily volatility:

$$\sigma_T = \sigma_D \sqrt{T} \quad (2.22)$$

Despite the help in terms of simplification, the validity is not empirically confirmed, as returns and price changes in general seem to be serially correlated (among others, Ball, 1989), that is, influenced by the movements in  $T - 1$  and not completely independent.

In a more realistic world, changes in market values may not have unitary effects as assumed so far. To deal with this matter, we may include a new factor  $\delta$ , which should capture the effects of changes in market factor on the position.

$$VaR = MV \times \delta \times \alpha \times \sigma \quad (2.23)$$

Additionally, to be consistent with the interest rate risk, we may further simplify  $\delta$  by considering it as the modified duration, which leads to:

$$VaR = MV \times MD \times \alpha \times \sigma \quad (2.24)$$

Unfortunately, what has been presented so far does not allow to understand why it is called variance covariance approach, since the sole variance has been used. The full name derives from the further extension towards a more realistic market portfolio, which takes into consideration the covariance among all positions. As just explained,  $\alpha$  is the key element that represents the sensitivity of the position to market factor changes, thus also changes in its volatility are weighted for  $\alpha$ :

$$\sigma_{\Delta MV_i} = \delta_i \times \sigma_i \quad (2.25)$$

For a market portfolio consisting of  $N$  positions, a change in value,  $\Delta MV$ , is determined as follows:

$$\Delta MV_P = \sum_{i=1}^N MV_i \times \Delta MV_i \quad (2.26)$$

The overall change in a market portfolio is the product of the individual market value and the single variation. From the latter, we may derive the variance of the portfolio as the sum product of any couple of market values and their covariance:

$$\sigma_{\Delta MV_P}^2 = \sum_{i=1}^N \sum_{j=1}^N MV_i \times MV_j \times \sigma_{\Delta MV_i \Delta MV_j}^2 \quad (2.27)$$

Which ultimately gives<sup>2</sup>:

$$\sigma_{\Delta MV_P} = \sqrt{\sum_{i=1}^N \sum_{j=1}^N MV_i \times MV_j \times \rho_{i,j} \delta_i \sigma_i \delta_j \sigma_j} \quad (2.28)$$

The portfolio value at risk is calculated as:

$$VaR_P = \alpha \times \sigma_{\Delta MV_P} = \sqrt{\sum_{i=1}^N \sum_{j=1}^N VaR_i VaR_j \times \rho_{i,j}} \quad (2.29)$$

Where  $\alpha$  depends on the selected confidence interval and is brought inside the root square, may allow us to simplify the formula, considering that  $\alpha \times MV_i \times \delta_i \times \sigma_i$  is nothing but the VaR's formula introduced previously. If additionally we assume that all risk factors are perfectly correlated ( $\rho_{i,j}=1$ ), the portfolio VaR is simply the sum of the single VaR composing

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<sup>2</sup> Using Pearson's correlation coefficient  $\rho_{XY} = \frac{Cov(X,Y)}{\sigma_X \sigma_Y}$  we may derive  $Cov(i,j) = \sqrt{\sigma_{\Delta MV_i \Delta MV_j}^2} = \sqrt{\rho_{i,j} \times \delta_i \times \sigma_i \times \delta_j \times \sigma_j}$

the portfolio, though, in general the portfolio VaR, according to the universally-known portfolio diversification theory, is lower than the sum of the single VaRs.

$$VaR_P = \sum_{i=1}^N VaR_i \quad (2.30)$$

This subadditivity feature is typical of parametric approaches: when multiple positions are pooled together, the total risk exposure, computed in terms of VaR, diminishes compared to the sum of standalone positions' risks. However, this trait belongs to the sole restricted parametric approaches and, as a consequence, the regulatory authorities have been searching for more complete and efficient measures other than VaR, such as Expected Shortfall. The market risk for regulatory purpose will be covered in the last dedicated paragraph.

### 2.2.2 The Basel Committee's approach to market risk

Throughout the last couple of decades and till the last major revision in 2016, the Basel Committee has been continuously adjusting its capital requirements for market risk as well as the actual method to compute such values. In the last review and in particular regarding the market risk, the Basel Committee has fundamentally modified the banking trading book, promoting a more adequate trading book capital requirement than "Basel II.5". To this extent, the Committee allows the financial institutions to deal with the market risk by implementing two methodologies: a standardized approach and the internal model. Albeit both are admissible, the Committee imposes to calculate the minimum capital requirements using the sole standardized method, in order to favor an easier comparison among banks across different jurisdictions.

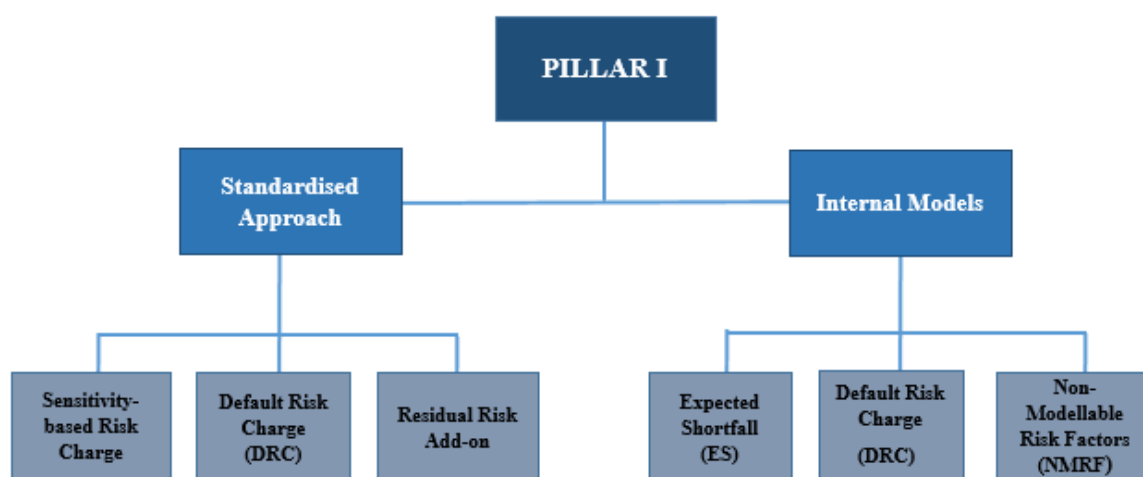


Figure 2.3. Market risk treatment according to the Basel Committee (Seal, 2016)

The standardized approach to compute di minimum capital requirements is the sum of three components: the sensitivity-based risk charge; the default risk charge (DCR); and the residual add-on.

The sensitivity-based method involves three risks: delta risk; vega risk and curvature risk. The first threat derives from sensitivity of bank's trading book to regulatory specific delta risk factors. Basically, it is the expected change in price deriving from a small price or rate shock to the value of each relevant risk factor. The vega factor characterizes only options and may be defined as the risk arising from sensitivity to regulatory vega risk factors: in other words, it is the threat arising from variations of volatility, calculated as the product of an option's vega and its implied volatility, i.e. in the volatility expected by market participants. In general, vega is positive for both call options and put options: increases in the expected volatility induce gains in the value of both types of options. Note that this risk cannot be hedged by purchasing or selling the underlying asset, but only by purchasing/selling other options. Both delta and gamma capture the linear component of market risk. Conversely, the curvature risk is indicated to deal with the non-linear part. In fact, the latter is an incremental risk, which catches the option price changes not covered by the delta factor.

The sensitivity model works basically as follows: firstly, we need estimate of sensitivity (delta and vega) based on bank's pricing model for each risk factor, for instance a 10-year USD bond. Then, multiply with corresponding risk weights and add up with correlations within the same bucket. The aggregation uses regulator-prescribed correlations factors, applied within a regulator-provided grouping formula. The resulting "bucket-level" capital charges are afterward summed to obtain the "risk class level" capital requirement and conclusively, the aggregate capital charge is nothing else but the sum of the seven single risk classes<sup>3</sup> capital charges. To this figure a default risk charge, (DCR) and a residual add-on shall be added. Starting from the former, we must estimate, in first instance, the Jump to Default (JTD) for each instrument. The JTD is a function of notional amount, market value and prescribed LGD. Then, long and short positions to the same obligor shall be offset to derive net JTD which, in turn, are allocated to buckets and multiplied by approved risk weights. Importantly, risk weights for non-securitization positions are set by credit quality rating. The DRC is just sum of bucket-level default risks. The final component, that is, the residual add-on is conceived to eliminate or more properly, to mitigate the residual market risk, not captured by the standardized approach. Such may be for instance, the correlation risk and the behavioral risk. This additional charge shall be computed as percentage of the instrument: for derivatives and

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<sup>3</sup> According to the Basel Committee, the seven market risk classes are: General Interest Rate Risk (GIRR); Credit Spread Risk: non-Securitization, Credit Spread Risk: Securitization (non-correlation TP) Credit Spread Risk: Securitization (correlation TP); Equity Risk; Commodity Risk; Foreign Exchange.

exotic instruments, it must be 1%, whereas, for other instruments it is 0.1%. Finally, the calculation of three risk charge figures based on three different scenarios on the specified values for the correlation parameter.

The internal model on three main components: the Expected Shortfall; the default risk charge (DCR); and the Non-Modellable Risk Factors (NMRF) or stressed capital add-on. The last two components are quite similar to the standardized approach, with the latter feature trying to capture the residual risk and the former to cope with the default risk of trading of credit and equity risk trading book exposure. In particular, a remarkable difference between the types of default risks lays in the computational process. Differently from the standardized approach, the internal model's method is based on the credit VaR computed on a 99.9% of confidence interval over a one-year time horizon and utilizes the same LGD of the internal rating-based approach. A different consideration must be carried out for the (Global) Expected Shortfall (ES)<sup>4</sup>. When we introduced the Value at Risk, it was clearly pointed out that one of the main limitation of this method is that it does not tell anything about what may happen in the far-left tail, i.e. in the region where negative outcomes can exceed the maximum expected loss (*tail risk*). In effect, whether the excess loss is ten billion or just one million cannot be determined. For this reason, along with the aforementioned lack of subadditivity, the Basel Committee substituted the stressed Value at Risk with an Expected Shortfall technique, which considers both the size and likelihood of losses above a certain confidence level, i.e. captures the tail risk. Nonetheless, similarly to the VaR, the Expected Shortfall has a confidence level and is valid for a determined time horizon.

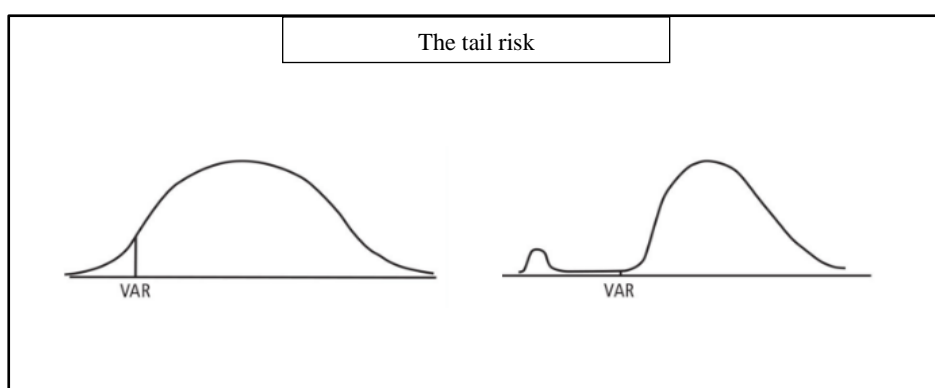


Figure 2.4. *The Expected Shortfall as a solution to the tail risk* (Hull, 2006)

The Expected Shortfall may therefore may be deemed as the expected value of all losses in excess of VaR (Resti, Sironi, 2007). As such, we may analytically describe this relation as follows:

<sup>4</sup> There are many names for the Expected Shortfall: average shortfall (AS), conditional VaR (CVaR), or extreme value at risk (EVAR) (Resti, Sironi, 2007)

$$ES = E[-(\Delta MV - E(\Delta MV))] \quad (2.31)$$

Such that:

$$-(\Delta MV - E(\Delta MV)) > VaR \quad (2.32)$$

Where the  $\Delta$  symbol may also be omitted, since we may consider future market values instead of its variation. From an exquisitely economic point of view, it is interesting to notice the possible relationship between the VaR and ES. The former may represent the capital which is required to be paid in so that to limit the probability of bankruptcy to  $1-c$  (where  $c$  is the chosen confidence level). Conversely, the difference between ES and VaR may be regarded as the expected cost that the regulatory authorities might incur to bail out a bank if its capital (i.e. its VaR) were not enough. Moreover, the expected payment that a risk neutral insurer would have to face, if the bank had insured itself against the risk of excess losses (Resti, Sironi, 2007).

## 2.3 Introduction to Credit Risk

The Basel Committee defines credit risk as the potential that a bank borrower or counterparty will fail to meet its obligations in accordance with agreed terms. To put it in another way, the credit risk is the threat of loss that arises as a result of the non-performance by customers and other counterparties of their payment obligations to the financial institution. Managing credit risk is extremely difficult, since it is a multidimensional issue and consequently there are many different approaches in use, some of which are quantitative whereas others comprehend qualitative, subjective judgements. Whatever the technique employed, the key point is to figure out the behavior and predict the realistic probability of individual credits defaulting on their obligations.

Broadly speaking, credit risk may be divided into six main categories. The most well-known are the *default risk*, which is, in a nutshell, the risk of loss deriving from the concrete insolvency of the borrower and the *migration risk*, that represents the damage triggered by a deterioration of the counterparty's creditworthiness. Thus, the credit risk may not be restricted to the sole default event, as the devaluation of the clients' rating can also provoke serious consequences in terms of profitability and overall economic value. In other words, the default risk represents the extreme case of the migration risk: they both may belong to the same continuous variable, which reflects both small changes in the creditworthiness, on the one hand, and the default event, on the other. Another risk included in the credit risk is the *spread risk*. The latter may be regarded as the risk of an unexpected increase in the spreads required by the market to borrow money. The *recovery risk* is strictly related to the default risk. Basically, this threat arises when the recovery of the expected liquidation value is lower than the initially-expected forecast; or in case the time of recovery is longer than estimated, which may indeed be relevant from a cost-opportunity point of view. Lastly, the *substitution risk* and the *country risk*. The former characterizes specific OTC transactions, namely, it is the threat that the counterparty of a OTC position becomes insolvent before the actual maturity of the obligation, hence obliging the bank to substitute it at new and potentially less profitable market conditions. The remaining country risk may turn out to be rather challenging to deal with, since it depends on macroeconomic and legislative policies, which are, at least directly, uncontrollable by the bank. Thus, this kind of risk is a typical example of systemic risk and as such it cannot be diversified away (Schwarcz, 2008).

### 2.3.1 Credit Risk: Regulatory Framework and Structural Approaches

Differently from the previous paragraphs concerning other banking risks, it would make no sense to separate internal credit risk modelling practices from regulatory purposes, as they are strictly correlated. In order to deal properly with the credit risk, we first have to introduce some fundamental concepts:

- Probability of Default (PD): Probability that the obligor will default within a selected time horizon
- Exposure at Default (EAD): the sum outstanding at time of default. Most of the times, banks calculate the exposure on single loans and an overall EAD as well.
- Loss given default (LGD): the percentage loss deriving from the *EAD*
- Maturity: effective maturity of the considered exposure.

As for other risks, the Basel Committee envisages different measurement methodologies to calculate capital adequacy requirements. Note that, the regulatory focus is not providing a universally-accepted method to compute credit risk, since financial institutions, under this point of view, have a lot of discretion. Rather, the ultimate goal is to ensure that banks hold sufficient capital to cover potential unexpected losses that may derive either from default events or from mere deteriorations of credits and loans. Under Basel II in particular, banks may adopt either of the two typologies to measure credit risk: the standardized approach and the internal rating-based approach (IRB). The main difference is represented by the utilization of either external ratings, as in the standardized method, or internal ones, as in the IRB approach. Specifically, the internal rating system is just allowed for banks that meet specific criteria<sup>5</sup> and may be divided into two techniques: *Foundation-IRB*, which allows banks to compute independently the probability of default (PD) for each asset; while the regulatory authority will determine both the Loss Given Default (LGD) and the Exposure at Default (EAD). The maturity (M) can be either assigned by the regulator or decided by the bank. Conversely, in the Advanced-IRB banks are permitted to use their internal models to calculate all the four key elements PD, LGD, EAD, and M. A summarising graph may be useful to dispel any confusing doubts.

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<sup>5</sup> The authorization is not given to all financial institutions. In fact, banks that aim at obtaining the go-ahead shall construct estimation models that must meet strict qualitative and quantitative criteria:

- 1) Internal models must to be risk-sensitive to the portfolio of the bank
- 2) The internal model shall distinguish obligor characteristics and have sufficient data to estimate the key risk factors within determined statistical confidence levels
- 3) There should be proper corporate governance and internal controls
- 4) The modeling and capital estimation framework should be linked to the day-to-day operations of the bank
- 5) There should be an appropriate validation and testing process, ensuring the estimation of the precise PD, LGD, EAD, and capital estimates for credit risk



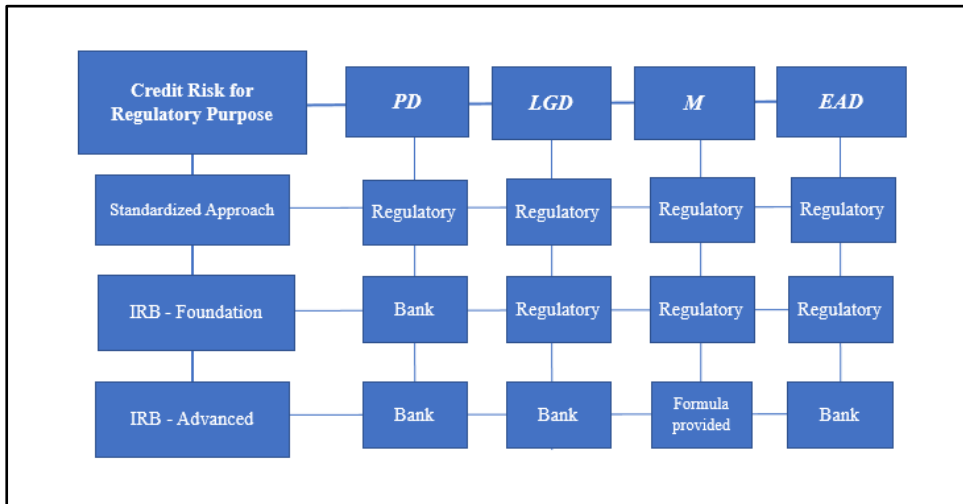


Figure 2.5. Summary of Regulatory Credit Risk. (Source: Author's elaboration)

Broadly speaking, banks may find it more advantageous to adopt an IRB mechanism, since the capital requirements calculated with an internal approach are lower than computed with the standardized method. Additionally, IRB models may better reflect specific peculiarities and risks of the banking credit portfolio. Although the international authorities are encouraging financial institutions to adopt the Advanced IRB approach, i.e. to develop internal models to calculate credit risk, they also acknowledge that internal models may generate distortion or by the way, make comparison across banks more challenging. Under the IRB approach, banks are required to categorize their banking book exposures into the following asset classes: corporate; sovereign; bank; retail and equity. To each of them, then, will be assigned a different risk weight and multiplied for the exposure at default.

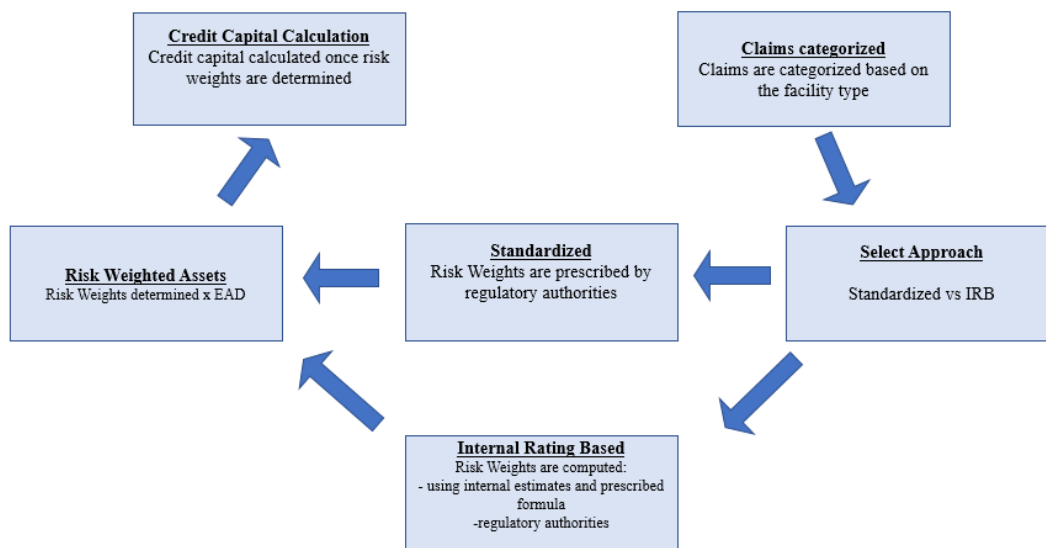


Figure 2.6 The Regulatory Compliance Process for Credit Risk (Source: CRISIL, 2017)

The Basel Committee provides the risk-weight formulas to calculate the capital requirements.

$$RWA = RW \times Exposure\ At\ Default \quad (2.33)$$

Where  $RWA$  denotes risk weighted amount and  $RW$  the risk weight. The formula varies depending on the exposure category and utilizes PD, LGD, and M as inputs. In particular, it strongly depends on the internal estimates of the probability of default. In effect, when the latter is zero, so is the risk weight and no capital requirement is needed. Let us focus on the cases where  $0 < PD < 1$  and when  $PD = 1$ . In the former case, risk weight is calculated as:

$$RW = \left[ LGD \times N \left( \frac{R}{\sqrt{1-R}} G(PD) + \sqrt{\frac{R}{1-R}} \times G(0.999) \right) - LGD \times PD \right] \frac{1 + (M - 2.5) \times b}{1 - 1.5 \times b} \times 12.5 \times 1.06 \quad (2.34)$$

Where:

$N(x)$  = the cumulative distribution function for a standard normal random variable

$G(Z)$  = the inverse cumulative distribution functions for a standard normal random variable (i.e. the value of  $x$  such that  $N(x) = z$ ).

$R$  = the coefficient of correlation computed as:

$$R = 0.12 \times \frac{1 - e^{-50 \times PD}}{1 - e^{-50}} + 0.24 \times \left( 1 - \frac{1 - e^{-50 \times PD}}{1 - e^{-50}} \right) \quad (2.35)$$

$b$  = the maturity adjustment factor, calculated as  $b = [0.11852 - 0.05478 \times \ln(PD)]^2$

For defaulted exposures for which banks apply internal LGD estimates, the capital requirement (RW)

$$RW = \max\{0, 12.5 \times (LGD - EL_{BE})\} \quad (2.36)$$

where  $EL_{BE}$  is expected loss best estimate, that is, the institution's best estimate of the expected loss for the defaulted exposure.

One important remark is that the risk weight formulas are meant to cope with the only unexpected loss and do not include expected loss provisions<sup>6</sup>, as the former tend to occur less frequently but consist of way larger amounts.

Once again, it is worth recalling that under the Foundation IRB approach, the formula assumes prescribed values for LGD and M, while under the Advanced method, all parameters are estimated using internal models. A complete analysis would be beyond the scope of this work. Consequently, we focus on the structural approaches, and in particular on the Merton model, as it might be regarded as the most comprehensive.

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<sup>6</sup>Expected loss is usually defined as the average loss that the bank may expect to incur in from an exposure over a determined time span, while an unexpected loss is the loss that the bank may suffer over and above the average loss expected from an exposure over the same period of time. Moreover, expected loss may cannot be eliminated by diversification, whereas unexpected loss may at least be mitigated by portfolio diversification policies (Resti, Sironi, 2007).

Since credit risk has become an increasing concern in recent years, especially after the Financial Crisis, various advanced methods have been developed extensively to measure credit risk exposures. Specifically, credit risk modelling may be divided into two macro branches: reduced forms and the aforementioned structural models. The main difference between the two may be grasped already in their names: the structural approaches try to trace an explicit connection between the credit default risk and the company's capital structure. To this extent, Brennan and Schwartz (1978) provide various numerical techniques. Sundaresan (2013) as well provides a deep analytical insight concerning structural and in particular Merton-derived models. Such models, in effect, are unsurprisingly widespread for distressed firm valuations. Conversely, the reduced form techniques treat credit defaults as something exogenous and are simpler to implement, for this reason more employed in the credit risk management framework.

The Merton model is the prince of the structural models: the first to ever employ the modern option pricing theory to the corporate debt valuation and as such, the undisputable milestone from which many other sophisticated structural approaches were originated. The most famous remark about the Merton model is the consideration of the firm's equity as a call option on its assets: as long as the company is performing well, its overall corporate value (i.e. the assets) is increasing and so is the equity stock price. Thanks to this analogy, we may apply the option-pricing findings of Black and Scholes (1973) to the valuation of the enterprise's debt. To analyze the Black, Scholes and Merton model, let us start from the simple accounting equation that characterizes all firms:

$$A_t = E_t + D_t \quad (2.37)$$

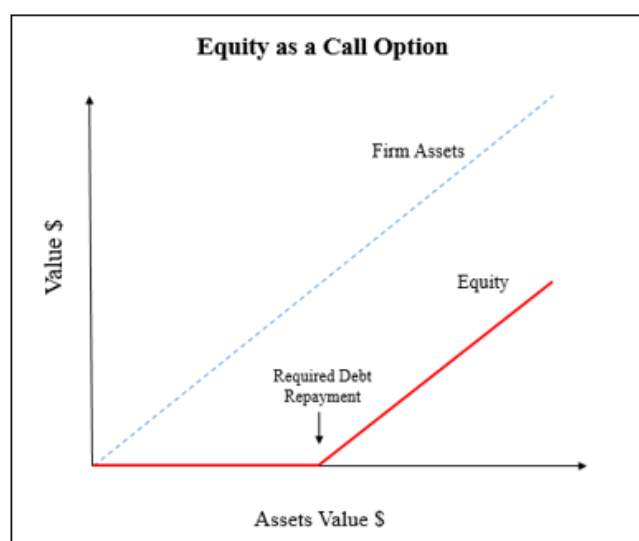


Figure 2.7. *Equity as a Call Option: boundless positive payoff* (Berk and DeMarzo, 2017)

This former equation states that the assets of a firm at time  $t$  are equal to the sum of the equity and the firm's debt at time  $t$ . The debt, in particular, is simplified to a zero-coupon bond, which of course may be unrealistic but nonetheless, still enough for exemplifying purposes. Assuming further that the face amount of the debt is  $K$ , if the bank at time of maturity  $T$  possesses assets whose value is greater value than  $K$  ( $A_T > K$ ), the bank will be able to entirely repay its debt and the equity will be worth  $A_T - K$ . Conversely, in case at maturity  $T$   $A_T < K$ , the firm is insolvent and debtholders will receive the residual value,  $A_T$ , while shareholders will be empty-handed. Thus, we may conclude that the equity value at time  $T$  can be represented as:

$$E_T = \max(A_T - K; 0) \quad (2.38)$$

This is exactly the payoff of a European call option contracted on the underlying asset  $A_t$  with strike price  $K$  maturing at  $T$ . Hence, the Black and Scholes formulas can be applied. But before entering into details, let us consider the position of the debtholder (Breccia, 2012). Assuming that the absolute priority rule (APR) holds<sup>7</sup>, at time of maturity  $T$  the debtholder's payoff is:

$$D_T = \min\{K, A_T\} = L + \min(A_T - L, 0) = K - \max(K - A_T, 0) \quad (2.39)$$

The creditor's payoff is therefore a sum of two components: a safe one,  $K$ , and a short position of a put option on the company's assets. To apply Black and Scholes, an additional assumption is required: the asset's value shall follow a geometric Brownian motion (GBM) process, with risk-neutral dynamics given by the stochastic differential equation:

$$\frac{dA_t}{A_t} = r dt + \sigma_A dW_t \quad (2.40)$$

where  $W_t$  is a standard Brownian motion under risk-neutral measure,  $r$  stands for the continuously compounded risk-free interest rate, and  $\sigma_A$  is the asset's return volatility. Next, applying the Black and Scholes formula for an European call option to the equity we arrive to:

$$E_t = A_t \Phi(d_+) - K e^{-r(T-t)} \Phi(d_-) \quad (2.41)$$

where  $\Phi(\cdot)$  denotes the  $N(0,1)$  cumulative distribution function, with the quantities  $d_+$  and  $d_-$  given by:

$$d_+ = \frac{\ln\left(\frac{A_t}{K}\right) + \left(r + \frac{1}{2}\sigma_A^2\right)(T-t)}{\sigma_A \sqrt{T-t}} \quad (2.42)$$

$$d_- = \frac{\ln\left(\frac{A_t}{K}\right) + \left(r - \frac{1}{2}\sigma_A^2\right)(T-t)}{\sigma_A \sqrt{T-t}} \quad (2.43)$$

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<sup>7</sup> The absolute priority rule is a concept that applies across different countries, especially during the winding-up of a firm. Accordingly, senior claims (debt and debt equivalents) shall be satisfied before junior claims (usually equity and equity equivalents)

The main focal point of interest is to understand how the option pricing techniques may relate to the credit default. In particular, the default event is triggered as soon as the company is not able to completely repay the amount  $K$  at time to maturity  $T$ . Using an exquisitely option-specific language, the default happens when the shareholders' call option matures out-of-money, analytically:

$$P(A_t - K) = \Phi(-d_-) \quad (2.44)$$

In a realistic framework, no debtholder would carry such an enormous risk without trying to hedge his position. To accomplish this task, they may write a European put option on the same underlying asset  $A_t$  and with identical maturity and strike price  $K$ . In this circumstance, the put option will allow to reach a fully-hedged position, since, in case  $A_T < K$  it will be worth  $K - A_T$  and zero otherwise. Thus, if we combine the debt and the put option we can arrive to a risk-free position with a payoff equal to the strike price  $K$ :

$$D_t + P_t = Ke^{-r(T-t)} \quad (2.45)$$

Where  $P_t$  is the price of a put option at time  $t$ . This can be easily determined by applying the Black and Scholes formula for a European put option:

$$P_t = Ke^{-r(T-t)}\Phi(-d_-) - A_t\Phi(-d_+) \quad (2.46)$$

Further, a typical corporate bond is quite risky and assuming a mere risk-free rate would of course defy credibility. As a consequence, a risk premium  $s$  is necessary in order to evaluate the corporate debt:

$$D_t = Ke^{-(r+s)(T-t)} \quad (2.47)$$

Specifically, combining the last three equations together (2.48); (2.49) and (2.50) we may derive directly a formula to calculate the risk premium, or credit spread,  $s$ :

$$s = -\frac{1}{T-t} \ln\left[\Phi(d_-) - \frac{A_t}{K} e^{r(T-t)}\Phi(-d_+)\right] \quad (2.48)$$

The component  $\frac{A_t}{K} e^{r(T-t)}$  is called “quasi-debt ratio” and is a form of leverage ratio (Breccia, 2012). Note that the model estimates the spread for a given  $A_t$  and  $\sigma_A$ . A trivial way to compute those two values is to assume the Brownian motion model for the equity price and using Ito's Lemma (Wang, 2009) to show that instantaneous volatility satisfies<sup>8</sup>:

$$A_t\sigma_A \frac{\partial E_t}{\partial A_t} = E_t\sigma_E \quad (2.49)$$

Note that  $\partial E_t / \partial A_t$  is nothing else but the Black and Scholes call option delta,  $\Phi(d_+)$ , which substituted in the previous equation leads to:

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<sup>8</sup> This is the underlying intuition of the KMV method. This model has the greatest feature of considering a company's debt to be realistically composed by a short-term account and a long-term one. Consequently, a company is defaulting when it is not able to repay its short-term obligations and a part of long term debt (*Default Point*), namely:  $DP = ST\ DEBT + \frac{1}{2} LT\ DEBT$ . From this value, a Distance to Default is computed following the following formula:  $DD = \frac{V_0 - DP}{V_0\sigma_A}$ . Finally, to each DD a default probability is attributed, based on the historical default frequency of a wide sample.

$$A_t \sigma_A \Phi(d_+) = E_t \sigma_E \quad (2.53)$$

Both  $E_t$  and  $\sigma_E$ , that is, the equity price and its volatility, may be directly obtained from the equity market. Consequently, by solving simultaneously (2.44) and (2.53) we may arrive to reasonable estimates of  $A_t$  and  $\sigma_A$ , which are critical to compute the credit spread  $s$ . Interestingly, Breccia (2012) proves that, differently from the bank's equity, an increase in volatility may impact negatively on the debt's value.

Wang (2009) purposes an interesting analysis of credit spreads under the Merton model. As shown in the figure 2.9, credit spreads vary significantly according to the financial stability of the firm. Specifically, Wang utilizes a debt-to-assets ratio to represent the financial soundness, identifying three main typologies of company: highly-leverage; medium-leverage and low-leverage.

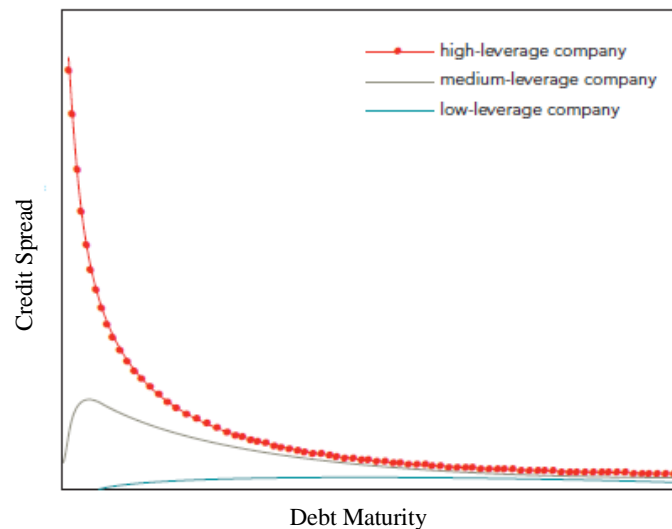


Figure 2.8. *Term Structure of Credit Spread under the Merton Model* (Wang, 2009)

An important peculiarity concerns highly-leveraged firms<sup>9</sup>. Looking at the dotted line of the previous picture, it is crystal clear that credit spread tend shrink as time goes by. This is due to the fact that when a company is insolvent, everybody expects its default to occur immediately or very soon anyway. But if the company survives the initial turbulence, its probability to default starts to decrease and market participants regain confidence about the firm, resulting thus in a lower spread demanded. This implicit fall of the leverage over time is strongly debated<sup>10</sup>.

<sup>9</sup> A firm may be regarded as highly leverage when the augmenting cost of capital deriving from the rising default probability start to exceed the tax benefits deriving from the tax deductibility of interest rates, compromising as a consequence, the own existence of the entity. Conversely, a low leverage firm is not able to take advantage of further corporate debt, which would indeed create economic value.

<sup>10</sup> Breccia (2012) states that as  $T-t$  tends to infinity, the credit spread tends to zero and thus the default probability is basically nil. This is the case of a perpetual bond.

Despite its consistency, the Merton model suffers yet of serious drawbacks, many of which deriving from its simplistic assumptions<sup>11</sup>. Crucially relevant is the absence of transaction costs and the presence of a single bond: the non-stationary structure of the debt that leads to the termination of all operations on a fixed maturity date, and default can only happen on that date. To overcome this issue Black and Cox (1976) introduced safety covenants and asset sale restrictions. Moreover, they allowed for default before maturity by providing a way to endogenize the default boundary (Sundaresan, 2013). Also Geske (1977) modified the Merton model to the case of multiple bonds of different maturities (*Compound Option Model*). Leland (1994) explicitly hypothesized the presence of taxation and bankruptcy costs, permitting the model to take part in the optimal capital structure and traditional debt-equity trade-off management. But regardless of any extension, structural models remain disproportionately difficult to implement besides computationally intensive and analytically complex. Surely, reduced models may fare better from this point of view but their heavy reliance on historical data may be rather limitative, in particular when it comes to out-of-sample predictive power.

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<sup>11</sup> See Resti and Sironi (2007) for a complete analysis.

## 2.4 Introduction to Liquidity Risk

Liquidity has a paramount importance for both financial and non-financial institutions, since without appropriate levels of cash available it would be almost impossible to survive. As a consequence, liquidity risk is a crucial issue for internal risk management and as well as for regulatory policies. In some cases, in fact, liquidity shortfalls of one company may have implications that go well beyond the internal walls. Liquidity risk may be in general terms defined as the lack of marketability of an investment, that is, the impossibility to sell or buy it in time so that to prevent or minimize losses. Specifically, liquidity risk for financial institutions may have a deeper meaning than the mere cash and investment management: for a bank, liquidity risk reflects its intrinsic ability of being able to fund increases of assets in order to meet obligations as they come to due, without facing unexpected losses. The Basel Committee (BCBS, 2008) links explicitly liquidity risk and banks' core business: their fundamental activity of maturity transformation, i.e. to convert short-term deposits into long-term loans makes banks unavoidably vulnerable to liquidity risk at firms-specific level and at market-as-a-whole level as well.

Banking liquidity may be decomposed into different types, all of them relevant for risk management purposes: central bank liquidity; market liquidity and funding liquidity. The *central bank liquidity* refers to the ability of central banks to supply liquidity to the market through open market transactions. Technically, what is provided by central banks is called base money, which through individual banking intermediation operations may be propagated consistently, increasing as such the overall money supply. All central banks, from the Federal Reserve to the European Central Bank, may implement specific monetary policies that represent a determined level of operational target, usually in terms of key policy rate. The main goal still remains the control of inflation but as the recent Financial Crisis has proven, another fundamental objective should be to guarantee and oversee the stability of the entire financial sector by reaffirming unconditionally its position as lender of last resort (De Grauwe, 2011).

To define the *funding liquidity*, we may adopt the Basel Committee's definition to avoid any misunderstanding. The Basel Committee of Banking supervision defines funding liquidity as the ability of banks to meet their liabilities, unwind or settle their positions as they come due (BCBS, 2008). But nonetheless, this definition may be widened to include market participants<sup>12</sup>, either as investors or as simple traders and precisely, by referring to their ability to raise funding in a short lapse of time. From a strictly banking perspective, though, the focus is on the banks' ability to raise funds to meet business duties. To accomplish so,

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<sup>12</sup> Brunnemeier and Pedersen (2007) and Strahan (2008)



banks carry out transactions with four main counterparties (Nikolaou, 2009): depositors; the market, intended as the virtual place where banks may sell assets or obtain liquidity through securitization processes; the interbank market, which is the most important and immediate source of liquidity<sup>13</sup> and the central bank. Thus, funding liquidity risk may be regarded as the impossibility, over a specific horizon, to obtain the required liquidity from one of the previous sources. In particular, the funding risk may take on three different forms (Fontaine *et al.*, 2009): the *margin funding risk*, which basically is the risk that margins will change; the *rollover risk*, that is, the risk that it will be more costly or impossible to roll over short-term borrowings and the *redemption risk*, which arises as soon as demand depositors or say equity holders of hedge funds withdraw funds. As a result, the bank will become unable to settle obligations with immediacy and this may concern two components: the future (random) inflows and outflows of settlement assets, such as money and the future (random) prices of obtaining funding liquidity from different sources.

Market liquidity is regarded as the ability to trade an asset at short notice, at low cost and with little impact on its price. A market is utterly liquid when agents can sell any quantity of assets anytime and at competitive price. Thus, three main features define a liquid market (Fernandez, 1999): volume; time and transaction costs. It follows that liquidity is measured by three dimensions: depth, breadth and resiliency (Harris, 2003), with the first property measuring the number of large transactions that occur without influencing huge price changes, the second, breadth or tightness, reflecting the variability of the price at which transactions are concluded. Finally, the resiliency indicates how fast market price fluctuations dissipate. Liquidity market risk, consequently, emerges whenever one of the three dimensions does not comply with the notion of liquid market, for instance, when price varies heavily after one transaction or when traders may execute transactions at exorbitant price solely. In a completely illiquid market, agents cannot trade at a fair price with immediacy (Nikolaou, 2009).

#### **2.4.1 Liquidity Risk: Stress Testing and Regulatory Perspective.**

An interesting way to manage liquidity risk is stress testing and scenario analysis. First and foremost, stress tests and scenarios are far more important for liquidity risk than for credit, interest or operational risks. In effect, the need for liquidity arises in many different situations and as such, the range of possible adverse and risky scenarios is ample: both the size and nature of a liquidity-related event may vary intensively from scenario to scenario. A stress

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<sup>13</sup> In the interbank market in fact banks may carry out over-night transactions (i.e. in a short time period) which means, receiving funds that they require to cover their positions.

test, as defined by the Basel Committee can either be a stress test scenario or a sensitivity stress test. The former is basically a multi-variant test based on historical or hypothetical scenarios. Scenario liquidity scenarios and stress testing tend to modify essential liquidity parameters while holding constant credit risk and other risks, such as interest risk. The key point is to figure out whether banks hold enough liquidity to purchase enough time to either outlive the negative event or implement recovery measures. Thus, through the usage of stress test scenarios, risk managers can understand how to properly deal with liquidity shortages, identifying in advance possible responses that may unwind the adverse effects. Scenario stress testing may also have the great advantage of honing future forecasts, by for instance, correcting assumption oversights and potential correlation misunderstandings between risk factors (Matz, 2007). More specifically, macro stress testing, i.e. testing the financial system as a whole, is an instrument of central banks and supervisory authorities to evaluate the impact of market-wide scenarios and possible second round effects. Such tests with regard to liquidity risk can enhance the insight in the systemic dimensions of liquidity risk and make market participants more aware about systemic risk (van den End, 2009). On the other hand, sensitivity analysis allows risk managers to figure out how much a single dependent or independent variable may influence the risk exposure in a specific scenario. Generally speaking, sensitivity analysis may be performed both at systemic level and at company specific level. Concerning the former, risk analysts focus usually on the following risk parameters: interest rates; credit spread and market access and time necessary to liquidate individual assets holdings. From a bank-specific level, financial institutions tend to perform deep analysis with regards to the following factors of interest: deposit loss assumptions, funding requirements for off-balance sheet items; new capital funding availability and rollover of expiring capital market funding hypotheses.

Returning to scenario stress testing, the Basel Committee recommends the use of a wide range of “what-if” analysis. In particular, approaches to scenario testing may be divided into two main groups: the top-down approaches and bottom-ups and, as we will see in section two, this distinction does not apply solely to liquidity scenario testing but may be regarded as a general division. The bottom-up approach is based either on internal assumptions or on common scenarios designed by the banking authorities for a determined time horizon. Conversely, top-down stress tests are conducted by the authorities themselves or by the IMF, usually based on in-house models and common assumptions across firms and supervisory and/or publicly available data (BCBS, 2013). By the way, as a universally-accepted measure has yet to be found, what happens concretely is that banks and supervisory authorities perform both top-down and bottom-up stress tests.

Herein, the model presented is the van den End's Liquidity Stress-Tester (2009)<sup>14</sup>. The reason behind this choice is easy to be explained. Firstly, it is an all-encompassing model, in the sense that it considers both idiosyncratic and systemic effects deriving from liquidity scarceness. In addition to that, it may help banks to adequate their capital buffer for liquidity risk while permitting senior managers to realize how to effectively and efficiently handle adverse situations. A final benefit of this approach is given by the fact that differently from other stress tests, this model addresses directly liquidity risk and its multiple dimensions, notably the funding and market risks and their interaction.

The Liquidity Stress-Tester is a three-step model, which tests the capital buffer at two levels. In particular, banks are subject to two consequent adverse liquidity-related events: after the first shock, financial institutions are supposed to mitigate the initial negative effects, before undergoing a second wider round.

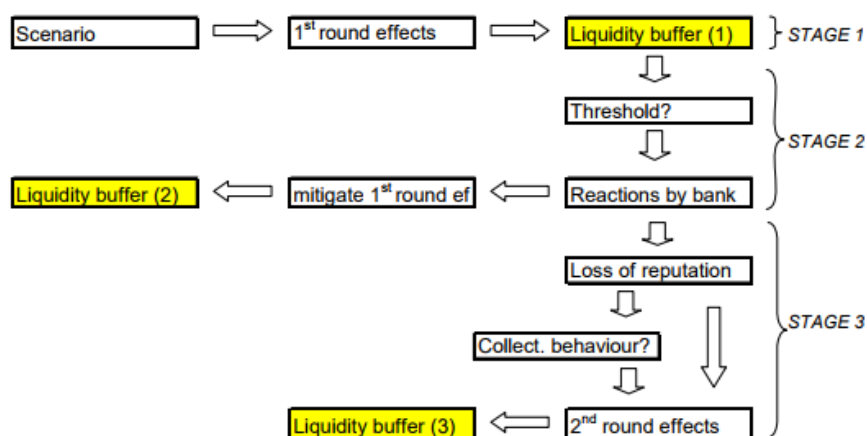


Figure 2.9. Flow chart of Liquidity Stress-Tester (van den End, 2009)

In the first stage, the focus is on banks' market and funding risks effects (*STAGE 1* in the figure above). Practically, this is accomplished by multiplying liquid assets and liabilities that are affected in the first round of the adverse scenario by the stress weight ( $w_i$ ). The weights ( $w_i$ ) denote the haircuts in case of liquid assets (i.e. shrunk liquidity values or mark-to-market losses) and run-off rates in case of liabilities. Obviously, the amount of ( $w_i$ ) is not uniform, since it varies as the sensitivity of assets and liabilities to liquidity stress changes. During the second phase, the bank is subject to both idiosyncratic and systemic risks. Notably, the former takes the form of reputational risk, since the bank may be perceived as unstable and thus untrustworthy. The systemic risk on the other hand describes how peer banks are jointly

<sup>14</sup> Another interesting model is Bank of England's RAMSI model. RAMSI is based on internal data and market prices and uses stochastic simulation to derive stress scenario outcomes Alessandrini *et al.* (2009) implement that model to calculate banking resiliency.

affected and how the financial market as a whole may be harmed: in other words, it depicts how powerful the contagion risk among banks may turn out to be. Both risks are considered when forming the capital buffer in the third stage (see *LIQUIDITY BUFFER (3)* in the figure). In each step, the model generates distributions of liquidity buffers by bank, including tail outcomes and probabilities of liquidity deficit. The simulation is made possible thanks to the adoption of the Monte Carlo simulation of univariate shocks to market and funding risk elements which are combined into a multifactor scenario<sup>15</sup>.

Let us proceed analytically through all stages of the Liquidity Stress Tester model. In normal conditions, that is, when the bank is not subject to any shock, the capital buffer  $B_0$  is described as follows:

$$B_0^b = \sum_{i=1}^{nc} I_{non-cal,i}^b \quad (2.54)$$

$b$  being the individual bank and  $I_{non-cal,i}$  the number of available assets of non-calendar items (the stock items of liquid assets  $I \dots nc$ ). The buffer, at this stage, is made up by deposits at the central bank, securities that can be turned into cash at short notice, ECB eligible collateral, in other terms, all assets that are available on demand. The first-round effect is then described by:

$$E_1^b = \sum_i I_i^b \times w_{sim_{1,i}} \quad (2.55)$$

$I_i$  denoting the amount of all liquid (non-calendar and calendar) asset and liability items of the individual bank. The other component,  $w_{sim_{1,i}}$ , represents the impact of the scenario on the  $i$ -th item. In particular, it derives from simulated weights generated by a Monte Carlo Simulation<sup>16</sup>. This negative shock leads to a liquidity buffer decrease:

$$B_1^b = B_0^b - E_1^b \quad (2.56)$$

Banks affected by the initial shock are supposed to restore their liquidity buffer to  $B_0$ . This, naturally, is a duty imposed by the supervisory authorities, who explicitly oblige banks to hold some minimum capital for liquidity risk. In the Stress Tester model, the ultimate cause,  $q$ , for a bank's reaction is a drop of its original liquidity buffer that exceeds a threshold  $\theta$ , which is either regulatory-required or internally self-imposed. The trigger  $q$  is based on a probability condition (probit), namely:

$$q = \begin{cases} 1 & \text{if } \frac{E_1^b}{B_0^b} > \theta \\ 0 & \text{otherwise} \end{cases} \quad (2.57)$$

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<sup>15</sup> This means that the scenario already includes different adverse events. For instance, the credit market scenario can be thought to comprehend credit spread rising, reduced funding liquidity and falling of market prices (i.e. market liquidity decreases)

<sup>16</sup> The Monte Carlo Simulation in this case is scaled by  $(w_i/3)$ . The scaled normal distribution is then transformed into a log-normal distribution so that to take into account extreme events that a normal distribution would not be able to capture.

As stated earlier, what a bank concretely actualizes after the first round is trying to restore its liquidity buffer. In practice, this means creating immediate funds from available instruments, for instance, by selling highly-liquid securities such as government bonds or asking for liquidity lines from other banks. Note that, banks may obtain liquidity only from instruments that are somehow available to be divested, i.e. recovery instruments and not from all items on the balance sheet. The size of the transactions that a bank conducts with instrument  $i$  is expressed by  $RI_i^b$  and in particular:

$$RI_i^b = (B_0^b - B_1^b) \times (I_i^b / \sum_i I_i^b) \quad (2.58)$$

And as  $B_1^b < B_0^b$ , due to the shock,  $RI_i^b$  must be positive although it does not tell anything about the type of transaction carried out (buy or sell). In effect, the term indicates an absolute value and specifically a size value that has to be reached so that to obtain liquidity. Thus, the mitigating actions lead to:

$$B_2^b = B_1^b + \sum_i RI_i^b \times (100 - w_{sim_{1,i}}) \quad (2.59)$$

With  $B_2^b > B_1^b$  but  $B_2^b < B_0^b$ , because of the market disturbance that does not allow a fully recovery of the liquidity capital. In the worst situation  $w_{sim_{1,i}} = 100$  and consequently no recovery is admissible. Fortunately, it rarely happens in reality, as it would signify that the bank has no access to any of the liquidity markets or, even worse, that all of its assets, e.g. collaterals, are worthless.

The second-round effect is described by the following equation:

$$E_2^b = \sum_i ((I_1^b + RI_i^b) \times (w_{sim_{2,i}} - w_{sim_{1,i}})) \quad (2.60)$$

In particular,  $w_{sim_{2,i}}$  is a function of  $w_{sim_{1,i}}$ :

$$w_{sim_{2,i}} = w_{sim_{1,i}} \times (\sum_b q^s (1 + \sum_b RI_i^b / \sum_i \sum_b RI_i^b) \times s) / \sum_b q \quad (2.61)$$

From the latter, we may clearly affirm that large values  $RI_i^b$ , i.e. higher demand of liquidity may affect negatively the liquidity in the market where the bank operates, in other words, the larger transactions or the larger financial institutions the greater the impact of the second-round effect. Specifically, the number of banks  $\sum_b q$  and the similarity of their effects  $(\sum_b RI_i^b / \sum_i \sum_b RI_i^b)$  are the crucial factors that determine the ultimate outcome of the second turn shock. The factor  $s$  denotes, instead, the level of market stress, or in other terms, the level of contagion risk and usually ranges between  $-1$  and  $+1$ . Nonetheless, for stress test purpose, it can indeed exceed  $+1$ , representing as such an extremely negatively-shaped scenario.

Eventually, the liquidity buffer after the second-round effects ( $B_3$ ) is,

$$B_3^b = B_2^b - E_2^b \quad (2.62)$$

In a concrete stress testing procedure, each scenario attempt has its specific effect on the distribution of the various buffers. More specifically, different scenarios allow banking authorities to grasp how liquidity needs may change according to more or less severe shocks, in first instance, and also, as a straight consequence, to dictate the level of regulatory capital requirement and in particular of contingency funding plans. In this regard, Nikolaou (2009) provides a complete theoretical overview of the functioning mechanism while van den End (2009) analyzes the model from an empirical point of view.

To conclude the regulatory framework for liquidity risk, two more ratios need to be introduced. Basel III, in fact, adds two fundamental capital constraints that banks must fulfil constantly: the Liquidity Coverage Ratio (LCR) and the Net Stable Funding Ratio (NSFR). The former may be useful to guarantee a short-term survival, notably, whether the bank possesses enough high-quality liquid assets (HQLA) to resist an intensive one-month stress scenario. Practically, this ratio is calculated as follows:

$$LCR = \frac{\text{Stock of HQLA}}{CO_{30}^S} \geq 100\% \quad (2.63)$$

With high-quality liquid assets comprehending all those items that are basically very easily-divestible in case of liquidity crisis. More precisely, to be regarded as a high-quality liquid asset it must satisfy two types of features: fundamental and market-related. From a fundamental point of view, the asset must have low risk, be easily and straightforwardly priced; listed on a developed and recognized exchange and lastly, to have a low correlation with risky assets. From a market-related perspective, the asset shall belong to an active and sizable market where prices and trading counterparties can be found at any time. Additionally, the asset's volatility must be low and stable: a high liquid asset, in other words, is an asset that bank can turn to during liquidity crisis, as its value does not change significantly (flight to quality).

In general, the HQLA assets may be divided into two levels according to the degree to which they may satisfy the previous conditions: the level I comprises all those extremely liquefiable items, such as currencies or central bank reserves and can be included into account at full value to determine the final value of HQLA. The level II assets apply a haircut of 15% for marketable securities representing claims on or guaranteed by sovereigns, central banks or multilateral development banks that satisfy some conditions; as well as corporate debt securities and covered bonds under some conditions (level II A). To the other remaining liquid assets (level II B) different levels of haircut are applied. Such are for instance: residential mortgage backed securities (RNBS) that satisfy some conditions (25% haircut); corporate debt securities (including commercial paper) that satisfy some conditions (50% haircut); common equity shares that satisfy some requirements (50% haircut).

The  $CO_{30}^S$  is the difference between the total expected cash outflows and the total expected cash inflows in the specified stress scenario for the subsequent 30 calendar days. Particularly, the total expected cash outflows are calculated by multiplying the outstanding balances of the regulatory-provided categories or types of liabilities and off-balance sheet obligations by the rates at which they are expected to run off or can be drawn down. Conversely, the total expected cash inflows are calculated by multiplying the outstanding balances of various categories of contractual receivables by the rates at which they are expected to flow in under the scenario up to an aggregate limiting cap of 75% of total expected cash outflows. In practice,  $CO_{30}^S$  is equal to:

$$CO_{30}^S = CashOut_{30}^E - Min\{CashIn_{30}^E, 75\% CashOut_{30}^E\} \quad (2.64)$$

Where  $CashOut_{30}^E$  is the total expected cash outflows and  $CashIn_{30}^E$  is the total expected cash inflows, both computed over the following 30 calendar days<sup>17</sup>.

The Net Stable Funding Ratio (NSFR) conversely shall guarantee a long-term resilience. In a nutshell, it is the ratio between amount of available stable funding relative to the amount of required stable funding and should be equal to at least 100% on an ongoing basis. Namely:

$$\frac{Available\ amount\ of\ stable\ funding}{Required\ amount\ of\ stable\ funding} \geq 100\% \quad (2.65)$$

The available amount of stable funding is computed based on the features of the bank's liabilities, namely on the quality of its funding sources. As a rule of thumb, the more reliable the funding source, the higher the percentage<sup>18</sup> allowed by the regulatory authorities to be included in the numerator. On the other hand, the amount of required stable funding depends on the liquidity risk profile of the bank's assets and off-the-balance sheet exposures and is divided into different percentages as well. Since in this case we are dealing with a denominator, the greater the quality of assets, the smaller the percentage taken into account<sup>19</sup>.

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<sup>17</sup>For more details BCBS (2013), *Basel III: The Liquidity Coverage Ratio and Liquidity Risk monitoring tools*, <http://www.bis.org/publ/bcbs238.htm>

<sup>18</sup>The Basel Committee foresees five Available Stable Funding percentages: 100%; 95%, 90%; 50% and 0%. For more details BCBS (2015), *Net Stable Funding Ratio disclosure standards*, <http://www.bis.org/bcbs/publ/d324.pdf>

<sup>19</sup>According to the Basel Committee, the required stable funding assets shall be divided into eight categories, with eight different percentages: 0%; 5%; 10%; 15%; 50%; 65%; 85%; 100%. For more details: BCBS (2015), *Net Stable Funding Ratio disclosure standards*, <http://www.bis.org/bcbs/publ/d324.pdf>

### **3. Overview of Banking Stress Testing Framework**

#### **3.1 Stress Test as a Fundamental Regulatory Toolkit**

The Financial Crisis has evidently pointed out once again all the fragilities of the financial sector and how, individual entities' troubles can generate uncontrollable damages to the entire global economy. For this reason, amongst others, the usage of stress tests has consistently increased throughout the last couple of years, turning out into a crucial toolkit for the regulatory authorities. A stress test, as the name suggests, is a instrument employed by various industries, from health care to real estate construction. But when it comes to the banking world, it measures the resilience of banks to hypothetical adverse scenarios, whereby banks are subject to extremely harmful events and conditions, such as economic recessions. The scope, needless to say, is to figure out, especially from central banks and regulators' perspectives, how to quantify risk impacts and act consequently, in terms of prudential policies, intended both on a micro and macro level, as well as with regards to banking capital requirements. Nevertheless, bank stress testing may be still regarded as a relatively new field and for this reason it is quite likely to enhance further over time, so as to better suit policymakers' needs, particularly concerning setting effective policies to promote resilience of the entire financial sector. To sum up, the inner principle in the application of stress test exercises is that these must help to evaluate and formulate regulatory and supervisory policies with the goal of increasing the soundness of the banking industry and the efficiency of the financial intermediation (Montes, Artigas, 2013). This, as the economic theory teaches, would enhance the overall allocation of scarce resources in the economy, with the resulting positive impact on social welfare. To this extent, stress tests are considered to be improving preventive policies, which are at the core of macroprudential objectives. The tests, moreover, can also support a credible disclosure of supervisory information to financial markets (Gick and Pausch, 2012). Generally speaking, a stress test may be defined as a set of techniques, tools or, procedures used by either individual institutions or regulatory authorities to gauge, as precisely as possible, the financial condition of the system under examination. In particular, stress tests are normally concentrated on the evaluation of the solvency and liquidity of the banking system, intended this time from an individual institution and as well as a sector-wide point of view. Stress testing aims not only at identifying possible vulnerabilities, expressed as adverse shocks that can affect the financial condition of a certain institution or financial system, but also to estimate and judge as accurately as possible, the quantitative and qualitative consequences of those shocks. In other terms, the objective is to probe the stability and resilience of the system or institution being assessed and reviewed. It is commonly



accepted that completing a stress test normally takes the following steps (Montes, Artigas, 2013):

1. Delimitation of the scope of application of the test. In practice in this stage, the main question to be answered is “*What is the ultimate aim of the exercise?*”
2. Definition, design and calibration of the shocks with which the system under examination is to be stressed. Here, the priority is to figure out the model and data.
3. Estimation of the effects of the shocks chosen and determination of the impact in terms of shifts in systemically-relevant variables
4. Identification of the possible considerations and policy amendments deriving from the results achieved in the point above.

The following figure explains the four stages in details:

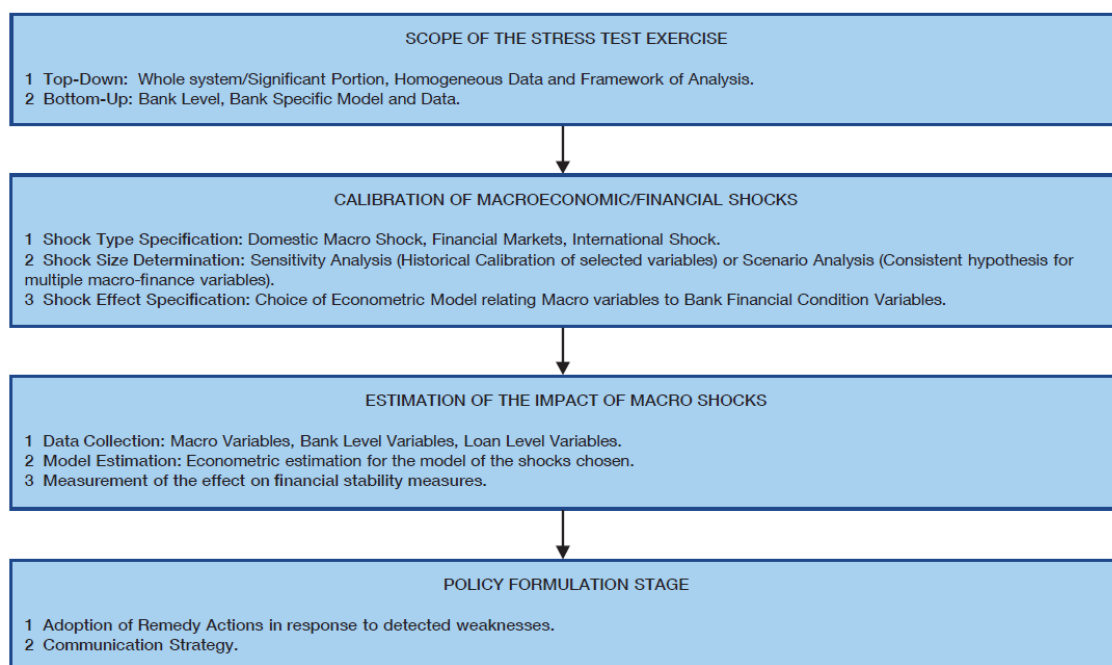


Figure 3.1. *Stress test implementation* (Montes, Artigas, 2013)

The scope of the application is based on the final purpose of the results of the stress exercise, which basically is a matter of choosing between a general, system-wide analysis and a review of smaller portions or specific entities. System-level tests (broadly speaking, *macroprudential tests*) encompass the analysis of the entire financial system, or at least that of its most significant players. Therefore, the intention is to assess the resilience and stability of the financial system as a whole and consequently, the adopted model is allowed, in first instance, to analyze single entities from an aggregate level, so that to successively descend to an individual-institution level. As such, the outcomes obtained are applied to each separate

representative of the system (top-down approach, see later). Implementing stress testing for macroprudential scopes has implications concerning the kinds of models needed for effective and efficient outcomes. In particular, the scenarios that supervisors impose on banks are relegated to a set of hypothesized paths for a relatively small number of macroeconomic variables. From this incipit, banks need to forecast losses across various categories of their loan and trading books. Analysts and experts have sought greater consistency by combining macro models with financial sector models. Specifically, this approach can consist of three or more layers of models, namely macro; sectorial and asset class, until detailed projections can be made at the level of the banks' own disaggregated data. Detailed loss projections can then be aggregated up to achieve implications for losses and capital at the bank level, at the holding company level, at the level of the pool of banks being tested, and finally for the entire banking system. It is clear that this combination top down and bottom up approach involves a lot of time, effort and resources, though it is still not clear whether the resulting system-level projection outcomes are necessarily superior to those obtained using less fine-grained approach (Anderson, 2016).

Alternatively, if models and information at individual level are used, then this exercise is deemed as a bottom-up model (see later). Furthermore, the time interval considered is another key parameter to be taken into consideration. Typically, stress tests cover more than one business year (two or three years). However, this implies an arduous trade-off. On the one hand, the choice of incorporating more years can be justified, since sufficient time must be given for the consequences of the programmed shocks to fully manifest. On the other hand, a long time horizon may signify an excessive loss of reliability in the estimations: in other words, there would be too many effects affecting the exercise, which may not relate with the stress test and the eventual results might be biased.

The second stage in a general stress-testing framework is represented by the definition of those unlikely yet plausible adverse shocks that may adversely destabilize the system being tested and with respect to which the system's soundness and resilience is to be reviewed. Borio (2012) correctly noted that the literature does not make any precise distinction between "shocks" and "scenarios". Accordingly, some authors employ the term "scenario" to describe a pool of exogenous shocks, while for others, the same word labels both the set of exogenous shocks and their estimated, model-specific, impact on the macroeconomic and financial environment. Herein, we use "scenario" and "shock" as synonyms. The process of identifying and selecting the shocks has various sub-steps. First and foremost, the type of shock to be included must be determined, that is, identified and well-defined. Subsequently, the shock needs to be calibrated and then implemented, i.e. to be introduced into the system and the

effect quantified. Naturally, the stress test is not a forecast exercise. As a consequence, shocks do not need to satisfy any criterion of realism and in effect, most of the adverse scenarios employed are highly improbable though still plausible. Additionally, the probability of occurrence is another factor to be addressed in the model. In fact, the credibility and utility of the outcomes obtained depend not only on the selection of acceptable scenarios in terms of macroeconomic variables affected, but also on the probability assigned to each of them. Once the shock is chosen on the basis of the risks to be measured and fine-tuned according to the typology of review to be conducted, the latter is concretely implemented utilizing the main variables that, due to their nature, have the greatest direct or indirect effect on those risks. To this extent, the determination of the shock calibration is another delicate issue. Namely, it may depend on the nature of the analysis to be performed: in sensitivity analysis, the common practice is to use a historical calibration, in which the size of the shock is selected according to the largest variation that a specific variable of interest has undergone during a selected time interval. Of course, the choice of this time period is closely connected with the specific risk being analyzed and to the market conditions prevailing over that time horizon. The periods are generally between 20 and 30 years, even though in case of lacking historical depth, the interval may be confined to 10 or 15 years. Nonetheless, the most accurate and widespread approach to gauge the size of the shock is employing complete scenario analysis. Specifically, it contemplates the variations of a wide set of macroeconomic variables, which may permit to grasp how these may affect the resilience of the financial system. Similarly to the single variable case, to the scenario chosen is assigned a certain likelihood of occurrence. Needless to say, also in this case, the ultimate credibility and utility of the stress exercise depends, amongst others, on the calibration of the probability of occurrence.

In the third stage, the spotlights move to the estimation of the reactions to the hypothetical adverse scenario. In this step, it must be declared how the shocks defined and calibrated in the preceding stage are to be amalgamated into the system: in other terms, at this point, we need a quantitative assessment of the impact on the system's financial condition, so that its resilience to the shocks can be estimated. This stage defines in concrete the relationships established between macro-variables and the main factors of the banking system, usually under the guise of economic and financial features. Notably, it consists of choosing certain key variables that directly affect the financial health of the system under analysis, and estimating how they can change in response to the designated shock. In other words, we are expressing how changes in macroeconomic variables are reflected into the financial system in terms of profitability and solvency. Finally, as a corollary to the previous stages, policy decisions must be carefully considered once the impact on the financial stability and the estimated resilience of the system

have been derived from the stress test attempt. There is a need to consider what measures will be beneficial to the smooth-working, efficient and continued stability of the system under examination. This is usually regarded as the policy-oriented phase. If critical inconsistencies have been detected, remedial actions must be a priority for all the banking authorities involved. Should that be the case, it will be necessary to focus on revising, adjusting and reinforcing the existing prudential framework currently in place. In general, the insolvency of one or more banks can generate costs that may expand well-beyond those directly faced by depositors and clients and which are not absorbed by bank shareholders too. These, namely, derive from contagion of other intermediaries throughout the banking sector and the overall economy. For this reason, the policy-oriented phase is fundamental to be included in a stress test procedure. Authorities have the power and duty to reduce the likelihood of these potential social costs: by imposing determined thresholds of capital requirements, they may limit the effects of banks' default. Capital requirements should be set at the socially optimal level: balancing the social value of permitting banks to "create liquidity" with the expected social costs associated with the concrete possibility, that banks default (Bologna, Segura, 2016).

### **3.2 Stress Test Classification**

A first taste of stress tests has been already given earlier, when dealing with liquidity risk<sup>20</sup>. However, liquidity stress testing is just a small part of a far larger and more complex picture. This field, additionally, has been less advanced and quite circumscribed (van den End, 2011). Moreover, a survey conducted by the ECB has pointed out that several banks carry out liquidity stress tests just to quantify their liquidity risk tolerance as expressed in survival periods or limit systems (ECB, 2008). Nevertheless, liquidity risk is indeed extremely relevant for a stress scenario perspective: according to van den End (2011), it may be regarded as the essential means through which contagion risks are transmitted cross-border.

One first possible categorization of stress testing may be between liquidity stress-testing and solvency stress tests. The main difference simply lays in the fact that in the first case, as stated before, the focus is on the sole banking liquidity and the related stress test serves to assess liquidity requirements in the event of cash shortages. On the contrary, the solvency stress tests provide a more comprehensive overview of the banking situation, in particular regarding banks' capital positions towards different risks. Moreover, international regulatory authorities tend to concentrate on specific adverse scenarios, applied to several banks simultaneously in order to capture any joint effect. The so-called concurrent stress tests have indeed the huge advantage of being easily comparable across financial institutions. This, in turn, may lead, on

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<sup>20</sup> Cfr paragraph 2.4

the one hand, to the development of better microprudential policies and, on the other, to understand whether shocks may affect only few banks or have wider effects, that is, to quantify the impact that amplification channels may have within the banking sector; between banks, the broader financial system and the overall economy. The amplification channels inclusion can help macroprudential regulators to determine the amount of the system-wide effect of negative events and may also support them in outlining policies with the ultimate aim of promoting and improving financial stability.

Stress testing models can be identified along two dimensions (van den End, 2011): macro vs micro and top-down vs bottom-up. Starting from the first feature, the main difference between micro and macro stress testing is that in the former case, individual banks themselves conduct stress tests as a part of their risk management policy. On the contrary, macro stress testing are performed directly by supervisory authorities and central banks to reckon the resilience of the entire financial sector. In a nutshell, the micro-macro characteristic specifies the ultimate scope of conducting a stress test. For instance, micro stress testing has evidently increased its importance as a risk management tool for financial institutions. In fact, it can be implemented to determine portfolio risks, set risk thresholds and lead the planning of capital resources within a financial entity.

The other interesting and well-known way to classify stress tests is between top-down and bottom-up. This distinction indicates the level at which the stress test is actually performed. The top-down approaches treat institutions as a pool of homogeneous features, which on the one hand may guarantee a lot of agility and computational easiness but on the other hand, it could oversimplify the reality, leading, as such, to unreliable outcomes. Still, the advantageous feature seems to prevail, as many national and international supervisors regularly implement the top-down way to stress testing. For instance, the United States (Covas *et al.*, 2013) and the European Central Bank (2013), among others, appear indeed quite confident about relying on their internal models to carry out stress tests.

The top-down approach can be described as follows. The initial point is, needless to say, the hypothetical stress scenario. Typically, this includes adverse shocks to crucial economic variables, such as economic growth; unemployment rate; short and long term interest rate spread; real estate and housing prices; inflation and so on. The utilized scenario, in other words, consider the main risks for the financial and economic sector on a multi-year horizon, since several effects do not manifest immediately<sup>21</sup>. The scenario elements will impact first and foremost the credit risk exposure of banks. Let us consider a sharp increase in

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<sup>21</sup> This is for example the case of social security provisions. Including more years is also beneficial if we consider that banks have many assets and liabilities with very long maturity, although this would increase the number of assumptions required (Daniëls *et al.*, 2017).

unemployment. The economic theory would suggest that many employees would lose their jobs and face a consistent salary reduction. As a straight consequence, many households may no longer be able to pay their mortgage obligations<sup>22</sup>. Thus, banks will incur losses on these positions. A similar reasoning holds for commercial loans. In the end, the overall credit quality and risk exposure of bank lending portfolios deteriorates tremendously, obliging the supervisory authorities to increase the amount of capital buffer requirements<sup>23</sup>. Moreover, the scenario variables will also affect market risk exposure: declining equity investments and government bonds can both lead to consistent impairments and value adjustments, which ultimately may condition the riskiness of the banking market portfolio and cause further capital requirements. The scenario usually also covers funding liquidity risk as it comprehends interest rate shocks and assumptions about funding conditions. These shocks will affect the interest expenses, which may translate into higher costs for the final customers, creating a lot of uncertainty around the interest margin earned by the bank. All the mentioned risks<sup>24</sup>, i.e. credit, funding and market risk have an effect on bank's capital level: losses may radically reduce the equity capital, posing many challenges as far as the minimum regulatory capital is concerned. In particular, regulators specifically regard core capital (Tier 1) as the primary means to absorb eventual losses, since it is readily available. Strictly connected with the increase in capital is the higher risk-weighted assets imposed. Namely, the core capital is nothing else but the ratio between the capital (the numerator) and the risk-weighted assets (the denominator). In order to determine whether a bank does still have enough capital available after being stressed, the former ratio can be compared against a pre-defined threshold value or hurdle rate. This is also the explicit caveat adopted by the EBA for the 2014 stress test, which required a core capital ratio of 5.5%. Banks that overpass the specified amount were compelled to enhance their capital position. Additionally, the size of capital reduction may provide significant information about the bank's risk-sensitivity as well. It is important to underline that during the assessment of a stress test, and in particular, of a top-down type of stress test, the outcome strongly depends on both the scenario and the modelling hypothesis on which the test is crafted: different scenarios, different modelling assumptions may unsurprisingly lead to disparate outcomes. As a result, stress test outputs should always be considered in context rather than in isolation (Daniëls *et al.*, 2017).

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<sup>22</sup> This is exhaustively described by Yaw Owusu-Ansa (2012) employs a Structural Vector Autoregression (SVAR) model to study the dynamics of the impact of unemployment and home price index shocks on mortgage default rates from 1979 to 2000 and from 2001 to 2010.

<sup>23</sup> Technically, the supervisors would require an increase in RWA (risk-weighted assets).

<sup>24</sup> Note that the operational risk was excluded for simplicity's sake. For more details on the mentioned risks, see chapter II.

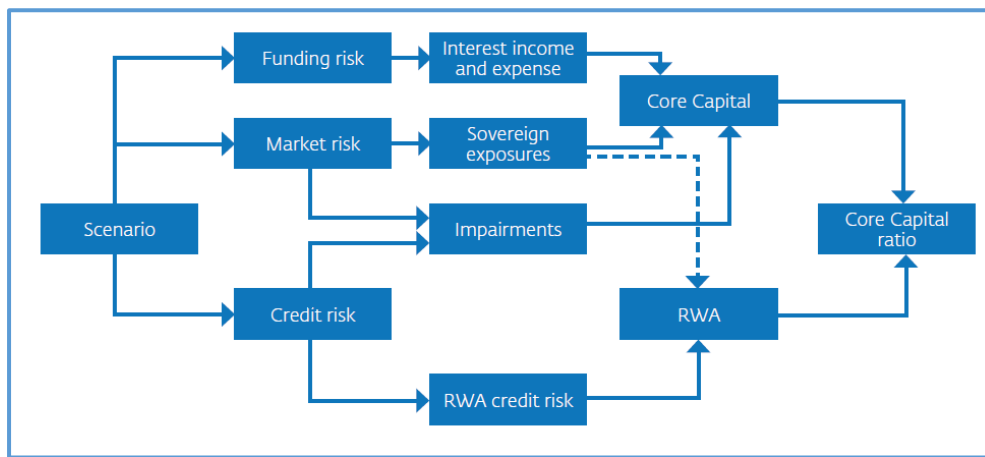


Figure 3.2. *Anatomy of a top-down stress test* (Daniëls et al., 2017)

In particular, the top-down approach may help supervisors and risk managers to understand potential sources of vulnerabilities in the financial system arising from economic changes. The top-down approach, moreover, delivers the crucial scope of capturing the “latent risk” deriving from structural breaks that might have remained undetected if just historical data were used (Enoch, 2006). In top-down stress testing, either the central bank or the supervisory authority simulate the impact of adverse shocks to financial institutions or sector by using in-house models. Compared to bottom-up stress tests, the use of internal modelling significantly enhances the comparability of outcomes between financial entities and guarantees a wider flexibility in terms of different scenario applicability. Some methods also allow to quantify the second-round effects in the overall economy and financial markets, what, as we will see, the bottom-up stress tests do not provide directly. Furthermore, another interesting peculiarity of most of the top-down approaches is the fact that they tend to focus mainly on credit risk as the main driver of crisis scenarios (van den End, 2011).

Top-down stress test may be divided into two principal categories, according to the pivotal focus of the test: macro-micro link models and integrated models. Foglia (2009) describes the former approach in details. Namely, these models describe, primarily for credit risk exposures, the interaction of macroeconomic variables with micro risk drivers. Many macroeconomic approaches do not foresee any financial sector variable and thus, satellite models, or better, reduced-form satellites, are used as good proxies for credit risk. In such cases, exogenous macro shocks are directly transformed into measures of banks’ assets quality. The models, naturally, may differ with regard to the measures of credit quality, level of aggregation and estimation method. On the micro side, credit risk measures are basically two: indicators of loan performance, such as non-performing loans, and default rates of household or corporate clients. The choice of the measure may depend on both subjective factors, like personal preferences, and as well as on objective constraints, such as data

availability. Düllmann and Erdelmeier (2009) compute credit losses on a system level, considering the inter-sector correlations. These correlations are represented by macro variables that embody the systemic risk component and capture the contagion implications between banks, although hidden risks deriving from unobserved correlation between banks across sectors might still be an open issue (van den End, 2011). Nonetheless, credit risk models use non-linear assumptions, such as logit or probit transformations, so as to take into account the nonlinearity feature when shocks are vast (Foglia, 2009). One relevant drawback of these models is represented by the fact that normally, feedback effects from credit risk to the macro economy are not considered. This can be partially solved with the adoption of VaR models<sup>25</sup> (De Graeve *et al.*, 2008) though it still represents a trivial approximation.

Many integrated models, on the other hand, provide a more structural approach, being more agile to capture the feedback effects within the financial sector. For this reason, they are more adequate in the field of systemic financial crises, which would unsurprisingly justify the wide adoption. One particular remark of these models is that they do not recommend any specific banking risk to be included. Consequently, related approaches may vary consistently, making comparison almost impossible. A valuable integrated framework is represented by the RAMSI model adopted by the Bank of England (Alessandrini *et al.*, 2009). The RAMSI approach comprehends a Bayesian *VaR* model to simulate macroeconomic scenarios, satellite models for credit risk, market risk, as well as interest rate risk. Further, it relies on an interbank network model and an asset price function to replicate market liquidity risk. Despite its potentiality, the model has been criticized since it does not allow for feedback effects from the banks to the real economy. A clarifying and, to some extent, superior example may be represented by the Liquidity Stress-Tester introduced in chapter II of this volume. In this specific case, we considered the iteration between market and funding liquidity risks as well as the liquidity position of bank for different scenarios.

The complexity of the model structures makes causal interlinkages and final results less transparent. Thereby, the integrated models may violate the fundamental cornerstone of “simple understanding”, which should characterize all stress test procedures, since they may be somehow too sophisticated and difficult for policymakers and the public (Kwast *et al.*, 2010). Nevertheless, these models do provide a clear picture of the possible repercussions of tail events, as they tend to consider multiple transmission channels and feedback effects. Most of the top-down approaches are calibrated to consider heterogeneous portfolios as aggregated and comparable, although in reality they can differ from a methodological and computational point of view. This may be a huge limitation since individual peculiarities need to be

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<sup>25</sup> For more details on *VaR* models see paragraph 2.2.1 of this work.



considered, so as to carry out a reliable analysis. An additional, strictly related problem is that financial institutions are increasing their usage of off-balance sheet items, which may ultimately pose many challenges concerning data homogeneity. Lastly, there may be an intrinsic difficulty of modelling and catching the interaction between changes in macroeconomic conditions and variations in risk factors. Notably, the models may not capture the real relevant effect and wrongly attribute to it a considerable weight although it may have just a marginal impact.

On the contrary, bottom-up approaches have the advantage of addressing the right, narrower and better-defined problem. Most bottom-up stress tests focus on credit risk as the greatest threat for banks and use multi-year scenarios to capture downturns in the business cycle. Conversely, market risk is usually considered over a much shorter time horizon, which may create a lot of challenges in terms of simultaneous treatment of credit and market risk (Boss *et al.*, 2006). Furthermore, stress tests scenarios pay less attention to liquidity risk as noted by Čihák (2007), in fact, the latter is basically introduced as mechanical run-off scenarios that assume unexpected withdrawals of banking funds.

In many countries, authorities apply bottom-up stress tests to check regularly the health of the financial sector as a whole. In such cases, usually, the competent supervisor or the central bank defines specific scenarios that financial institutions subsequently run in their internal models. To guide the computation of stress test outcomes by institutions, the authority in charge translates the simulated macro shocks in default and loss ratios via reduced form satellite models. As a result, macroeconomic factors are connected to the banking portfolio drivers. This macro-micro interaction is a key issue of stress test models (Van Lalyveld, 2009). From an exquisitely bottom-up perspective, the macro-micro issue is handled by aligning stress tests to individual banks' risk profiles. Of course, it is facilitated by greater access to the information from the institutions: single financial entities may have access to complete proprietary databases, which can tremendously improve both the reliability and the precision of the outcomes (Daniëls *et al.*, 2017). As the last step in the process, the stress test results of individual financial institutions are pooled into system level, in order to evaluate whether the banking sector in its entirety is able to resist adverse shocks, or whether there may be weak individual situations that could threaten the equilibrium of the financial sector. Neither the quantification of such contagion risks nor the feedback effects from the banking sector to the real economy are usually part of the bottom-up stress tests (van den End, 2011). This is partly due to the unpredictability of banks' behavior during stress or crisis situations. Nonetheless, the coordinating authority could indeed gather qualitative information on potential management actions and second round effects from bottom-up stress test outcomes.

Since 2008, bottom-up stress tests have evolved from a mere re-active to a more pro-active tool, fundamental for crisis management. The Financial Crisis, moreover, has underlined how much of a diversified stress test taste international supervisory authorities can have. In particular, bottom-up stress test can either be vertical, i.e. aimed to treat specific risk exposures or business models and applied, for instance, by the Financial Services Authority (FSA) in UK, or horizontal, that is, as a system-wide exercise based on uniform scenarios, preferred by US authorities. In 2009, the Committee of European Banking Supervisors (CEBS) launched a third variant of the former two methodologies. Specifically, they coordinated a regional stress test with the objective to capture possible cross-border effects. But regardless of the specific bottom-up test, all of them should satisfy at least the following three criteria (van den End, 2011): clear and synchronized communication of the results; high level of disclosure and complementarities with other policy actions for institutions that fail to pass the stress test. From a drawback side, bottom-up models and in particular vertical stress tests, seem not to always rely on a precise economic scenario, mainly due to the great admissible discretion. In addition, many bottom-up stress-testing models employ historical data as initial input. As a result, the usage of historical data may have the gargantuan disadvantage of being unable to forecast out-of-sample events that may realize in the future. Lastly, using sophisticated internally-developed techniques can create a false sense of security and complacency and consequently this may discourage a thoughtful analysis of the current and future economic and financial situation. Nevertheless, bottom-up modelling for stress testing seem to be the preferred methodology yet to Basel III, at least in the long term (Krayn, Day, 2013).

To conclude, both top-down and bottom-up stress testing models have advantages and drawbacks as well. For this reason, it is important to bear in mind that the best way to carry out stress tests is to cleverly integrate multiple approaches in order to end up with more reliable outcomes and precious crosschecks. Individual financial institutions and supervisors may indeed adopt different approaches, top-down; bottom-up or a hybrid one, nevertheless, the ultimate outcomes should be quite similar and easily comparable. Thus, the results could be aggregated and examined to test any convergence between the methods. Ideally, the exercise carried out by the authority should replicate the results reported by the individual institutions using their own methodology (Montes, Artigas, 2013).

### **3.3 Stress Tests: Criticalities and Cross-border Propagation**

This specific section contains details about carrying out a macro-stress test exercise, considering, as the scope of application the entire banking sector and the resilience of the

system as primary objective. Note that herein we will recall the concepts explained in the chapter II of this volume.

As stated earlier, a stress exercise generally may include two main types of analysis: a very trivial sensitivity analysis and other, way more sophisticated scenario analysis. The former seeks to evaluate how the main determinants of the financial condition of credit institutions are affected by particular one-off shocks to specific banking risk factors. Unlike sensitivity analysis, scenario analysis employs econometric models to investigate how the macroeconomic and financial aggregates of the system would be affected under a certain scenario. In a complete scenario analysis, also balance sheet and the profit and loss account are taken into consideration in order to model the transmission of the macroeconomic shock. Notably, the shock will make an impact on the entire business of the bank, which is reflected on both balance sheet items and certain elements of the profit and loss account. Moreover, credit risk may affect the profit and loss statement via credit provisions of expected losses. Depending on the approach, these financial statements would be either those of the system as a whole, or those of individual banks. A scenario model should not be limited to estimating a single equation, such as the bottom line of the profit and loss account. Rather, the analysis should be developed further in order to provide a more comprehensive insight that distinguishes different balance sheet items and their contribution to the profit and loss account. This approach considerably enriches the exercise and it enables step-by-step monitoring of the various items comprising a bank's main activities and operations. Thus, any concealed effect that influences and alters the interpretation of the banks' risk profile and sensitivity to certain risks is correctly taken into account. In addition, distinct balance sheet items may show varying sensitivities to certain shocks and may also respond by different amount to changes in the value of macroeconomic variables. Let us consider for instance equity instruments. They may vary more consistently to a fall in stock market prices than to domestic credit contraction. The items of the profit and loss account that are usually considered in a stress exercise include: interest income; fees and commissions; operating expenses and provisioning charges, such as impairment losses. In particular, net interest income is one of the main items that a stress test exercise should comprehend. To model this specific item of the income statement, many components of the balance sheet are utilized. In effect, these elements are introduced in the stress context with equations that relate interest rates and exposures to macro-variables. A particular example could be the mortgage credit portfolio, which is one of the components on the asset side generating income. In this respect, the stress exercise models, on the one hand, the average rate charged to the loans in this portfolio, on the other, the average mortgage exposure. Their interaction provides the

contribution of this asset item to the net interest income. Similarly, the remaining items on the asset side are treated analogously. Modelling financial costs, i.e. rates and amount of the financing obtained, from the liability part gives its contribution to interest expenses. Summing up the cost of all financing sources leads to the total cost of liabilities. Eventually, net interest income is achieved by subtracting from the asset value the liability cost.

Regarding the impact on credit risk, stress tests for this type of risk should necessarily distinguish between banking portfolios (different asset types), e.g. a differentiation between risk exposures to corporate clients and individuals. Moreover, within the latter mortgage loans should be specifically separated from consumer credit. This division enables the specific design, calibration and adequate determination of the consequences of the shock in question on every differentiated exposure. A particular shock, for instance, may have a different depending on the portfolio considered. Given the different levels in the values of the risk parameters that delineate each portfolio, it is categorically necessary to distinguish between them so that the amount of shock can be accurately determined for calibration purposes. In chapter II we introduced some key concepts to define credit risk and its components. Specifically, the key parameters employed in credit risk analysis are basically: probability of default (PD), loss given default (LGD) and exposure at default (EAD) and maturity (M). Determining the amount of the shock to which they are to be subjected is the next step in the stress exercise for this particular risk. One convincing solution to measure more precisely the credit quality of the bank's borrowers is using the obligor's probability of default. The underlying reason is quite easy to be explained. This parameter is the measure generally used by banks in their internal models to estimate and handle credit risk. In addition, since Basel II, it is also the basic standard parameter for the supervisory authorities in determining this particular risk. Therefore, the estimated change in credit loss provisions under each stress scenario may be driven and triggered by change in the expected loss deriving from shifts in the PD, due to shocks to the economic and financial variables used in the specific stress scenario. The probability of default is calculated using statistical model, wherein different factors are taken into account. Specifically, macroeconomic and financial system-related components, such as economic activity (GDP growth); unemployment rate; interest rates and other variables likely to influence the debt service capacity of bank borrowers. Eventually, this would lead to a cyclical probability of default, dependent on the economic conditions of each scenario under examination. Granularity in the estimation of PD is obtained by differentiating several crucial key portfolios within total banks' credit exposures. Particularly, a typical stress test framework may include the following portfolios: mortgage portfolio; exposures to real estate developer loans; loans to other non-financial firms and consumer

lending (Montes, Artigas, 2013). Let us consider for instance the PD of the mortgage portfolio. This specifically depends on interest rates, economic activity, which is usually expressed in GDP terms, and on the housing price index. Conversely, consumer lending strongly hinges on interest rates, economic activity and unemployment rate. To complete the credit risk assessment, other two parameters are required: the Loss Given Default (LGD) and the Exposure at Default (EAD). Both of them can be intended in macroeconomic terms as the probability of default. Considering the LGD, changes in loan-to-value ratios, real estate prices or interest rates, may directly affect the value of the LGD for modelling purposes. The common procedure for LGD, in particular, assumes an ad-hoc increase by a given percentage or defines some kind of interval of variation and utilizes it to compute the change in credit risk. For what concerns EAD, its estimation will move consistently with the estimates of credit growth, assumed by the specific macroeconomic scenario under consideration and, naturally, the values forecasted for the variables of interest. In principle, the EAD parameter should also depend on cyclical fluctuations in broad economic activity, affecting, as such, the total credit exposure of banks. Lastly, the maturity does not present any remarkable consideration, since it may be regarded as an arbitrary choice. Once all the stressed values of the risk parameters are known, the stressed expected losses connected with each scenario can be found immediately, which in turn, determines the amount of provisions to be arranged aside by banks to meet those expected losses and the consequent impact on the profit and loss account.

In section two, when we presented the Liquidity Stress Tester model, it was clearly pointed out that the effects of a scenario analysis do not limit themselves to a sole first round. And the exact reasoning also applies for the general stress-testing framework. Banks' solvency and financial equilibrium generally depends on a variety of risks that can be categorized as major economic shocks, contagion and corrections in market imbalances (sometimes referred as "bursting of bubbles"). While the initial stress-testing background may capture the economic shocks, the contagion effects are harder to deal with, as they do not manifest immediately. Nonetheless, neglecting these additional components could be deceptive because they may represent a relevant part of a stressed scenario framework. In fact, a complete exercise would also consider the second round effects, which, basically, depicts the system-wide impacts of the contagion risk. The importance of these second round effects is highlighted by the fact that they are regularly published as part of the assessment of resilience of financial institutions in the semi-annual ECB Financial Stability Review (Constâncio, 2015). In this successive phase, the original shock runs over the real sector (Montes, Artigas, 2013). The Financial Crisis undoubtedly highlighted that cross-border effects, or technically, *spillovers*, can be

extremely large and pervasive. Particularly, cross-border bank holding and sovereign markets turned out into powerful means of propagation during the crisis. A spillover can be regarded as the outcome of a shock in an economy, which is transmitted to another one through single or more channels. From both quantitative and qualitative perspectives, spillover effects hinge on different features (D’Auria *et al.*, 2016): the transmission channels, the type of shock and the amplification or stabilization mechanism operating in the originating and receiving economies. The transmission channels are basically four: trade channels; financial connections; confidence channels and institutional and political linkages.

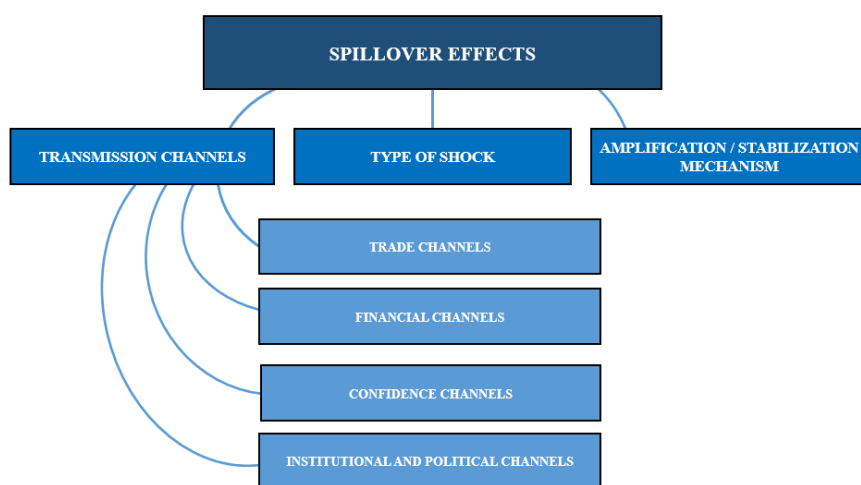


Figure 3.3. *Spillover Effects Decomposition* (Author’s Elaboration from D’Auria *et al.*, 2016)

The trade channels may determine two different effects: a demand effect and a competitiveness one. From the former point of view, any shock crafting a variation in income is likely to convert into changes in demand for imported goods and services, provoking spillover effects whose magnitude tends to augment with the deepness of the trade interconnections. The diameter of the demand effect depends on macroeconomic components, such as the monetary reaction to the demand shock, import propensity of a country and on the composition and value added embodied in trade partners’ exports. On the contrary, the competitiveness effect of a country are likely to trigger variations in the import and export flows. These reactions may derive from the endogenous answer of firms and the economy in its entirety to shifts in the economic framework. Interestingly, these effects can have different time of realization and can be mutually bolstering or go in opposite directions. As shown by the Figure 3.4 for the euro area, the trade flows were intense in the pre-crisis years, mirroring both global tendencies and incremented economic integration. In effect, the sum of total exports and imports balance of the euro region countries from 75% of their aggregate GDP in

2000 to a 84% in 2009, after shrinking during 2009-2012 and recovering afterwards. Similar considerations can be presented for intra-euro area trade, which grew from 31% of 2000 to a 36% in 2008, though its relevance has been constantly decreasing since the crisis, declining to a 32% of GDP in 2013.

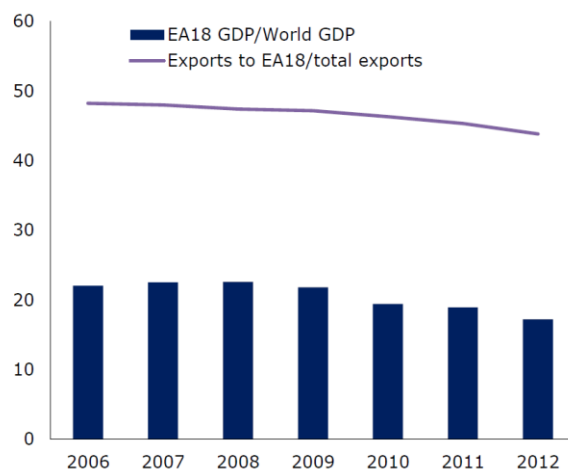


Figure 3.4 *Export of Euro Area EA18 during 2006-2012* (World Bank and D’Auria *et al.*, 2016)

The financial channel works through changes in cross-border financial flows and balance sheet exposures. Several transmission mechanisms can be identified:

1. *Spillovers via financial prices.* This is the most common channel through which financial shocks are diffused across borders, following the interest parity theory and via risk premia variations. Generally speaking, since financial markets are internationally integrated, variations to prices on any asset market are conveyed quickly into asset prices in other economies. In practice, investors rebalance their portfolio compositions on different markets (Tokat, Wicas, 2007).

2. *Spillovers via cross-border balance sheet exposures.* The Financial Crisis increased the awareness on the importance of effects that go beyond the transmission of movements to asset prices and affect balance sheets in other economies. Let us consider the case of a household possessing cross border assets. In this case, any shift of the assets *value* may trigger deeper consequences. In fact, such “wealth” effects can affect consumption levels of the domestic household. For a corporation, balance sheet effects can affect the domestic demand via investment and wage levels, whereas banks, specifically, may be affected from a lending ability point of view.

3. *Information spillovers.* The information spillovers follow the expectations that market participants anticipate for the economic fundamentals. These can be engendered by policy

announcements, although there might be a problem of credibility, as described in the Barro Gordon model (1983), amongst others. Information spillovers are essential for explaining contagion impacts, in particular concerning “wake up call” effects, which may arise when new information regarding a country conducts to a reassessment of the fragility of other countries.

In general, financial flows are much more volatile than trade flows, implying rapid propagation and amplification of shocks through large changes or reversals. For this reason, financial spillovers are more complex to treat<sup>26</sup>.

The confidence channel consists of transmitting changes in consumer and business sentiment in one country to confidence in another one. Given the strong correlation between confidence and economic activity, the confidence channel may play a pivotal role in assessing consumption and investment decisions, especially between countries with very close trade and financial links.

The institutional interlinkages and political economy effects represent another way to transmit shocks. The expression comprehends shared institutions and common policy frameworks. This channel also involves peer effects, mutual learning from best practices or sharing of common institutions or resources. As one would imagine, the effects are tough to quantify but could play a significant role in the proliferation of shocks, especially in the context of a monetary union, where for instance, the member states adopt common fiscal policies and structural reforms. In the euro zone specifically, the single monetary policy, the common external exchange rate and the consequent absence of bilateral nominal exchange rates can empower negative spillover outcomes across the euro region states. Generally speaking, different typologies of shocks can have very different spillover effects. In addition, also various conditions related to market structures and policy regimes can either amplify or reduce contagion impacts. For example, a great degree of trade openness simplifies the propagation of shocks across well-integrated economies. Real and nominal rigidities, such as sticky wages, can play a crucial role in establishing the amplitude and resistance of spillover effects too (Dao, 2008). As regards specific financial spillovers, their power may depend on different factors, including the degree of international portfolio diversification; the degree of risk aversion in the market; the size and activity of multinational banks; the level of financial market integration and the nature of markets’ regulations.

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<sup>26</sup> Hozba and Zeugner (2014) provide a clarifying illustration of the financial intermediation and how rapid capital flows may move. In particular, they described the central role played by France as buyer and seller during the Financial Crisis.



More specifically, cross-country financial spillovers and contagion have been the paramount topic in policy discussions since the very beginning of the Financial Crisis. As stated earlier, financial shocks transmit to other countries in many different ways. When dealing with financial shocks, many scholars and practitioners seem to confuse interdependence with contagion (D'Auria *et al.*, 2016). While the former relates to the correlation across financial markets in normal conditions, the latter refers mainly to the side effects that go far beyond the normal state of equilibrium: spillovers during a contagion incorporate the negative effects of amplification channels. The empirical evidence in support of contagion during financial crises seems to back up this hypothesis. Forbes (2012), for instance, analyzes correlations in stock market returns since the 1980s to mid-2012 and concludes that interdependence increased notably over the period. Favero (2012) employs a Global Vector Autoregressive (GVaR) model to analyze the co-movement of bond spreads within the euro region. The paper finds a significant non-linear relationship between spreads and fiscal fundamentals as well as some consistent evidence of contagion effects during the financial crisis. Ludwig and Sobanski (2014) provide a complete review of the banking sector's fragilities between euro area Member States over the period 2007-2010. Namely, they find out that spillover risks across national banking sectors increase tremendously during periods of financial instability and that the epicenter of risk in the period before the crisis was to be found in the periphery of the euro zone, and precisely in Portugal and Greece. As the crisis spread its wings, they noted that a variety of stability measures were introduced, which however, could not save the banking systems of core countries from increasingly becoming a continuous source of fragility spillover.

Stress testing and, in particular, macro stress testing puts great emphasis on examining the outcomes of major macroeconomic shocks such as sharp drops in GDP and increases in unemployment. Supervisors and central banks have gained considerable modelling abilities to analyze risks of this nature. Regarding the specific analysis of contagion risk and how the initial impacts are propagated to other economies, regulators have begun to implement practical models that can be calibrated to real world data, which in turn might be useful to study macroeconomic implications deriving from stress tests. Nevertheless, a workhorse model has yet to be found (Anderson, 2016).

Let us consider a trivial example to start to figure out how second round effects and especially contagion consequences are propagated in cross-border economies. Firstly, a scenario of zero growth is assumed. This will imply a cutback in credit quality of banks' borrowers, represented by an increase in credit risk. Banks, in turn will react by reducing the amount of new lending, which will manifestly upset economic agents and their borrowing capacity. As a

consequence the initial economic background will aggravate and thus, the original shock will nothing but worsen, leading into a negative growth that obviously will affect obligors' credit quality more harmfully than the initial situation. All the previous events may be described by an individual equation, leading, as a result to a multi-equation model able to bring the feedback process to an end and to determine the overall amount of the shock. Nonetheless, the relations occurring between the financial and the real sector are generally not easily captured by any equation: the estimates would always represent approximations. Another possible solution could lay in amplifying, to some extent, the initial amount of the shock deriving from the originally-set stressed scenario. Of course, the increase must be massive enough to capture the additional impact that feedback effects would trigger on the financial system. To recap, once a shock and its size have been determined, its impact on the financial condition of the system is estimated with the final goal of testing the system resilience. This is accomplished by determining the consequences on the different items on the profit and loss account as well as the impact on solvency. It is crucial to analyze the effect of shocks by pooling the profit figures for each year to end up with a cumulative figure for the last year of the time horizon. This aggregated value best illustrates the impact of the stress test on the system's financial condition for each of the scenarios under review. Accordingly, the impact on profitability is regarded as the difference between the profits calculated under the baseline scenario and those for each of the specified scenarios. Analogously, the burden on solvency is determined by comparing the ratio of the baseline scenario with that of each of the stress scenarios taking the cumulative effect of that comparison on the capital ratio at the end of the selected time span. As an alternative, more sophisticated approaches that engage a deeper conceptual and methodological framework, could be put in place. For instance, a general equilibrium model can be adopted, which considers a three layer endogenous default, in the household, corporate and the banking sector, the so-called 3D model (Clerc *et al.*, 2015). The macroeconomic-feedback interaction has also been described by econometric models, which test banks' response to capital shocks in a time-series context, such as GVaR (Gross *et al.*, 2015) and FAVaR (Budnik *et al.*, 2015). These methods can also be implemented for macroprudential policy cost-benefit analysis as well as to quantify cross-border effects. Furthermore, the GVaR approach could also be integrated with early warning models to account for the medium-term boom-bust cycles by rendering endogenous the predictor variables employed in the logistic early-warning model (Behn *et al.*, 2015).

For simplicity's sake, we present herein another model, which notwithstanding its plainer theoretical assumptions, fares quite well at describing the amplification effects. Namely, the model in question is the Conditional Value at Risk or CoVaR model (Adrian and

Brunnermeier, 2008). The CoVaR approach describes direct and indirect connections at country level. This, obviously, may turn out to be extremely important from a macro financial stability and a sovereign risk management point of view. In effect, this may help to understand the systemic importance of individual economies. The CoVaR model in this context provide a good applicative framework, in the sense that this model tries to underline the bilateral linkages through co-risk measure, which may capture the increase in risk of one country when another country falls into insolvency or distress. Specifically, the CoVaR captures the degree of intensification of the risk, taking into consideration the non-linear properties of risk, as correlations and the risk measure may vary with the level of risk. We already introduced Value at Risk previously<sup>27</sup>. But nevertheless, the *VaR* introduced in the earlier chapter is a model that operates efficiently in an isolated economy, whereby the effects in other countries are basically neglected. Applying the CoVaR may be regarded as a clever way to include spillover effects that one state may exercise on another. Statistically, the CoVaR for one country is defined as the VaR of the economy conditional upon the VaR of another state's economy. Let  $CoVaR_q^{i|j}$  be the  $VaR_q^i$  of a state  $i$  conditioned upon the  $VaR_q^j$  of the country  $j$ . It can be shown that:

$$Pr(\Delta X^i \leq VaR_q^{i|j} | \Delta X^j \leq VaR_q^j) = q \quad (3.1)$$

Wong and Fong (2010) propose a fascinating practical application of the CoVaR model in their analysis of the euro zone. Accordingly, they employ the CoVaR as a non-linear approach to estimate the conditional risk, making use of quintile regressions. These particular regressions allow practitioners to cut the distribution at the quintile of interest and obtain the corresponding cross-section of the conditional distribution. In this case, the quantile of interest will correspond to the level of *VaR* specified in the regression framework. Wong and Fong, notably, estimate the changes in the credit-default-swap spread of one euro-area Member State with another's, employing quantile regressions:

$$\Delta CDS_i = \alpha_q^{i|j} + \beta_q^{i|j} \Delta CDS_j + \sum_{k=1}^N \gamma_{k,q}^{i|j} + \varepsilon_q^{i|j} \quad (3.2)$$

Where  $\Delta CDS_i$  is the variation of the CDS spread of the country  $i$ , expressed as a function of the CDS spread of country  $j$ ,  $\Delta CDS_j$ , and a set of common risk factors  $F_k$ . The equation is computed at the 99<sup>th</sup> quantile, denoted by  $q$ . Note that the quantile level is an arbitrary choice. The estimated coefficients  $\alpha_q^{i|j}$ ,  $\beta_q^{i|j}$  and  $\gamma_q^{i|j}$  represent the measure of how credit risk of one country affects another at 99<sup>th</sup> quantile of the distribution. The independent variables are usually embodied by indicators that are commonly used in research and analysis of financial risk and market equilibrium: business cycle; liquidity condition, risk aversion; general

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27 See section 2.2.1 for more details.

sovereign default risk; the risk premium; the default risk in the interbank market and so on. Once we derived the CDS spread at 99<sup>th</sup> percentile of country j, that is the VaR for country j, we may derive easily the CoVaR measure by substituting the VaR<sup>j</sup> into the equation:

$$CoVaR_{99}^{ij} = \hat{\alpha}_{99}^{ij} + \hat{\beta}_q^{ij} \Delta VaR_{99}^j + \sum_{k=1}^N \hat{\gamma}_{k,99}^{ij} F_k \quad (3.3)$$

Where the 99 means that the parameters are estimated by the 99th quantile regression and that the 99th percentile of the empirical distribution of the CDS spreads have been utilized. The analysis of the conditional credit risk represents a versatile monitoring tool, as it reveals which countries are perceived as to be more interconnected to each other. In turn, the conditional co-risk measures are more informative, since they provide a market assessment of the increase in a country's credit risk induced from its linkages to another. Furthermore, it also captures the tail events (D'Auria *et al.*, 2016), which is fundamentally important for policymakers and risk management strategies. It is no coincidence that in the example a 99th percentile was adopted: it could perfectly represent a period of distress or an economic recession.

### **3.4 Supervisory Stress Testing: Historical Development and Criticism**

Prior to the last Financial Crisis, stress tests were largely conducted by banks for internal risk management scopes. Nonetheless, some regulatory authorities did indeed perform stress tests before the Financial Crisis but with practically no direct relevance on policy settings. A first explicit reference to banking stress test was introduced in 1996 with Basel I. Specifically, those bank-wide stress tests were addressed to banks that were using internal models to quantify market risk for regulatory purposes. However, a consistent step forward was reached only in 2004 with Basel II, whereby stress tests amplified their applicability horizons extending to credit risk too. In particular, the second Pillar clearly states the indispensability of stress testing for credit risk: both the advanced and foundation IRB approaches in fact shall require the utilization of stress testing programs in order to review the robustness of their internally-developed models and to evaluate the adequacy of the banking capital buffers. At the end of the Nineties, the International Monetary Fund (IMF) and the World Bank decided to implement the Financial Sector Assessment Program (FSAP) whose final goal was to provide a quantitative measure of the vulnerability of a country's financial and economic system to different macroeconomic scenarios, reviewing, as a consequence, the regulatory risk management framework where necessary. The FSAP assessment encouraged national central banks to adopt stress-testing procedures, which ultimately would have paved the way to the present concurrent stress tests.

The Financial Crisis, as stated earlier, highlighted consistent deficiencies in risk measurement and management across the entire financial sector. In effect, the stress testing assumptions used until then turned out to be excessively benign and overoptimistic compared to the actual performance recorded by banks (BCBS, 2009). In addition to revealing many shortcomings of stress-testing approaches, the Financial Crisis has also the great merit of having radically changed the stress tests' role within the regulatory framework. The interest in stress testing started to grow more pressingly, which eventually encouraged the Basel Committee to release, in 2009, the *Principles of Sound Stress Testing Practices and Supervision* (BCBS, 2009). Furthermore, in that period, greater reliance on stress testing also could be heard from the banking industry itself. The Basel committee well-noted those complaints and in Basel III they decided to strengthen the use of some asset classes in Pillar 1 computations of regulatory capital and stress testing obtained augmented emphasis in the Pillar 2 review of a bank's internal capital adequacy assessment process (ICAAP) (Anderson et al., 2016). Supervisory stress tests moved from being an isolated and marginal tool within the broader risk assessment programs, to large-scale, fully comprehensive risk-assessment procedures in their own right, conducting straightforwardly to policy interventions. The very first example of this new way to stress testing was surely the American Supervisory Capital Assessment Program (SCAP) performed by the Federal Reserve at the beginning of 2009. The overall reaction to this event was generally highly positive (Anderson et al., 2016). Basically, the SCAP stress test evaluated whether the large US banks had sufficient funding resources to absorb losses and continue to be operationally efficient under a common stress scenario. In particular, the scenario was extremely severe compared to the expected path of the economy at the time (Bernanke, 2010). The results, differently from the past, were published on a bank-by-bank basis, with the low-performing financial institutions obliged to increase their capital resources within six months. Moreover, on that occasion, the US Treasury Department guaranteed a concrete backstop in the event that any bank were unable to accomplish so in private markets, though actually there was no need. The SCAP is undoubtedly deemed to have made a crucial contribution to stabilizing the US financial system and restoring the investors' confidence, with the Treasury support acknowledged as the most important driver of its success (Schuermann, 2013). The SCAP was followed by the development of many frameworks for regular concurrent stress testing across central banks and supervisory authorities (Dent et al., 2016).

From an European perspective, stress testing procedures were analyzed in the "de Larosière Report", which called for more severe scenarios (de Larosière Group, 2009). The first EU-wide stress test was conducted in 2009 under the guide of the Committee of European

Banking Supervisors (CEBS). A similar test was again performed by the CEBS in 2010, but this time with the operational help of the European Central Bank (ECB). The test covered 91 financial institutions from 20 EU member states, both inside and outside the Eurozone. On that occasion, only seven banks did not pass and the overall stress test results showed that, systemically, the required Tier 1 capital could be about 9.5% under the adverse scenario, that is, well above the 6% threshold envisaged for the stress exercise. The 2010 stress test was characterized by a detailed disclosure of the methodology and by the fact that for the first time, also sovereign risk was taken into account. Specifically, to deal with the latter, a series of haircuts to the banks' sovereign debt holdings were applied. Nonetheless, the market agents deemed those scenarios as being too mild and following the publication of the results, the credit spreads on European periphery sovereign debt consistently widened (Andersen et al., 2016).

Starting from 2011, the European Banking Authority (EBA) started to exercise its own series of stress tests as a direct replacement of the CEBS. The peculiarity of the EBA lays in the fact that this supervisory body has more power to force national authorities to take specific actions. The results of test were released in July 2011 and eight banks did not perform well, since their capital fell below 5% of the Tier 1 equity capital (CET 1) hurdle considered in the exercise. Not surprisingly, the EBA specifically required these banks' responsible national supervisors to take remedial actions, so as to align with the capital standards. Similarly to the previous stress test, also the EBA-conducted exercise provided the public with an extremely high degree of methodological details. The aim was obviously to boost the credibility of the European stress testing, though very soon, negative events would have conquered the spotlight. The worsening sovereign debt crisis, and namely, the failure in 2013 of DEXIA (Whitbeck, 2013), raised a lot of concerns regarding the reliability of the European stress tests, since the bank in question did successfully pass the preceding stress test. At this point, it was crystal clear that the European macro stress testing had not proved to be a relevant instrument that policymakers could avail of to build market confidence and end the financial crisis in Europe. Differently from the US, the EU stress tests were regarded to be "too little too late" (Anderson et al. 2016): even though the transparency and severity were augmented in each successive attempt of test, they continually fell short of being credible. As a result, no system-wide stress test was carried out, neither in 2012 nor in 2013, this time span was used to gather ideas and develop more solid and conclusive stress testing regime. Borio *et al.* (2012) critically reviewed the state of the art in macro stress testing and concluded that, from a regulatory point of view, stress tests failed to be as useful as they were supposed to. Accordingly, stress tests are indeed a useful device for crisis management and rescue, but are

unreliable as an early-warning means, especially, as it happens empirically during placid periods of time, when dangers and risks are calmly building up.

The more comprehensive structure was put in place only after the EU established the single supervisory mechanism (SSM), in which the European Central Bank plays a direct role in the supervision of systemically significant banks within the Eurozone and, potentially, some other EU member states. To fully empower the SSM, a comprehensive assessment was agreed, which included both Eurozone banks and other outside the Eurozone banks that were not sure to be supervised by the SSM. Namely, this involved two parts: a first asset quality review (AQR), comprising a thorough and detailed audit of bank exposures and the adequacy of collateral and provisioning; and a stress test to examine, on a forward-looking perspective, the capacity of the bank to withstand macroeconomic shocks. Notably, the ECB was responsible for the overall

quality assurance and for the asset quality review that provides the starting point of the stress test. On the other hand, the ESRB and the European Commission provided the underlying macroeconomic scenarios. The purpose, needless to say, was to dispel any doubt about the resilience of major European banks and, contemporaneously, to establish eventually the credibility of European stress testing. Before being subject to this comprehensive assessment, the European banks raised around €50 billion as core Tier 1 capital, in order to fare better during the supervisory examination. The AQR identified some €136 billion of incremental non-performing loans, requiring system-wide adjustments of €34 billion to participating banks' balance sheets. Conversely, the 2014 stress test concerned 123 financial institutions, accounting for 70% of the European banking assets. The methodology was again meticulously explained, and results for individual banks were disclosed in detail. In the end, 23 banks did not succeed to in meeting the required standard of 5.5% CET 1 under the stress scenario and were thus required to take remedial actions. The reaction of the international financial markets following the release of the results of the stress test in October 2014 entails that the test was regarded as informative (Georgescu, 2014). Stock prices and credit default swaps spread moved consistently, enhancing for banks that performed well and deteriorating for those that appeared unhealthy under the adverse scenario. Till then, there was a lot of radical skepticism about the European stress tests and still, after the 2014 exercise, part of that untrustworthy feeling has remained. Nevertheless, it represented a milestone, a substantial step-forward compared to the previous attempts. Moreover, the outcomes convinced policymakers to keep on employing the basic framework of the comprehensive assessment, including an AQR and stress test to be performed annually on an ongoing basis. But returning to the actual 2014 results, the aggregation of the AQR outcomes with the stress test results,

generated a combining capital impact of around €263 billion, more or less 27% of the capital held by the participating banks and a median 400 basis point hit to Eurozone banks' phased core Tier 1 ratios. Nonetheless, the resulting shortfall against the 5.5% phased core Tier 1 capital requirement was €25 billion, i.e. only 2.5% of the Eurozone banks' capital base. Therefore, considering the capital already raised, the effective cumulative shortfall was only €9.5 billion, divided between only 13 banks. As one would easily imagine, the interest of the mass media was on the simple pass-fail outcomes, and in particular on three quoted banks, Monte dei Paschi di Siena (€ 2.1 billion shortfall), Banca Carige (€0.8 billion shortfall) and BCP (€1.15 billion shortfall). However, many banks were found short of a provisioning level, which the ECB considered as merely prudential. Additionally, Bisseker (2014) observed how the stress test was conducted against the sole phased core Tier 1, pointing out that investors' focus should have been on "fully loaded" ratios<sup>28</sup>, that is taking into account full deductions for balance sheet items such as goodwill; holdings in other banks; internal ratings-based provisions shortfalls and deferred tax assets. Accordingly, on fully loaded basis, nine out of 15 Italian banks would have failed to overcome the 5.5% hurdle imposed by the exercise. This is unquestionably important; especially for the investors, as the banking regulation is moving towards fully phased requirements in 2019, with all the capital adjustments that it may imply (see Barucci, Corsaro, 2014). In addition to all said so far, Acharya *et al.* (2016) criticize the excessive emphasis on regulatory capital ratios. Namely, this concentration on capital ratios can be misleading due to problems with both the denominator, (i.e. RWAs) and the numerator (i.e. the regulatory capital) of the ratio. Concerning the former, the main issue lays in the fact that the risk weighted assets are based on banks' own internal models, which are rather blurred from the external market point of view, besides reflecting different national supervisory positions that may consistently vary within the EU. Further, the regulatory capital under Basel II envisaged the possibility for different supervisors to apply divergent criteria of what would qualify as Tier 1 or Tier 2 capital, and this absence of consistency has not been fully removed by Basel III's attempt to emphasize CET 1. Because of these shortcomings, Archarya *et al.* (2012) tried to compare the results deriving from regulatory stress tests with the outcomes of an alternative measure of systemic risk based on publicly available information. The model, namely, is the so-called SRISK, which practically measures the amount of capital that a firm would need to raise in the event of a crisis. This amount is calculated as the expected shortfall of the market value of capital relative to the regulatory minimum level of capital conditional on the entire economy being subject to a crisis. Archarya and Steffin (2015) carried out an empirical application of the model using, as a

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<sup>28</sup> See Appendix I for more details.



sample, the financial data of 39 publicly listed banks out of the pool of 130 banks that were included in the 2014 EU Comprehensive Assessment. For simplicity's sake, they define a crisis as a 40% fall in the stock market index. Based on this measure, they come to conflicting conclusions from those of the EU. Notably, they find a total shortfall under their stress scenario that is more than 20 times that of the capital shortfall calculated by the European authorities. The largest SRISK losses are in Germany, France, Spain, Italy and Belgium. In contrast, the included banks in the first three of these countries realized no shortfall whatsoever in the EU tests. Finally, there is a striking negative correlation between a bank's SRISK measure and its expected shortfall in the EU test. These strong findings have raised criticisms not only on the EU's Comprehensive Assessment program, but also implicitly on all the methods of regulatory stress tests. Once again, the argument of their position is easily understandable: from a macroprudential point of view, it is not always true that more details can generate more reliable estimates. The SRISK model relies in fact on the sole historical covariance between the market value of a bank's equity and the value of the overall stock market. Naturally, this may be regarded as an extreme reduced-form model, which finds in the simplicity and resource savings its greatest advantage. Nonetheless, all that glitters is not gold. Until now, regulators have not decided to incorporate any reduced-form, market-based assessments in the supervisory procedures. Constâncio (2016) explains the underlying reasons behind this reluctance. First and foremost, by relying on the sole stock market index, these measures are parted away from any reflection of the broader macroeconomic framework. Second, the market-based systemic measures like SRISK are extremely sensitive to the choice of parameters: different parameter values can translate into extensively variegated estimates of the amount of capital required to withstand a shock. In addition, computed losses are highly volatile over time and are, by their nature, procyclical (Bologna, Segura, 2016). Accordingly, the shock severity should increase during economic expansions and shrink during recessions, so as to counterbalance the amplifying effects of the surrounding economic environment.

As such, for instance, in 2009 when SCAP was employed to clarify the underlying valuations based on projected expected earnings under stressed conditions, utilizing a simple reduced-form and market-based model instead of the actual regulatory stress test would have certainly frustrated the overall confidence of the market.

In the first three stress tests of the European banking sector, the national supervisors retained the responsibility for performing the tests on individual banks and for any regulatory actions that was required as a result of the tests. At the very beginning, the role of the European Central Bank was to provide guidance on the setting of macro scenarios. This arrangement

changed radically with the introduction of the SSM, which basically has the task to support the ECB. Regarding this, Constâncio (2016) describes how the division of efforts of the ECB and the SSM are being coordinated and integrated. In particular, the SSM is responsible for the implementation of the stress tests for microprudential purposes, including accurate review of exposures and consequences of bank solvency ratios. Conversely, the accountability of the ECB is not limited to providing the framework for the development of consistent macro scenarios. In fact, it also has responsibility for determining the implications of the stress tests for macroeconomic policy, for example, examining stress test results for possible contagion effects using system-wide models.

Generally speaking, the major regulatory focus on stress testing has helped to enhance banks' own stress-testing capabilities and risk management procedures, developing sophisticated bank-wide stress test models. This is pivotal, especially for systemically important banks. Since the global recession has started to abate, the focus of regulators has shifted from immediate capital requirements to an ongoing assessment of the adequacy of financial entities' resources, which, needless to say, is important from both a micro and macroprudential policy point of view.

### 3.5 Micro and Macprudential Issues in Stress Testing

The brief overview of the stress testing history in the US and EU highlights two fundamental issues: the transparency of the stress tests and the need for a credible backstop to handle capital shortfalls pinpointed by the results of the tests. Much of the media's attention has focused on the transparency of such exercises, or, in some cases on the lack thereof. Nevertheless, this may be misleading, especially during the unfolding of financial crises, where the accomplishment of a stress test may not guarantee any restoration of financial stability. This is well-illustrated by Anderson (2016). Namely, he considers case of Cyprus. Namely, in 2011 because of a fear of contagion from the Greek fiscal crisis, confidence in the Cypriot banking system started to decline drastically, and as part of the negotiations with the EU and IMF, it was explicitly agreed that stress tests would be executed. The tests were finally performed in mid-2012, employing a famous fund management company. The outcomes reported a €5.8 billion loss, €4.5 billion of which derived from the application of a 79% haircut of bank holding to the Greek government bonds held by the Cypriot banks at that time. The Greek bond write-down represented nearly 25% of the national GDP (Demetriades, 2012). In other terms, it was crystal clear that there was no way to recapitalize the Cypriot banks, neither through international markets, nor with the public funds of the Cypriot government, which was already running a consistent primary deficit. Eventually, a bailout package of €5.8 billion was agreed with the supervisory authorities, in the guise of bail-in of Cypriot bank creditors, comprehending some insured depositors. Therefore, transparency is not enough. Regardless of the level of details given, the methodology disclosure or the individual results, a stress test has to express straightforwardly how banks would recapitalize if significant losses were found. Concerning European stress tests, in particular, this issue has laid at the heart of its weak credibility. It is no coincidence that the AQR of 2014 took place after the financial conditions had improved relative to the extent of the sovereign debt crisis. And the EU had taken measures to be able to manage large-scale solvency questions should they materialize in the future, notably through the European Recovery and Resolution Directive and the Single Resolution Mechanism (SRM). Whether this will be sufficient to assure the credibility of future European stress tests is still uncertain. The dilemma may only have an answer once the *SRM* itself is tested with a large bank insolvency which it satisfactorily resolves. Moreover, another relevant theme is whether stress testing by public authorities is a tool of microprudential or macroprudential regulation. From our discussion, since the very beginning of supervisory stress testing, it is easily understood that these exercises serve both microprudential and macroprudential policy purposes. Furthermore, as stated earlier, these two functions complete each other, in the sense that carrying out both type

of tests may serve to double-check the results, so as to determine more reliable and precise values. Nonetheless, one should always bear in mind that the scopes are not identical, and the design of stress testing frameworks ought to be adapted to the specific roles that policymakers intend for the instrument. Banking supervision is the primary tool envisaged to implement microprudential regulation. This may involve the examination of a bank's financial situation based on recent performance, with a particular focus on capital and other regulatory ratios. Supervision will also include a review of the bank's internal processes, systems and models, including its use of stress testing. Historically, and in many cases still today, the outcomes of a bank's supervisory revision are not made public. But the establishment of CCAR in the United States and the AQR in the EU has changed this supervisory process. For large banks under direct supervision of either of these authorities, the financial condition is examined on a forward-looking basis under stress scenarios set by the competent supervisor, their projected capital position under stress scenarios is compared to a capital standard set in the test, and any deficiency requires recovery actions under a plan approved by the regulator itself. Further, in some particular cases, stress test results of individual banks are revealed in details. This stress testing for microprudential purposes typically examines in detail different portions of a bank's banking and trading books, which are valued under adverse conditions using techniques that are specific to those exposures. Conversely, in macroprudential regulation, the focus lays in the health of the financial system as a whole and the capacity of the banking system to support investment and economic activity generally on a continuous basis. Of course, this may be useful as an input in monetary and fiscal policies. Moreover, regulators may consider implementing specific macroprudential tools as well. A useful approach that has been use in a number of countries is to impose a cap on the loan-to-value LTV ratio on mortgage loans. Alternatively, in 2013 the Swiss authorities proposed a temporary increase in the regulatory capital charge applied to Swiss residential mortgage loans, so as not to directly evaluate the collateral for mortgage loans (Danthine, 2014). This may be regarded as an example of an instrument that is applied to consider a counter-cyclical element into capital regulation. In effect, this measure was generalized in Basel III, which requires a counter-cyclical capital buffer of between 0% and 2.5% of risk-weighted assets to be phased between 2016 and 2019. The activation of the buffer relates to the national authorities' responsibility, who should assess the business conditions. Notwithstanding, the Basel Committee privileges the credit-to-GDP ratios. Given the extreme versatility and flexibility, stress tests could be used in setting macroprudential regulation in many different ways. Adapting stress tests to macroprudential needs may require hypothetical specifications concerning scenarios settlement, models used to calculate stressed values and results-driven policy implications. Diverse scenarios can be

selected to explore system-wide vulnerabilities that can be either structural or cyclical. An example of structural risk factor may be the strong dependence of an economy and the related banking system upon the import of a single commodity, such as gold. Therefore, to capture a structural vulnerability, a stress test could consider a commodity price decline, with an even larger hypothesized downfall for those countries that show significantly more reliance on the importation of that specific commodity. On the contrary, cyclical risk factors might typically reflect a credit build-up based on a boom in collateral values, such as housing prices. As a result, this could be captured in the amplitude of a hypothetical deterioration of housing prices in the adverse scenario context. Policymakers may be interested to understand what the banks themselves believe may be their most important fragilities. For instance, as pointed out by Edge and Lehnert (2016), the *CCAR* recommends firms to evaluate their capital developments against their own stress scenario, as well as those specified by the regulators. By doing so, banks and supervisors may glean precious information, directly or indirectly relevant for the financial system as a whole.

### **3.6 Limitations and Areas of Improvement**

One of the main limitations of stress tests is that the robustness of the results depend heavily on the data; assumptions and methodologies used. Therefore, in extreme cases, different stress tests may lead to incomparable results and even similar exercises may have a high degree of uncertainty. For this reason, so far, stress tests have been employed as just one of several inputs into the policymaking process when assessing the right level of bank capital.

Dent *et al.*, (2016) summarize the main points where regulators and policymakers may concentrate their focus, so as to further enhance stress testing's usefulness for micro and macroprudential policy (Figure 3.5).

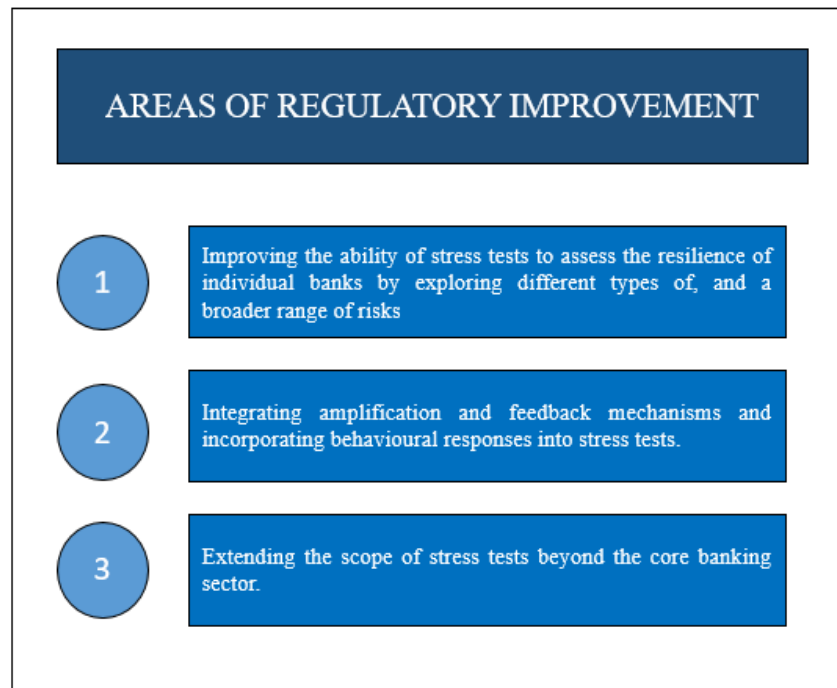


Figure 3.5. *Areas of Regulatory Improvement.* (Source: Dent *et al.*, 2016)

Improving the ability of stress tests to assess the resilience of individual banks. When microprudential regulators evaluate the impact of severe, yet plausible scenarios, they have the chance to gain awareness about the resilience of the regulated entities. At the present, the concurrent stress test frameworks run by many authorities are neglecting other important metrics, which may guarantee additional insight about the resilience of the individual banks.

A major problem that concerns basically all stress test models is the fact that they can do little against financial bubbles and market anomalies in general, which are exceedingly tough to detect. A possible solution could be traced in the approach of the Bank of England (Brazier, 2016). In particular, the new method by the English authorities envisages the use of “exploratory” scenarios, on the one hand and more traditional stressing scenarios on the other. This derives from the fact that, since UK banking system has emerged from the crisis, the brand new task of the UK stress testers has become to probe the economy, so as to discover points of fragility that could threaten financial stability in the future. In this sense, the UK approach could be also used to explore effects deriving from relevant market corrections. Nonetheless, given the resource costs that this approach would imply, its actual implementation has been quite restricted. The regulatory supervisors shall carefully evaluate whether the pros may be superior to the drawbacks that adopting such model would signify.

Alternatively, Gallardo *et al.* (2015) back the approach developed by the US CCAR program, which requires testing not only under the scenario imposed by the supervisor but also against the banks’ own scenarios. This may have consistent advantages. In first instance, it may allow

the supervisory entity to learn about the capacity of an individual bank to test its own potential vulnerabilities in an independent way using its own risk management toolkit. This could help to rebalance a potentially harmful tendency towards risk “mono-culture”, which could establish if banks simply consider their stress testing as a mere compliance exercise wherein they need to prove that they meet a predefined number of routine health checks. Additionally, by analyzing the individual outcomes, the supervisors may learn something about the assortment of potential hazards incurred by the financial sector in its entirety. As such, they could adjust their own models and processes in order to have a more comprehensive approach to macroprudential policymaking.

In addition to all explained so far, improving the ability to assess resilience of single entities may also regard all the insolvency procedures that insolvent banks may be required to comply with. Goodhart (2016) conceives stress tests as a fundamental supervisory tool outside of a crisis. Namely, he identifies in stress tests as an indispensable connector in the banking recovery and resolution framework. Warrick *et al.* (2016), clarify the role that the stress test should have in this context. Accordingly, it should assess the amount of capital and banking liquidity necessary to survive under stressed conditions. Conversely, the recovery planning needs to ensure that the institution holds appropriate level of contingencies to resist significant shocks while remaining a going concern entity. And lastly, the resolution plan should function as a roadmap, that allows the orderly resolution of a failed institution while generating enough liquidity and capital to preserve its critical functions and operations and, at the same time, avoiding any systemic impact. The two crucial issues in resolution have been the designation of authorities specifically charged with the resolution decision and the introduction of bail-in that is intended to accelerate resolution procedures and thereby avoid contagion, as well as shelter against bailouts by taxpayers. Nonetheless, the main unresolved topic in this architecture is still how to induce recovery in advance of the point of insolvency, when the going-concern value of the bank is worth preserving. Experience has shown that bank managers are reluctant to undertake recovery, because of their aversion to share dilution and a fear for their jobs if their actions were to admit the failure of previously chosen strategies. Supervisors, though, may be aware that the bankers are perhaps postponing recovery actions too long, but they have lacked concrete instruments to force responsible authorities to operate promptly. In fact, what they really need is a practical tool that would allow them to intervene. And Stress testing potentially can be the tool that provides a formal trigger for the resolution process.

### **3.7 Conclusions: The Future of Stress Testing**

Over the last two decades, stress tests have turned from being an isolated risk management instrument, mainly used by banks to determine the resilience of their trading portfolios, to become an indispensable part of the regulatory toolkit at worldwide level. Nonetheless, today's stress tests are not flawless, since there are indeed various areas where further improvements could increase the overall usefulness for policymakers.

Regulatory stress tests have focused primarily on banks' capital positions, that is, whether financial institutions possess sufficient capital requirements compared to the set out specified by the supervisory framework. As a consequence, stress tests are not a substitute for a robust capital framework but a complement to it. Similarly, stress tests cannot stress testing exercises cannot replace any supervisory assessment that ensures banks have adequate and operating risk management governance processes.

Two strongly-related metrics that may enhance stress tests frameworks are liquidity and funding resilience. The former deals with the bank's capacity to meet its short-term obligations as they come to due and properly answer to sudden, unexpected increase in withdrawals by its depositors and other clients. In other words, it measures the ability to quickly satisfy such withdrawals. Funding resilience, in turn, assesses the sustainability of a bank's funding profile. Especially during stressed times, a bank's ability to roll over and raise capital funds may become excessively problematic such that it is unable to obtain sufficient funding, or can only accomplish so at a much onerous cost. Trying to include both funding and liquidity resilience in a more comprehensive way within concurrent stress-testing frameworks would give a more complete picture of banks' resilience to the stress scenario. Although some authorities already operate liquidity and funding stress tests, they are generally less advanced (BCBS, 2013). Additionally, although they do perform liquidity, funding and solvency tests, these tend to operate independently. Of course, this does not work in practice. Let us consider for instance, a bank that is facing liquidity troubles and has not enough liquefiable assets or is not able to raise capital funds. This may oblige the institution to sell long-term assets at discounted prices to attain liquidity. As an extreme consequence, the accumulated losses could lead to the insolvency or even the bankruptcy of the bank.

A radical solution is represented by the Stress Test Buffer (STB) proposed by Bologna and Segura (2016). The SBC is nothing else but an additional, bank-specific capital requirement, which shall be complement to the capital requirements envisaged in Pillar 1. Needless to say, this further imposition would have the ultimate scope to increase the individual bank's ability to withstand, as a going concern entity, a severe macroeconomic scenario. Precisely, to compute the amount of STB, Bologna and Segura divide capital requirements of Basel III into



two classes, depending on whether the buffers can be eroded to absorb the eventual losses resulting from the exercise (*usable buffer*) or not (*non-usable buffer*). For instance, Countercyclical capital buffer may be regarded as an example of usable capital, which as such, may increase the banks' loss-absorbing capabilities during adverse shocks. Conversely, the G-SII buffer and O-SII buffer, introduced to augment the resilience of institutions whose failure would be harmful for the entire financial system, should be deemed as non-usable buffers. Then, the stress test hurdle is defined as the sum of the hard minimum capital requirement and the bank-specific non-usable buffers. Ultimately, for each bank the losses deriving from the supervisory stress test (*ST losses*) are compared to its usable capital buffers. Naturally, in case the latter are higher than the former, the bank has adequate loss-absorbing ability to survive the adverse economic scenario and the consequent STB is set directly to zero. Otherwise, the STB is equal to the difference between the two, so that by construction the sum of the usable buffers and the STB is sufficient to absorb the ST losses should the adverse scenario materialize. Specifically:

$$STB = \max \left\{ \frac{ST \text{ losses}}{Risk \text{ Weighted Assets}} - (CCoB + CCyB), 0 \right\}$$

Where CCoB stands for the Capital Conservation Buffer and CCyB represents the Countercyclical Capital Buffer.

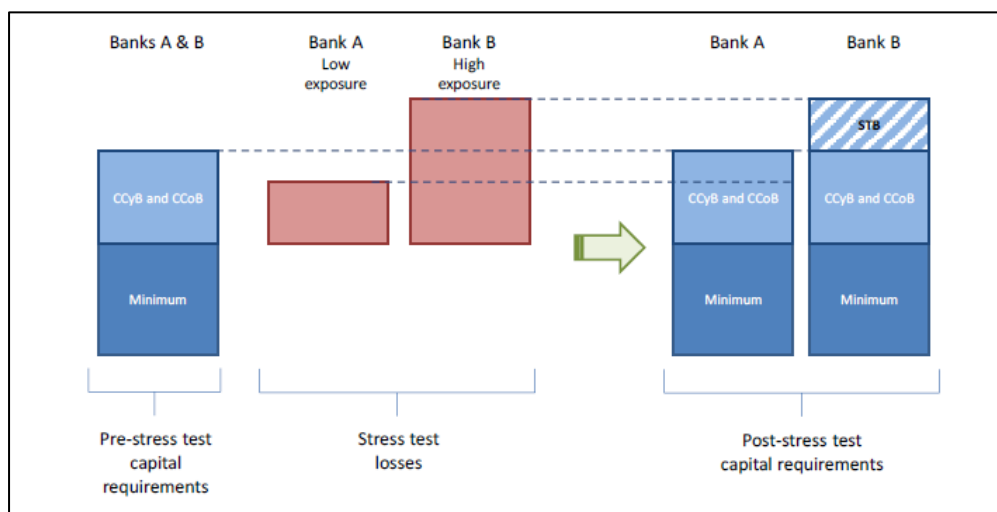


Figure 3.6. *Defining the Stress Test Buffer (STB): a stylized example.* (Bologna, Segura, 2016)

Figure 3.6 illustrates the operating mechanism of the STB capital requirements. In particular, bank A in the figure, shows after-test losses, which are inferior to the CCyB and CCoB capital amounts. For this reason, the resulting STB additional requirements is zero. A different story concerns Bank B. In this specific case, the computed losses are higher than the sum of CCyB and CCoB. As a consequence, the STB buffer would require a further capital increment,

corresponding to the amount calculated using the previous formula. Of course, if the bank happen to hold extra voluntary capital, this would be considered for STB purposes, therefore, not implying any additional provision.

Currently, authorities are also likely to explore risks emanating from a wider range of resources. At the moment, regulatory stress test incorporate an individual or dual scenario approach. But since any single scenario is very unlikely to materialize, it may turn out to be convenient to increase the flexibility of stress test, by creating a greater number of scenarios that can be explored any year. A multiple scenario approach has the inestimable advantage of exploring new and emerging threats to financial stability, as well as testing the banking resilience against an ordinary set of risks. This more flexible approach could significantly increase the resource burden that stress tests may pose on both participating banks and supervisory authorities. Consequently, supervisors are striving towards more automated and systemic exercises, to make the accomplishment of multiple scenario approaches more feasible. On the contrary, this, as a drawback, might allow banks to predict more easily, which would eventually induce them not to dedicate the necessary effort and attention, besides discouraging the individual research in this field. But as Dent *et al.* (2016) noted, qualitative reviews of bank risk management practices, conducted by regulators in conjunction with their stress test exercises could indeed help to mitigate the potential downside deriving from enhanced automation.

Another interesting point is integrating amplification and feedback mechanisms and incorporating behavioral responses into stress tests. This concerns the core design of stress tests. In an earlier paragraph, it was stated that feedback and amplification channels have proved to be essential in driving contagion effects and exacerbating the impact of a starting shock Constâncio (2016). For instance, during the global crisis, significant losses eroded banks' loss-absorbing capital resources and shed some darkness on their ability to keep on meeting their regulatory capital requirements. As a result, market uncertainty over the solvency of many banks led to strains in bank funding markets, hitting banks' capacity to raise funds. In such circumstances, the behavioral responses that banks themselves may implement turns out to be another crucial feedback channel. If, for example all banks respond to market funding constraints by looking to substitute wholesale funding for retail deposits, increased competition in retail deposit markets may likely drive up interest rates. This, then, is likely to have a negative impact on bank profitability. Understanding such feedback and amplification channels, and the role they play in driving contagion losses and contributing to systemic risk is a key issue for policymakers. This should be a key duty to be fulfilled on a continuous basis, since they possess a comparative advantage over individual institutions in

this specific area because of their ability to access projections across stress-test participants. As such, they are enabled to grasp the broader market conditions that might prevail during the stress, and evaluate the feasibility of individual banks' proposed adjustments in light of this. Many different authorities have already made efforts to comprise behavioral answers into their stress-testing regimes, mainly through the usage of dynamic balance sheets and consideration of management actions. Still, an ample room of improvement related to the consistency of such actions is foreseeable. And the analysis of other feedback and amplification channels is also at a very early phase.

The most challenging development that stress tests are required to carry out is represented by extending the scope of stress tests beyond the core banking sector. As the Financial Crisis pointed out, interconnections between different players of the financial system can represent a means through which stress effects originating in a particular market segment are propagated across the larger financial system, amplifying the effects of the initial shock. Investigating interconnections between banks and the wider financial and economic system implies the analysis of both direct links, such as financial transactions, and indirect links, like for instance, behavioral analysis of different financial institutions, that may have the conductivity to transmit and magnify shocks. Previously, we described how financial and behavioral spillovers could be transmitted at a system-wide level. Let us recall it briefly. Financial transactions can create direct links between both banks and non-bank institutions. For instance, repurchases agreements may be considered as an example of such transactions, and in times of stress, the haircuts demanded by the buyers has the tendency to rise, which, in turn may provoke further damages to the funding difficulties faced by other financial institutions. Even in the absence of direct links, the behavior of different institutions in a stress situation could propagate shocks to the entire financial and economic system. Deb *et al.* (2011) review the effects that assets price decrease had on the market during the Financial Crisis. Many assets were notched down and this forced various asset managers to sell. This caused sharp reduction in market prices and significant losses for other institutions holding these same assets.

Despite the fact that macroprudential authorities are already performing analysis of possible interconnections between different players and entities of the financial system, no supervisor has yet undertaken a comprehensive system-level stress test. Such a global exercise would require the inclusion of other financial institutions, including central counterparties, hedge funds, insurers and money market funds, just to cite some. Thus, the correct form of a system-wide stress test might well differ from bank stress tests. Nonetheless, it could contribute to an improved understanding of how shocks can be transmitted through the entire financial system,

giving rise to systemic risk, which might be reflected in banks' losses as well. Extending the thresholds of stress testing beyond the core banking level could also prevent institutions from moving activities outside the core banking sector into the so-called "shadow banking sector". Additionally it may help policymakers to ensure that financial institutions and other regulated entities are resilient to contagion risk originating from unregulated financial entities. To this scope, the Financial Stability Board recently has urged supervisory authorities to take into account a system-wide stress testing. And in such systemic context, stress testing is likely to retain and consolidate its primary role in banking regulation and supervision, should the participants in the process fully understand both how stress testing can contribute to promoting financial stability and what it takes, in terms of costs, to achieve those benefits.

## **4. Stress Test Results and Effects on Banks' Performance: An Empirical Analysis of the European Market**

The disclosure of stress test results has always been a fascinating topic for scholars and financial experts. In fact, many of them successfully attempted to trace a potential relationship between abnormal returns and the release of the stress test outcomes. Although a multitude of different models and techniques have been employed to accomplish so, it seems quite clear that financial markets are not indifferent to the actual disclosure of stress test results. This unquiet reaction, in turn, can be interpreted in various ways. However, the most plausible one relates disclosure effects and lack of information. And as a consequence, strong adverse reactions may signify an inadequate level of information provided to the market, which, needless to say, must be addressed by the international regulatory authorities.

### **4.1 Information Disclosure: Efficient Market and Bank Opacity**

#### **4.1.1 Market efficiency: Price as reflection of fundamental value**

The scope herein is to assess whether the information provided has already reached a sufficient level of details or, conversely, if more insights are needed. As the market is (semi) strong efficient, this implies that prices reflect all the publicly-available information. Notably, Fama (1970) defines "efficient market" as the market wherein security prices reflect all the available information. Additionally, he argues three sufficient conditions for an efficient market: i) no transaction costs ii) all information is costlessly available and iii) all participants agree on the implications of current information. Nonetheless, he underlines how these conditions do not need to be met as long as there is a sufficient amount of investors who takes transaction costs into account and also have access to accurate information.

Under this hypothesis, stock markets should react spontaneously and immediately to any new relevant information. A direct consequence of this assumption is that past prices have limited predictive power for future prices once the current prices have been employed as explanatory variables: to put it in another way, changes in future prices should hinge only on disclosure of new information that was unexpected today, i.e. surprise information. Moreover, another relevant consequence of this hypothesis is that arbitrage opportunities are necessarily wiped out instantaneously. However, from an empirical point of view, many attempts failed to confirm the random-walk hypothesis of stock returns even with heteroscedasticity-robust models. In effect, different studies have found empirical regularities that are contrasting with the efficient market hypothesis. For instance, the monthly, weekly and daily returns on stocks

tend to show discernable patterns, such as seasonal effects, month of the year effect, day of the week or hourly affect and so on. The presence of patterns and seasonal trends can be interpreted in two opposite ways. On the one hand, predictable patterns and tendencies can be deemed as the outcomes of stock traders' ability to forecast the direction of movements of individual stock prices over the medium and long-run. Nonetheless, the possibility to predict pattern in the medium term would indirectly signify that prices tend to adjust to new information only slowly, that is, security prices do not reflect fundamental values in the short term and consequently, stock markets are not efficient. But there is another possible explanation too, which basically is the reverse of the previous one. Accordingly, markets are indeed informationally efficient and adjust quickly and in full to any new piece of information, however the information arrives in a systematic pattern, hence the observed systematic pattern in stock returns. Obviously, the relative relevance varies in accordance with the kinds of information, since not all news items are equally important in the eyes of investors. Additionally, some news may be already expected by the market therefore not making any impact on the market returns in case of efficient markets. To be specific, the effect of news depends upon change in market valuation times and the probability of announcement:

$$\text{News Effect} = \Delta MV \times (1 - \text{Prob}_{\text{Announcement}}) \quad (4.1)$$

To the extent the announcement is already anticipated the probability of surprise tends to zero and hence the consequence of news on the market tends to zero. This creates an attenuation bias in the test of market efficiency. For the purpose of this project, the market is assumed to be efficient and market participants, i.e. investors and stakeholders in general, to be fully informed and capable of pushing and maintaining security prices around their fundamental values. Though, generally speaking, the larger the firms, the harder it becomes for investors and analysts to assess a reasonable estimation about their fundamental values. In effect, organizational infrastructures, human resources, commercial products, just to cite a few, may considerably increase the level of complexity, posing as such many challenges for all external stakeholders. Banks are no exception. The risk exposure of banks is notoriously hard to judge for the public. And as for publicly traded companies, financial institutions are required to disclose significant amount of information, in particular concerning their investment behavior.

#### **4.1.2 Bank Opacity**

Bank opacity has been a huge topic among scholars and practitioners. The basic idea of a bank is that most of its investments are risky and the lion's part of their liabilities is associated

with depositors (Bodie *et al.*, 2011). The information asymmetry theory suggests that, in a transaction, one part may have better or more information than the other. Unfortunately, all firms suffer, to some extent of information asymmetry and most of the times they just rely on market mechanism to resolve this problem (Flannery *et al.*, 2002). Greenspan (1996) highlights how this could be the main ground for opacity. Specifically, he notes that bank loans are customized products, which derive from privately negotiated agreements and as such, they may lack of transparency as far as outside investors are concerned. Thus, risk level of loans are rather hard to quantify and just for this reason, it could be a source of opacity. Peristian *et al.* (2010) two contrasting hypotheses can be traced with regards to bank opacity. On the one hand, there is the assertion that banks are completely opaque, like black boxes. Should be this the case, we would expect markets to react promptly to any relevant information disclosure. At the opposite extreme stands the hypothesis according to which banks are fully transparent to the market. In this case, we would expect market to react only to unexpected, surprising revelations. The core rationale for the banking regulation lays on the assumption that banks are intrinsically opaque, which implies that the market is unable to consistently assess the fundamental value of banks. Generally speaking, opacity prevents outside stakeholders from being able to distinguish between sound and unhealthy entities. On the contrary, as concerns transparent banks, the market seems to be able to punctually determine their true values (Haggard, Howe, 2007).

#### **4.1.3 Disclosure of stress tests: Between Opacity and Market Efficiency**

In particular, the Financial Crisis has clearly highlighted the scarcity of public information about the risk exposure of individual banks. As a consequence, regulators around the globe responded with a series of measures, among which the publication of bank stress test results. Disclosure of stress test results has become fundamental after the recent financial crisis. This information seems to be valuable as it has constantly provided new insights on an individual and system-wide level (Morgan *et al.*, 2014 and Georgescu, 2016). Bernanke, former FED Chairman, even called the 2009 U.S. Stress Test one of the critical turning points in the Financial Crisis (Bernanke, 2013). Effectively, a huge part of the damages caused by the crisis can be attributed to bank opacity. Banks were blamed of having taken too much risk, which was not adequately disclosed so that such risks could not be correctly reflected into market prices. To this purpose, disclosing stress test results may inform outsiders, and specifically investors, about the overall soundness of banks and whether they hold sufficient proprietary capital to absorb the impacts of negative shocks, thereby improving the market discipline. This, in turn, could prevent managers from engaging in excessive risk taking transactions that

may endanger the stability of the bank, as it happened in the recent Financial Crisis. Greater transparency could have allowed supervisory regulators to better monitor the banks and allowed them to intervene promptly enough to take corrective measures for troublesome or insolvent banks. Unfortunately, this was not implemented until the crisis had already unfolded its wings and the financial crisis collapsed. By disclosing stress test information, part of the investors' confidence in the banking sector would be restored, which could ultimately positively impact on the real economy. The benefits of disclosing stress test results are quite evident, as they may provide unique insights to bank supervisors and market participants about the current market discipline and resilience conditions. However, information disclosure and the consequent transparency enhancement present indeed some relevant drawbacks. As Peristan *et al.* (2009) pointed out, banks operate in second-best environments, that is, environments that are subject to market and informational frictions and influenced by externalities, which most of the times are extremely hard to cope with. These environments are characterized by endogenous costs that regulators need to take into account in assessing the design of stress tests and how to manage the disclosure of the outcomes. This means that more disclosure cannot fully guarantee an increase in market discipline and market efficiency. Additionally, Jungherr (2016) argued that disclosure of results may in reality create more panic, thus lowering the confidence in the banking sector and affecting harmfully the real economy as well. A further negative aspect is that most of the times an increase in information requirements may affect individual banks negatively from a strategical point of view: banks and all firms in general are reluctant to provide detailed proprietary information to the public, as this may favor their direct competitors. Therefore, there is an evident trade-off between bank opacity, on the one hand, which is costly for the entire society because it diminishes market discipline and encourages banks to take on too much risk and, in some cases, fraudulent behaviors as well. On the other, augmenting the information disclosure could provoke serious economic damages and notably, in terms of competitive advantages: direct rivals could well benefit from detailed information about, for instance, specific asset or equity investments. Jiang *et al.* (2014) found a positive empirical relationship between banking competition and transparency for the US. Accordingly, the removal of regulatory constraints to bank competition by individual American states has consistently improved the informational content of banks' financial statements.

The banking sector remains one of the most controlled and regulated due to its systemic relevance, as we saw previously, when dealing with spillover and propagation effects. For this reason, regulatory authorities have always tried to regulate this sector as much as they can, especially through balance sheets discipline requirements, since the latter may be regarded as



the pivotal means to reach transparency. But as we pointed out, the level of information needs to take into account the cost-benefit tradeoff deriving from the disclosure of more additional information. Of course, we indeed think that details concerning stress test results, and specifically, capital shortages and insolvency issues, are publically relevant, regardless of the costs that individual banks may be obliged to face. The ultimate aim of this work is to figure out whether financial institutions are providing enough critical information to the market, that is, to what extent we are removing banks' opaqueness veil and boosting the overall market efficiency.

## **4.2 Related literature**

The related literature on stress test disclosures and their implications is not as developed as other branches of banking topics but surely, it is catching more and more attention among practitioners and scholars, in particular, with regards to US stress testing framework. For instance, Jordan et al. (2000) analyze the impact on US bank stock returns to announcements of formal supervisory actions. The banks included in the sample were those that supervisors believed urged of remedial actions in order to avoid bankruptcy. They proved that the release of supervisory information provided significant new information to financial markets, with stock prices shrinking of about 5 percent around the announcements, underlining once again the opaqueness that may characterize the banking sector. Peristan et al. (2010) conduct an analysis of the informational value of stress test results concerning the 2009 stress test performed by the FED. Their findings showed that the stress exercise had indeed an informational impact on the market. Despite the fact that the market anticipated on its own which banks would have capital shortages before the actual stress outcomes were disclosed, banks with wider (compared to market expectations) capital gaps experienced higher negative abnormal returns. Flannery *et al.* (2016) find out concrete evidence that the Federal reserve stress tests produce indeed new information about stressed banks and the overall health of the banking industry. Notably, they discover that stress disclosures are related with higher absolute abnormal return, and higher abnormal trading volumes as well. In addition, they also prove that higher levered holding firms are likely to be more affected by stress information.

One of the earliest papers is from Morris and Shin (2002). They showed that information disclosure must be sufficiently high; otherwise, market participants may overreact, which in turn may lead to coordination failures. In a similar fashion, Gick and Pausch (2012) present a game-theoretical framework that macro stress tests can be welfare-improving if the methodological framework and actual outcomes are effectively communicated to the market.

Nonetheless, they also find out that results disclosure cannot necessarily achieve the microprudential role of providing market discipline for individual banks. Petrella and Resti (2013) also use event study methods to analyze the 2011 EU-wide stress test. They find that stress tests produce relevant information for market participants, helping to mitigate bank opaqueness. Alvés *et al.* (2013) outlines a relevant impact of disclosure of the 2010 and 2011 European stress test results on stock prices. In particular, the stocks of banks that clearly pass the exercise showed higher cumulative abnormal returns than other financial securities. Comparing American and European stress tests, Schuerman (2013) and similarly and Candelon and Amadou (2015) provide valuable insights on governance aspects, which according to them are fundamental to ensure the effectiveness of stress tests. Such are institutional framework; the scope and methodology; the scenario design; the granularity of disclosed information as well as the subsequent actions by the competent authorities. Their conclusions suggest that a reliable institutional, a credible backstop and an efficient communication campaign to the market participants are the indispensable features for an effective stress test, rather than the technical specifications of the stress test itself. The existing empirical evidence on stress tests suggests that the compulsory disclosure of stress test results are generally associated with the revelation of new information to the market.

Another branch has studied the impact of disclosure on the credit market and especially on the CDS. In this field Hull *et al.* (2004) analyze potential post-announcement effects in the CDS market and conclude that the CDS market can be regarded as informationally efficient since no pre-announcement impact was identified. A similar analysis is also performed by Norden and Weber (2004) who come to pretty identical conclusions. Breckenfelder and Schwaab (2015) deal with the reaction of equity and CDS markets to the publication of 2014 stress test results, so as to determine the amount of the cross-border spillovers from changes in banks CDS and equity prices in stressed countries to the sovereign CDS in non-stressed countries. Alvés *et al.* (2015) detect a positive effect of disclosure of stress test results in both the CDS and stock markets. More recently, a similar review was carried out by Georgescu *et al.* Their analysis takes into account both the 2014 and 2016 stress tests carried out by the EBA and conclude that both exercises were significantly informative to the market. They also prove that the market price impact may differ across the banks when banks' returns are measured according to how well they performed in the stress tests. So far, the empirical literature seems to be confirming the hypothesis that stress tests do provide new valuable information. This implies that the information disclosure requirements have not reached the market-efficient level yet: further and persistent regulatory interventions are therefore expected.

### 4.3 2016 EU Stress Test

*"The objective of the stress test is to provide supervisors, banks and other market participants with a common analytical framework to consistently compare and assess the resilience of large EU banks to adverse economic developments. Along with the results, the EBA is providing again substantial transparency of EU banks' balance sheets, with over 16,000 data points per bank, an essential step enhancing market discipline in the EU."*<sup>29</sup>

(see EBA, "EBA publishes 2016 EU-wide stress test results", 29 July 2016)

The results of the 2016 EU-wide stress test were released on 29<sup>th</sup> July 2016. In particular, the main objective of the exercise was to significantly assess the resilience of the European banking system and largest EU banks to hypothetical adverse economic scenarios. Unlike the 2014 stress test, the 2016 stress test did not envisage a "pass-fail" CET 1 ratio threshold and as a consequence, the results did not automatically originate any mandatory capital increase. Nonetheless, individual banks' performances were indeed crucial inputs for the supervisory review process. Namely, the European Banking Authority announced during the performing phase of the stress test that the outcomes would have been part of the supervisory guidance. Additionally, the ECB specified that the SSM significant institutions taking part in the exercise, the results would "...contribute in a non-mechanistic way as one of several input factors to determine Pillar 2 capital in the ECB's overall Supervisory Review and Evaluation Process (SREP)" (ECB, 2016). Specifically, the ECB underlined that adverse scenario ratio for CET 1 should level at 5.5% or, in case of global systemically important banks (G-SIBs), 5.5% plus the G-SIB buffer. This statement was interpreted as the threshold by the market: the banks that fell below the limit were expected to carry out some form of recapitalization. In general, the adverse scenario led to a decline of 380 bps in the initial point CET 1 ratio, and 13.2% by the end of the three-year forecast time span. The fully-loaded CET 1 ratio fell from 12.6% to 9.2%, whereas the aggregate leverage ratio shrunk from 5.2% to 4.2% in the adverse scenario.

The outcomes of the 2016 EBA stress test revealed consistent differences across European banks. In particular, the results of the 51 institutions that took part in the exercise suggest clearly that not economic growth but rather the exposures to non-performing loans (NPLs) and to governments and corporates seem to be the main drivers behind the impact of the adverse scenario (De Groen, 2016). To be specific, the worst performers were Monte dei Paschi di Siena and Allied Irish Banks, with only the former in tremendous need of new capital injection according to the European regulatory authorities (Durden, 2016).

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<sup>29</sup> <https://www.eba.europa.eu/-/eba-publishes-2016-eu-wide-stress-test-results>

Specifically, in the stress test conducted by the EBA, banks would lose an average 3.4% of the fully-loaded common equity tier 1 in the three-year lag under the adverse scenario. However, the differences are extremely large. For instance, the Italian Monte dei Paschi di Siena would lose some 14.5% of its CET 1, which is equivalent to more than three times the regulatory minimum requirement of CET 1 (4.5%), though the negative performance had already been anticipated by the market with consistent advance, given its undeniable exposure to non-performing loans (De Groen, 2016). On the contrary, the Scandinavian banks were undoubtedly among the top performers (Kinmonth, 2016). In particular, the Norwegian DNB would barely feel the effects of the adverse scenario, losing less than 0.1% of its CET 1.

To fully comprehend the outcomes, it is necessary to take a look at the adverse scenario design and the different channels through which the shocking effects are propagated to profit and loss accounts and capital positions. Briefly, the adverse scenario includes a foreign and domestic demand shock as well as a financial downturn between the years 2016 and 2018. Moreover, the detrimental impacts foresee also residential and commercial real estate prices and foreign exchange rate shocks in Central and Eastern Europe. Notably, the shocks are assumed to lead to an average comprehensive drop in real GDP of 7.1% from the baseline scenario<sup>30</sup>. In practice, the 2016 stress test may be regarded as a large container, wherein many different shocks are mixed up together. For this reason, comparisons and valuations are not immediate. In addition to that, very few insights about the fundamental soundness of the European banking system are provided, although this was supposed to be one of the critical priorities of the stress test framework. Ayadi *et al.* (2016) criticize the fact that different European banking groups may respond in non-comparable ways to various kinds of risks, since they may be structured in diversified ways. To this extent, De Groen (2016) suggests that introducing a more intriguing test, with a longer time horizon and multiple scenarios would be heavily beneficial.

#### **4.4 Methodological Framework**

The ultimate aim of this empirical research is to determine whether the disclosure of stress test results can have a remarkable effect on stock prices of the tested institutions and, in affirmative case, to attempt to address that impact. Theoretically, no relevant consequence should be detected, as, on the one hand, the market is supposed to be efficient and banks are assumed to be transparent, on the other. Therefore, the information contained in the results disclosure are expected to be already reflected in current market prices. The general

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<sup>30</sup> This is an average percentage: GDP declines in fact may range from the 4.8% of Hungary to the 14.8% of Latvia. The difference between the largest EU countries, however, are fairly limited in both real and nominal terms: France (5.6%), Germany (6.6%), Italy (5.9%).

framework of this empirical research relies on the event study modelling and theoretical assumptions exhaustively presented by MacKinley (1997). For simplicity's sake, we divide the methodological framework of the empirical research into steps.

#### 4.4.1 Event Definition

First of all, we need to define the event of interest. In our case, the stress test results disclosure by the EBA on 29<sup>th</sup> July 2016. This date will be the  $t_0$  of our analysis. Thus, when we refer to  $T-1$ , the date of interest will be 28<sup>th</sup> July 2016 and so on. Furthermore, we define “event window” as the time interval comprehending the event of interest. Our analysis will focus on six particular time intervals:  $T-1$  to  $T+1$ ,  $T-3$  to  $T+3$ ,  $T-3$  to  $T-1$ ,  $T-1$  to  $T_0$ ,  $T_0$  to  $T+1$  and another from  $T_0$  to  $T+5$ , as shown in the figure 4.1.

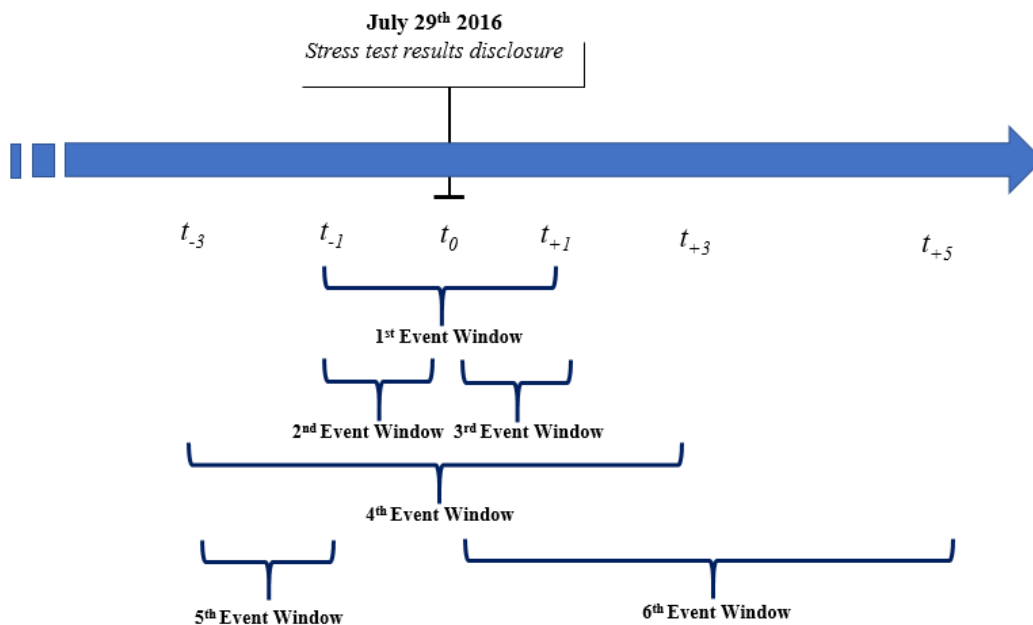


Figure 4.1 Event Windows for the empirical analysis. (Author's elaboration)

#### 4.4.2 Normal and Abnormal Returns

We follow the approach recommended by MacKinley (1997) and implemented more recently by Alvés (2013), Neretina et al. (2015) and Georgescu et al. (2016). Notably, they implement market models to compute normal returns. These models envisage the estimation of market returns from which, subsequently, individual normal returns are derived. Such techniques are for instance the CAPM or the FAMA Three-Factor model. For the purpose of this work, we opted for a CAPM-based model, since it is well-established among practitioners and scholars. Specifically:

$$R_{it} = \alpha_i + \beta_i R_{Mt} + \varepsilon_{it} \quad (4.1)$$

Where:

- $R_{it}$  represents the normal return of the  $i$ -th security at time  $t$ ,
- $\alpha_i$  is a constant
- $R_{Mt}$  is the market return at time  $t$
- $\varepsilon_{it}$  is the residual term

Let us focus on each single parameter.  $R_{it}$  is the return at time  $t$  of the specific security. In order to compute this value, we could use two simple methods. The first one is just to compute the percentage difference as follows:

$$R_{it} = \left( \frac{\text{Stock Price}_{it} - \text{Stock Price}_{i,t-1}}{\text{Stock Price}_{i,t-1}} \right) \% \quad (4.2)$$

Tough this may be a good approximation; we prefer to define stock returns in logarithmic terms. Namely:

$$R_{it} = \ln \left( \frac{\text{Stock Price}_{it}}{\text{Stock Price}_{i,t-1}} \right) \% \quad (4.3)$$

Where  $R_{it}$  is the log-return for the stock  $i$  at time  $t$ ,  $\text{Stock Price}_{it}$  is the current closing price and  $\text{Stock Price}_{i,t-1}$  is the beginning of the period closing price. We decided to employ continuously compounded returns so as to avoid issues with non-stationarity in the data. The econometric consequences of non-stationarity can turn out to be quite severe, leading to test statistics and predictors that are unreliable (Cardinali, Nordmark, 2011). Moreover, there is exhausting empirical evidence that stock returns become stationary when they are integrated of order 1, i.e. after taking the first ln-differential (Gujarati, 2003).

The second element,  $R_{Mt}$ , represents the market return. Also in this case, there are different valuable solutions. For instance, one possible solution may be employing a country indexes, thus considering market return as nationally-bounded (Candelon, Amadou, 2015)<sup>31</sup> or, alternatively, adopting worldwide indexes, such as the *MSCI World Index* or the *S&P 500*. The choice between the two is not an issue at all, since, basically, they present very similar results and are highly correlated<sup>32</sup>. We decided to pick up the *MSCI World Index* as a proxy of market return in accordance with Peristan (2010) and Cardinali and Nordmark (2011). The underlying reason is quite intuitive: given that most of the banks in the sample conduct business at a worldwide level, it would be misleading to choose a national or even an

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<sup>31</sup> Candelon and Amadou (2015) employ a comprehensive *CAPM* model, using bank stock returns, country stock market indices, and a proxy for the risk-free rate (*EONIA*)

<sup>32</sup> The two indexes had a 95.8 percent correlation between 2000 and 2009 (Koller *et al.* 2015).

European index as a proxy of market returns, since it would reflect just a part of banks' business territory. Therefore, normal returns are computed as follows:

$$R_{it} = \alpha_i + \beta_i R_{MSCIt} + \varepsilon_{it} \quad (4.4)$$

Where  $\varepsilon_{it}$  is the zero mean disturbance term. In order to carry out a more solid estimate of the parameters  $\alpha_i$  and  $\beta_i$ , we must determine their values over a consistent estimation window. Regarding this issue, scholars and practitioners usually rely on the time horizon just before the event window. Nonetheless, there is still a wide debate concerning the length of the estimation window. For instance, Campbell *et al.* (1997) estimate the parameters of the normal return model over the 120 days prior to the event, Peristan *et al.* (2010) Cardinali and Nordmark (2011) use a year of daily returns. We decided to define the estimation period according to Peristan (2010), since a longer time horizon may allow us to obtain estimates that are more reliable on average.

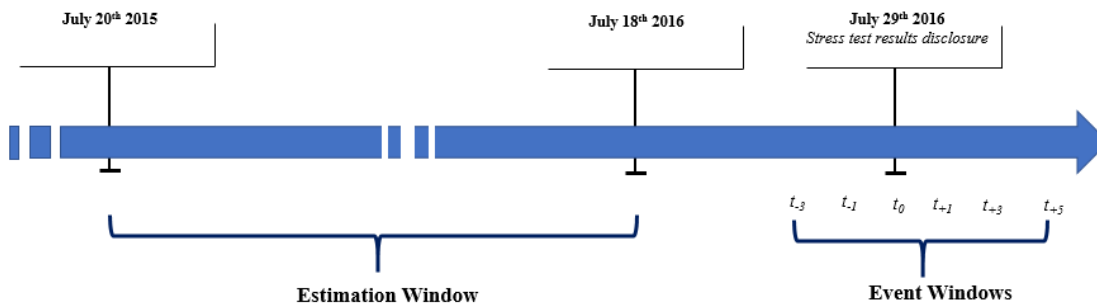


Figure 4.2 The estimation period. (Author's elaboration)

Once the normal returns are computed, the abnormal or excess returns are easily derived. Specifically, they are nothing but the difference between the actual ex-post returns of the security and the normal returns computed over the event window. In practice, normal returns are the returns that would be reasonably expected if the event (in this case, the stress test) did not take place. Mathematically:

$$AR_{it} = R_{it} - E(R_{it}|X_t) \quad (4.5)$$

Or equivalently,

$$AR_{it} = R_{it} - (\hat{\alpha}_i + \hat{\beta}_i R_{Mt}) \quad (4.6)$$

Where  $AR_{it}$  stands for the abnormal return of the  $i$ -th security at time  $t$ , while both  $E(R_{it}|X_t)$ <sup>33</sup> and  $\hat{\alpha}_i + \hat{\beta}_i R_{Mt}$  stand for the normal returns. Note, once again, that the values for  $\hat{\alpha}_i$  and  $\hat{\beta}_i$  are derived from the regressions over estimation window.

As pointed out by Cardinali and Nordmark (2011) single firm's return data might not be very informative, since stock price movements are also triggered by information or circumstances unrelated to the event. Therefore, by averaging over a number of firms, our analysis may become more productive: given that the abnormal returns are centered around a particular event, the computed mean should mirror the effects of that event. In other terms, all irrelevant information, i.e. information not linked to the event, should cancel out on average (de Jong, 2007). Namely, the unweighted cross-sectional average of abnormal returns in period  $t$  is:

$$AAR_t = \frac{1}{N} \sum_{i=1}^N AR_{it} \quad (4.7)$$

Our analysis does not focus solely on the average abnormal returns, since it would be quite reductive and not informative at all. For this reason, we introduce the cumulative abnormal returns, CAR, and the cumulative average abnormal returns CAAR. The former are defined as the sum of all the abnormal returns in a specific window and the latter simply as the mean of the CAR. To be specific:

$$CAR_{T_1, T_2} = AR_{i, T_1} + \dots + AR_{i, T_2} = \sum_{t=T_1}^{T_2} AR_{it} \quad (4.8)$$

And

$$CAAR_{T_1, T_2} = \frac{1}{N} \sum_{i=1}^N \sum_{t=T_1}^{T_2} CAR_{it} \quad (4.9)$$

Where  $T_1$  and  $T_2$  are the time span of the event window.

#### 4.4.3 Data

We gathered and analyzed 84 financial institutions: 34 of them represent our treatment group (see Annex 1), that is, the banks that were subject to the stress test exercise on 29<sup>th</sup> July 2016. The remaining 50 institutions correspond to our control group (see Annex 2). Both the treatment and control group share two common features. First, they only include entities, which are either monitored by the European Banking Authority, or under the direction of the European Central Bank. In addition to that, all the analyzed financial institutions are publicly traded entities. Thus, following Candelon and Amadou (2015), we do not capture the effect of stress test on non-listed banks. Nevertheless, to argue in favour of this choice, we may claim that the analysis of listed banks only is coherent with our market efficiency hypothesis, as the

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<sup>33</sup>  $X_i$  is the conditioning information for the normal model.



latter envisages immediate reflection of new relevant information into security prices. And this would not be that straightforward with private companies. The two sample sizes are in line with the recent academic researches (see Georgescu *et al.*, 2016). The purpose of this empirical analysis is to find out possible relationships between arrival of pivotal information and excess returns. The short term and immediate effects of information can be only observed in daily data. We obtained the historical daily stock prices from *reuters.com* although we acknowledge the existence of many valid alternative platforms that provide historical data. The choice of daily returns derives from the fact that new information can affect the stock market on same day. Nevertheless, if markets are not informationally efficient, then the effects may appear after one, two or three days. This peculiar insight is impossible to obtain with monthly or weekly data. In addition to that, employing longer horizon data may trigger difficulties in assessing excess returns. It may be even undetectable when three or more days of excess returns are pooled together. As it were not enough, monthly data adjust persistently to the new information much easily as compared to the weekly and daily data, which needless to say, may lead to fooled results. The academic literature seems to back up this position: Jun and Uppal (1994), for instance, pointed out that monthly data might create ambiguous conclusion about the efficiency of market due to adjustment of information.

#### 4.4.4 Testing Procedure

Our testing procedure aims at understanding whether the abnormal returns are significantly different from zero in the event windows of interest. In particular, we will proceed per steps. In a first general analysis, we will test the significance of the AAR for each single day of our event window. Specifically, the test is performed for pooled data; for the control group and the treatment sample. The t-statistic is reported as  $G$  in the results tables. We want to test whether the daily average returns are significant. Obviously, the significance of this first analysis is fundamental for the rest of our project, since it would not make any sense to compute CAR or CAAR in case of statistically insignificant average abnormal returns. To be precise we want to test the following null hypothesis:

$$H_0 : E(AAR_t) = 0 \quad (4.10)$$

Against the two-sided alternative hypothesis

$$H_1 : E(AAR_t) \neq 0 \quad (4.11)$$

The most common test for this kind of null hypothesis is a simple t-test (Georgescu *et al.*, 2016). To perform this test, we assume that the individual  $AR_{it}$  and the  $AAR_t$  are independently and identically distributed (*IID* assumption). Additionally, they are assumed to follow a normal distribution with mean zero and variance  $\sigma^2$ . Given that  $\sigma^2$  is unknown, a consistent estimator of  $\sigma$  must be estimated. In our case, we employ the cross-sectional variance of the abnormal returns in period  $t$ :

$$s_t = \sqrt{\frac{1}{N-1} \sum_{i=1}^N (AR_{it} - AAR_t)^2} \quad (4.12)$$

Which determines the this test statistic for the average abnormal returns:

$$G = \sqrt{N} \frac{AAR_t}{s_t} \sim t_{N-1} \quad (4.13)$$

This statistic is reasonably assumed to follow a student-t distribution with  $N - 1$  degrees of freedom. Remarkably, for large numbers,  $G$  may follow a standard normal distribution (de Jong, 2007).

The second stage takes place only in case we managed to prove the significance of average abnormal returns. Hereon, the focus will be on the CAAR for the event windows identified in figure 4.2. Similarly, also in this case we will perform the analysis for pooled data; control and treatment group. In particular, we are interested to test the following null hypothesis:

$$H_0 : CAAR_{(T1,T2)} = 0 \quad (4.14)$$

Against the alternative, two-sided hypothesis:

$$H_1 : CAAR_{(T1,T2)} \neq 0 \quad (4.15)$$

The variance of the cumulative average return is calculated as:

$$\sigma_{CAAR_{(T1,T2)}}^2 = \bar{\sigma}_{CAAR_{(T1,T2)}}^2 = \frac{1}{N^2} \sum_{i=1}^N \sigma_{i,(T1,T2)}^2 \quad (4.16)$$

The relative t-statistic ( $J$ ) is constructed as follows:

$$J = \frac{CAAR_{(T1,T2)}}{\sqrt{\hat{\sigma}_{CAAR_{(T1,T2)}}^2}} \approx N(0,1) \quad (4.17)$$

The t-statistic is presented as  $J$  in the result tables.

To increase the reliability of our results, we carry out a complementary analysis following Brown and Warner (1980). Namely, they introduce a cross sectional t-test, which is robust to event-induced variance. This test utilizes a daily cross-sectional standard deviation instead of sample time-series standard deviation. Thus, the test statistics for the day  $t$  in event time is given by:

$$t_{CAAR} = \frac{CAAR_{(T1,T2)}}{\hat{\sigma}_{CAAR_{(T1,T2)}}/\sqrt{N}} \quad (4.18)$$

Where  $\sigma_{CAAR_{(T1,T2)}}^2$  is defined as:

$$\begin{aligned} \sigma_{CAAR_{(T1,T2)}}^2 &= \frac{1}{N-1} \sum_{i=1}^N \left( CAR_{i,(T1,T2)} - \frac{1}{N} \sum_{j=1}^N CAR_{j,(T1,T2)} \right)^2 \\ &= \frac{1}{N-1} \sum_{i=1}^N (CAR_{i,(T1,T2)} - CAAR_{(T1,T2)})^2 \end{aligned} \quad (4.19)$$

The relative t-statistic is presented as  $B$  in the results tables.

In the last part, we will introduce a statistics to validate the results obtained for the stressed banks. The ultimate objective herein is to figure out whether the abnormal returns are effectively linked to the release of stress test. In fact, by introducing a generalized sign test we may compare the proportion of positive abnormal returns around the event window to the proportion with those of the estimation window. This test is a refined version of the sign test devised by Cowan (1992). Basically, the sign test it is a simple binomial test, which ascertains whether the frequency of positive abnormal returns are equal to 50% or not. In the generalized version, the fraction of positive abnormal returns in the event window is not assumed to be half of the total, but rather they are proportionately compared with those of the estimation window.

In this way, the generalized sign test may take into account a possible asymmetric return distribution under the null hypothesis. Cowan (1992) demonstrated that the generalized sign test is proper for the event windows of one to eleven days. Additionally, he also argues that the test is consistently powerful and becomes relatively more reliable as the length of the  $CAR$  estimation window augments.

$$\hat{p} = \frac{1}{N} \sum_{j=1}^N \frac{1}{257} \sum_{t=E1}^{E257} S_{jt} \quad (4.20)$$

Where:

$$S_{jt} = \begin{cases} 1 & \text{if } AR_{jt} > 0 \\ 0 & \text{otherwise} \end{cases} \quad (4.21)$$

The test statistic uses the normal approximation to the binomial distribution with parameter  $\hat{p}$ . We introduce  $w$  as the number of stocks in the event window for which the cumulative abnormal return  $CAR_{j,(T1,T2)}$  is positive. Therefore, the generalized sign test assumes the form of:

$$Z_G = \frac{w - n\hat{p}}{[n\hat{p}(1-\hat{p})]^{1/2}} \quad (4.22)$$

Under the null hypothesis, there is no difference between the proportion of positive returns in the event window and in the estimation period. As a consequence, if rejected, the positive return frequency between the two time windows is relevantly different.

The generalized sign test is extremely helpful in case of event-induced volatility increase. In our specific case, it may allow us to figure out whether the significance (or insignificance) of the outcomes has to be attributed to any potential volatility increase.

## 4.5 Empirical Results

In this paragraph, we present the results obtained from the empirical analysis. First of all, we will focus on the average abnormal returns, then we will move to the cumulative abnormal returns and to the sign test results. Overall, the results are consistent for the time interval comprehending the days just before and after the publication of the outcomes, whereas weak evidence is found for longer time intervals.

In first instance, we decided to analyze the daily average abnormal returns. As clarified in the methodological framework, the significance of the AAR will serve as the basis upon which the empirical analysis has to be constructed. In effect, drawing conclusions on a single day basis might be misleading, since event-induced effects tend to act on a slightly larger time span. On the contrary, employing excessively long time intervals might blend many firm-specific anomalies with the disclosure effect. The table 1 below presents the results for the pooled average abnormal returns. In general, the daily average abnormal returns are comfortably significant, implying that analyzing the cumulative abnormal returns does indeed make sense.

<i>AAR t-test pooled banks</i>					
<i>Date</i>	<i>AAR</i>	<i>St. Dev</i>	<i>Max</i>	<i>Min</i>	<i>t-test (G)</i>
26/07/2016	-0,0063	0,01718	0,066	-0,048	-1,252
27/07/2016	0,0108	0,01703	0,054	-0,048	5,804 (***)
28/07/2016	-0,0113	0,01796	0,022	-0,073	-4,387 (***)
29/07/2016	0,0083	0,02137	0,095	-0,040	3,586 (***)
01/08/2016	-0,0101	0,02323	0,034	-0,090	-4,055 (***)
02/08/2016	-0,0147	0,04241	0,155	-0,154	-3,189 (***)
03/08/2016	0,0081	0,0261	0,116	-0,085	2,776 (***)
04/08/2016	0,0075	0,06546	0,078	-0,567	0,824
05/08/2016	0,0117	0,02484	0,114	-0,082	4,040 (***)

(\*) significant 10%, (\*\*) significant 5%, (\*\*\*) significant 1%

Table 4.1. *AAR t-test pooled banks*. (Author's elaboration)

As shown in the figure 4.33, average abnormal returns are quite volatile over the event window. This strengthens our conviction that analyzing data on a single day basis does not provide any deep insight about the real consequences of an event. Nevertheless, a very interesting pattern can be observed when looking at the reported average abnormal returns. Namely, the stressed banks seem to overreact or, in other terms, to exacerbate the market reaction: when the latter is showing a positive trend, the stressed bank respond with substantially higher peaks. The same holds for reverse tendencies. This suggests that the stressed institutions are consistently more volatile on average than the market. Specifically, on the day of the disclosure, most of the pooled banks showed positive abnormal returns. This is even more evident if we look at the sole tested banks, which basically replicate the strong significance of the pooled dataset (Table 4.2). On the contrary, a much feebler reaction is observed for the control group (Table 4.3).

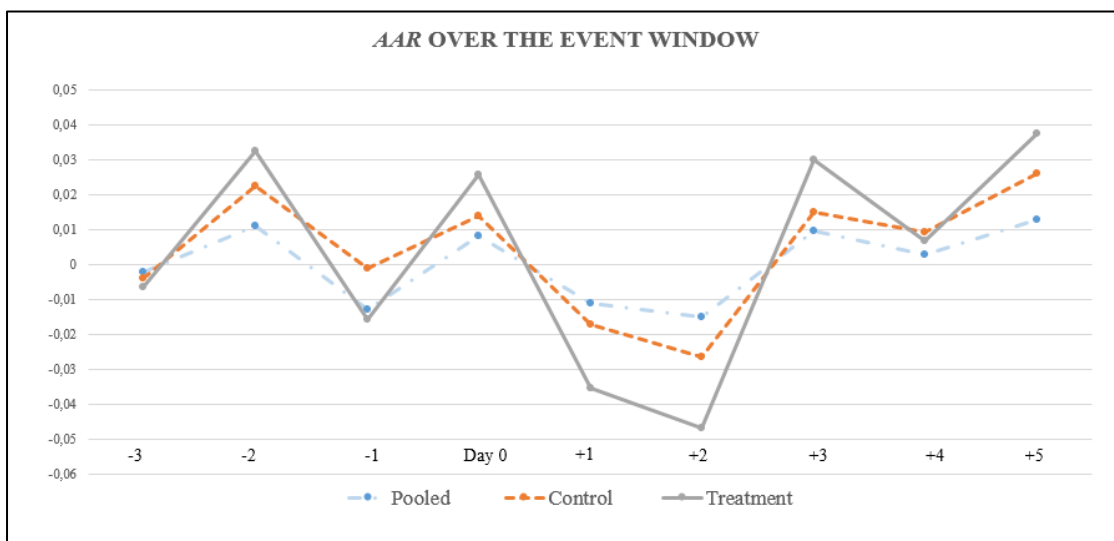


Figure 4.3 *Average Abnormal Returns during the event window*. (Author's elaboration)

Interestingly, potential conclusions based on just AAR outcomes returns would suggest that the market reacted positively to the disclosure of stress test results, and thus, that the market has already reached a satisfactory level of transparency and efficiency. Not only, detecting an upward-sloping effect would signify that market participants were expecting worse results and reacted with relief to the actual outcomes. Nonetheless, as stated earlier, the daily average abnormal returns are statistically significant yet too unpredictable to be used as unique drivers of an event study.

<i>AAR t-test for stressed banks</i>					
<i>Date</i>	<i>AAR</i>	<i>St. Dev</i>	<i>Max</i>	<i>Min</i>	<i>t-test (G)</i>
26/07/2016	-0,0026	0,0187	0,0563	-0,0481	-0,8105
27/07/2016	0,0100	0,0201	0,0543	-0,0479	2,8631 (***)
28/07/2016	-0,0146	0,0297	0,0219	-0,0600	-2,8275 (***)
29/07/2016	0,0117	0,0197	0,0660	-0,0404	3,4169 (***)
01/08/2016	-0,0179	0,0249	0,0181	-0,0903	-4,1390 (***)
02/08/2016	-0,0204	0,0365	0,0615	-0,1545	-3,2000 (***)
03/08/2016	0,0150	0,0284	0,1165	-0,0299	3,0243 (***)
04/08/2016	-0,0026	0,1004	0,0782	0,0498	0,1483
05/08/2016	0,0114	0,0220	-0,5672	-0,0815	2,9744 (***)

(\*) significant 10%, (\*\*) significant 5%, (\*\*\*) significant 1%

Table 4.2 AAR t-test for stressed banks. (Author's elaboration)

<i>AAR t-test for control banks</i>					
<i>Date</i>	<i>AAR</i>	<i>St. Dev</i>	<i>Max</i>	<i>Min</i>	<i>t-test (G)</i>
26/07/2016	-0,0018	0,0161	0,0660	-0,0334	-0,7996
27/07/2016	0,0115	0,0146	0,0491	-0,0366	5,5438 (***)
28/07/2016	0,0115	0,0187	0,0168	-0,0734	-4,3217 (***)
29/07/2016	0,0057	0,0221	0,0951	-0,0381	1,7962 (*)
01/08/2016	-0,0063	0,0208	0,0339	-0,0638	-2,1299 (**)
02/08/2016	-0,0114	0,0456	0,1555	-0,1152	-1,7493 (*)
03/08/2016	0,0056	0,0236	0,0552	-0,0849	1,6586
04/08/2016	0,0064	0,0177	0,0651	-0,0358	2,5350 (**)
05/08/2016	0,0134	0,0266	0,1140	-0,0446	3,5406 (***)

(\*) significant 10%, (\*\*) significant 5%, (\*\*\*) significant 1%

Table 4.3 AAR t-test for control banks. (Author's elaboration)

Furthermore, as no effective pass-fail threshold was envisaged, or at least on the result release date, the market could have been simply fooled by the lack of this crucial detail, or just unable to properly interpret the information disclosed. Naturally, should this be the case, an issue of

communication effectiveness would necessarily arise: as correctly pointed out by Dent *et al.* (2016), it is fundamental for policymakers to convey the right message in the right way, so as to enable investors and all the stakeholders to form a fair opinion.

Moving to cumulative average abnormal returns, CAARs, the results are somehow reversed compared to the AAR values, in the sense that almost the totality of the event intervals considered turn out to be statistically insignificant at 0.01 level, with the sole exception of the  $(-1 +1)$  event window (Table 4.4).

<i>CAAR t-test pooled banks</i>					
<i>Event Window</i>	<i>CAAR</i>	<i>t-test (J)</i>		<i>t-test (B)</i>	
(T-1) (T+1)	-0,0270	-4,0748	(***)	-2,8529	(***)
(T-1) (T 0)	-0,0087	-1,7126	(*)	-1,7969	(*)
(T 0) (T+1)	-0,0041	-0,7115		-0,7381	
(T-3) (T+3)	-0,0213	-1,7565	(*)	-0,6163	
(T-3) (T-1)	-0,0069	-1,2546		-1,1769	
(T 0) (T+5)	0,0102	0,6088		0,1630	

(\*) significant 10%, (\*\*) significant 5%, (\*\*\*) significant 1%

Table 4.4 CAAR *t-test pooled banks*. (Author's elaboration)

Specifically, both the normal t-test (J) and the cross sectional t-test (B) are solidly confirming the significance of the CAAR on that event time span. This is remarkably important, since the two statistics are based on different assumptions. Namely, the latter, t-test (B), accounts for a potential volatility increase during the event window, i.e. the so-called event-induced volatility and therefore, being able to capture also this feature may further enhance the reliability of our outcomes. Thus, we may deduce that during the interval from  $T-1$  to  $T+1$  the market was more turbulent than usual. In particular, we have a solid proof from the sample of stressed banks (Table 4.5). Both t-tests are statistically significant, although only the cross-sectional one at a 0.01 level. As a consequence, supposing a general negative reaction from the market is not unrealistic, on the contrary, it seems the most plausible conclusion based on our outcomes.

<i>CAAR t-test for stressed banks</i>					
<i>Event Window</i>	<i>CAAR</i>	<i>t-test (J)</i>		<i>t-test (B)</i>	
(T-1) (T+1)	-0,0208	-2,5105	(**)	-3,5494	(***)
(T-1) (T 0)	-0,0029	-0,4946		-0,9471	
(T 0) (T+1)	-0,0062	-1,2655		-1,3878	
(T-3) (T+3)	-0,0188	-1,5891		-0,7016	
(T-3) (T-1)	-0,0072	-1,1196		-1,6360	
(T 0) (T+5)	-0,0028	-0,1399		-0,0352	

(\*) significant 10%, (\*\*) significant 5%, (\*\*\*) significant 1%

Table 4.5 CAAR *t-test* for stressed banks. (Author's elaboration)

At this point, one may be trying to figure out a persuasive motivation to justify the adverse reaction of the market. Firstly, an intriguing explanation could be considering the negative CAAR as a sort of “dissatisfaction signal” from the market to the regulatory authorities: in other words, market participants either complained about the fact that results were much more difficult to decipher than expected, for instance, because no specific fail-threshold was contained, or more realistically, because they predicted superior performances initially. This, in turn, could have well persuaded investors to reassess downwardly their own expectations. In fact, comparing the outcomes for the stressed and non-stressed banks may further increase the last hypothesis (Table 4.6). To be precise, the CAAR for non-stressed banks is not significant at 0.01 level and the average market reaction is consistently lower than the one detected for the stressed sample, symptom that stressed banks were indeed catalyzing the attention of the market.

<i>CAAR t-test for control banks</i>					
<i>Event Window</i>	<i>CAAR</i>	<i>t-test (J)</i>		<i>t-test (B)</i>	
(T-1) (T+1)	-0,0122	-2,4206	(**)	-2,2206	(**)
(T-1) (T 0)	-0,0059	-1,4362		-1,6712	
(T 0) (T+1)	-0,0006	-0,1497		-0,1889	
(T-3) (T+3)	-0,0117	-0,8867		-0,3763	
(T-3) (T-1)	-0,0019	-0,4595		-0,4747	
(T 0) (T+5)	0,0134	1,4003		0,8852	

(\*) significant 10%, (\*\*) significant 5%, (\*\*\*) significant 1%

Table 4.6 CAAR *t-test* for control banks. (Author's elaboration)



The striking difference between the two samples further confirms that market participants did indeed possess an uneven level of insight. As it were not enough, our last test, the generalized sign test (Cowan, 1992) definitely allows us to conclude that stressed banks significantly underperformed compared to the fellow financial entities that did not take part to the exercise (table 4.7).

<i>CAAR generalized sign test for tested banks</i>	
<u>Event Window</u>	<u>t-test</u>
(T-1) (T+1)	-3,4802 (***)
(T-1) (T 0)	-0,3734
(T 0) (T+1)	-0,3734
(T-3) (T+3)	-1,4090
(T-3) (T-1)	-1,4090
(T 0) (T+5)	2,7334 (**)

(\*) significant 10%, (\*\*) significant 5%, (\*\*\*) significant 1%

Table 4.7 CAAR t-test for control banks. (Author's elaboration)

Namely, this test underlines that during the event window of interest, the actual number of cumulative positive abnormal returns was unusually and meaningfully lower than during the estimation horizon. This is further validated by the fact that the generalized sign test controls for any possible event-induced volatility. Consequently, differences in abnormal returns cannot be attributed to volatility increases deriving from the release of the stress test results and this, consequently, implies that the publication of stress test results has clearly revealed new valuable information to the financial markets. Moreover, assuming realistically that the market is efficient, we may reasonably deem this mismatch as an issue of bank opacity, intended, basically, as insufficient amount of information disclosed. Jones *et al.* (2012) impute bank opacity as the main driver of inefficient transmission of information into security prices. In effect, had the stressed institutions provided an adequate level of informational details, they would have likely triggered a less impactful reaction in terms of abnormal returns, as it occurred for the control banks.

## 4.6 Conclusions: Moving to the Right Direction

Bank opacity has always been a crucial topic among practitioners and scholars. As presented in the introductory paragraph, it is not as easy as it seems at first sight for supervisory authorities to regulate this issue. In fact, obliging financial institutions to disclose too many details may turn out to be extremely unproductive from a competitive advantage point of view. Thus, any regulatory framework has to be conceived taking into account all the pros and cons that may derive from increasing the information disclosure duties. The ultimate goal should always be to guarantee a high level of transparency, in particular concerning banking risk exposure. At the same time, banks should be allowed to keep their most delicate information safely under wrap, so as to protect their profitability. As a consequence, a comprehensive and efficient supervisory intervention must consider this trade off: the market should be given an adequate level of information disclosure to correctly judge banks' performances, conversely, banks shall be protected from any unnecessary and harmful detail release. The empirical analysis suggested that this equilibrium level has yet to be reached: markets still need some additional insight. And this necessity seems to have been well noted by the supervisory authorities in the upcoming 2018 stress test framework. First of all, similarly to the 2016 stress test results, the outcomes of the next stress test will be used as an essential input for the Supervisory Review and Evaluation Process (SREP). The major change from the previous exercises will be the introduction of the IFRS 9 framework, which will represent a disruptive milestone in terms of data and parameters computation. In particular, the new regulation will concern primarily the credit risk. According to different surveys, the latter represented the largest effect on the CET 1 in the 2016 exercise.<sup>34</sup> The shift to IFRS 9 will have an additional impact on CET 1 compared to the current IAS 39, which will probably range between 180 and 300 basis points (Nawani, Shcheredin, 2017). Currently, several banks are still finalizing the adoption of the IFRS 9. Nevertheless, this may serve as a further connecting bridge between the financial and accounting worlds, involving more people and widening as such the possibility to enhance and promote testing models and techniques. In other words, the completion of the IFRS 9 and the development of the stress test will encourage the cooperation of different areas or teams within individual banks. It turns out to be essential for each specific financial entity to optimize the internal and external resources in order to automate and integrate as much as possible of the two projects. Therefore, it may also improve the quality and quantity of feedbacks across single institutions. This convergence could also be beneficial from stakeholders' point of view, since, at least in the medium-long

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<sup>34</sup> A survey of Deloitte (Bujoc *et al.*, 2016) demonstrated that the negative impact of credit losses accounted for the 57% of the total downward movement of CET 1.

term, a more standardized language could be adopted, thus permitting a potentially faster and deeper understanding of both the accounting and financial information.

Should the benefits of the IFRS 9 be limited to the sole synergies within the internal project teams, it would not be as innovative as declared earlier. And surely, it would not bring any solution to the bank opacity problem. Fortunately, there is something more about IFRS 9, which may pose a real step forward in terms of informational value. Specifically, with the IFRS 9 we move from an incurred-loss perspective towards an expected-loss perspective, which, needless to say, will guarantee a greater reflection of current, or better, *fair* values. In fact, historical series are useful only in case we expect future performances to be quite analogous to the previous ones. However, this would rule out potential unexpected events and make any forecast of them excessively hard or even impractical. Thus, by abandoning the historically-based framework and implementing an approach that, starting from historical data, integrated with current and forward-looking information, may significantly enhance the reliability and consistency of the information, besides providing more uniformity in the treatment of financial instruments. Another interesting aspect concerns specifically the *LGD* parameter. Namely, if we compare the LGD for IFRS 9 purposes with the current regulatory (Advanced) Internal Rating-Based approach, we may clearly realize that the *IFRS 9* loss given default will feature two drastic changes, which may support the additional informational requirement demanded by the market. First, no downturn correction is envisaged by the *IFRS 9* and this, may lead to estimates that are more realistic and closer to the actual market values. But most relevantly, the new principle substitutes the historical discount rate with an effective interest rate, which is undoubtedly more reflective of the current conditions<sup>35</sup>.

Notwithstanding that the IFRS 9 will represent in general a positive introduction to the stress test framework, there may be some potential implementation drawbacks, at least during the first time adoption of the new accounting principle. For instance, it will be necessary for financial institutions to revisit their stress-testing capabilities and put attention to three crucial points. The first issue concerns scenario definition and calibration, whereby, unlike IAS 39, banks will have to define a pool of different scenario paths for each time point in the forecast horizon. Therefore, assuming a realistic five-year testing horizon, banks will have to elaborate a minimum of 15 to 20 additional scenarios under the base case and stress scenario respectively. Moreover, strictly related to the former point, a process of probability-weighting of scenarios will have to be accomplished alongside. Secondly, the forward-looking assessment of provisions poses another consistent challenge. Notably, IFRS 9 models might

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<sup>35</sup> The *IFRS 9 LGD* has basically other relevant differences compared with the regulatory Internal Rating-Based approach: the inclusion of the sole direct costs and of all guarantees, regardless of their eligibility for regulatory purposes.

complicate assumptions for transition criteria under stress scenarios, stressed lifetime probabilities of default and stressed behavioral assumptions, amongst others. Additionally, the three-stage procedure for estimating provisions may represent a further issue. The migration of assets between the three stages<sup>36</sup> is in fact a function of quantitative risk measures and individual banks' own policies as well, and thus, uncertain estimates can result from the definition of migration from stage one to stage two<sup>37</sup>. The last factor regards business assumptions. Specifically, the IFRS 9 provision stress testing will result from key business assumptions that back the financial and business strategy of the bank. These may comprehend hypotheses around portfolio movements, product mix, underwriting criteria; product maturity; fees and interest rates across the product mix and so on. All these issues will definitely increase the overall volatility of loan loss provisions under stress scenarios. Consequently this will complicate medium-term financial planning and threaten the capital adequacy of financial institutions and how all the higher volatility impacts on the CET 1. To sum up, herein we introduced just some of the numerous challenges connected to the adoption of the IFRS 9 principle. Nonetheless, should those issues be addressed in the right way, the IFRS 9 will be definitely allowed to spread all its potentiality, at least in the medium-long run.

The upcoming stress test will probably solve some of the problems that have characterized the previous exercises. But we are still far to get the job done. In the previous paragraph, we listed some of fields where major improvements are expected, although they will likely take place only after the conclusion of the 2018 regulatory exercise, since several adjustments may require longer time to be carried out. The 2018 stress test will probably serve as a "litmus test" for the European regulatory authorities to figure out, whether they are moving to the right direction or not. Moreover, it will serve as a feedback to the accounting supervisors, as far as the IFRS 9 is concerned. Therefore, we expect a lot of attention from the market to both the release of the stress test methodology and results. And we also expect further studies and empirical researches on those two events and on the banking opacity issue in general.

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<sup>36</sup> The three stages comprehend different provisions: Stage 1 point-in-time expected loss; Stage 2 lifetime expected loss and Stage 3: defaulted assets.

<sup>37</sup> A practical solution could be using the same classification cut-off of the internal rating-based approaches.

## Annex I

<b>BANK</b>	<b>COUNTRY</b>
ABN AMRO GROUP N.V.	THE NETHERLANDS
ALLIED IRISH BANKS PLC	IRELAND
BANCA MONTE DEI PASCHI DI SIENA S.P.A.	ITALY
BANCO BILBAO VIZCAYA ARGENTARIA S.A.	SPAIN
BANCO DE SABADELL S.A.	SPAIN
BANCO POPULAR ESPAÑOL S.A.	SPAIN
BANCO SANTANDER S.A.	SPAIN
BANK OF IRELAND	IRELAND
BARCLAYS PLC	UNITED KINGDOM
BNP PARIBAS	FRANCE
COMMERZBANK AG	GERMANY
CRÉDIT AGRICOLE GROUP	FRANCE
DANSKE BANK	DANMARK
DEUTSCHE BANK AG	GERMANY
DNB BANK GROUP	NORWAY
ERSTE GROUP BANK AG	AUSTRIA
HSBC HOLDINGS PLC	UNITED KINGDOM
ING GROEP N.V.	THE NETHERLANDS
INTESA SANPAOLO S.P.A.	ITALY
JYSKE BANK	DANKMAR
KBC GROUP NV	BELGIUM
LLOYDS BANKING GROUP PLC	UNITED KINGDOM
NORDEA BANK (GROUP)	SWEDEN
OTP BANK NYRT.	UNGHERIA
POWSZECHNA KASA OSZCZEDNOSCI BANK POLSKI SA	POLAND
RAIFFEISEN-LANDESBANKEN-HOLDING GMBH	AUSTRIA
SKANDINAVISKA ENSKILDA BANKEN (GROUP)	SWEDEN
SOCIÉTÉ GÉNÉRALE	FRANCE
SVENSKA HANDELSBANKEN (GROUP)	SWEDEN
SWEDBANK (GROUP)	SWEDEN
THE ROYAL BANK OF SCOTLAND GROUP PLC	UNITED KINGDOM
UNICREDIT S.P.A.	ITALY
UNIONE DI BANCHE ITALIANE S.P.A.	ITALY
VOLKSWAGEN FINANCIAL SERVICES AG	GERMANY

## Annex II

BANK	COUNTRY
AKTIA BANK ABP A	FINNLAND
ÅLANDSBANKEN	FINNLAND
ALPHA BANK S.A.	GREECE
AVANZA BANK HOLDING AB	SWEDEN
BANCA CARIGE	ITALY
BANCA FINNAT	ITALY
BANCA MEDIOLANUM	ITALY
BANCA TRANSILVANIA	ROMANIA
BANCO BPI SA	PORTUGAL
BANCO COMERCIAL PORTUGUES SA	PORTUGAL
BANCO DESIO E BRIANZA	ITALY
BANCO POPOLARE DI SONDRIO	ITALY
BANK COOP AG	SWEDEN
BANK MILLENIUM	POLAND
BANK OF CYPRUS	CYPRUS
BANK OF VALLETTA	CYPRUS
BANCA PROFILO SPA	ITALIA
BANCO DI SARDEGNA SPA	ITALIA
BANKIA SA	SPAIN
BANKINTER S.A.	SPAIN
BANQUE CANTONALE DE GENEVE	SWITZERLAND
BINCKBANK	THE NETHERLANDS
BPER BANCA SPA	ITALY
CAIXA BANK	SPAIN
CREDIT SUISSE	SWITZERLAND
CREDITO EMILIANO SPA	ITALY
CREDITO VALTELLINESE SPA	ITALY
DEUTSCHE POST AG	GERMANY
DEXIA NV	BELGIUM
EUROBANK ERGASIAS S.A.	GREECE
FINECOBANK	ITALY
GETIN NOBLE BANK	POLAND
GRAUBÜNDNER KANTONALBANK	SWITZERLANDD
KOMERCNI BANKA	CZECH EPUBLIC
MEDIOBANCA - BANCA DI CREDITO FINANZIARIO S.P.A	ITALY
NATIONAL BANK OF GREECE S.A.	GREECE
SKANDINAVISKA ENSKILDA BANKEN AB A	SWEDEN
SPAR NORD BANK	DANMARK
SPAREBANK 1 NORD-NORGE	NORWAY
SPAREBANK 1 SR BANK	NORWAY
SPAREBANKEN MORE	NORWAY
SPAREBANKEN VEST	NORWAY
SPAREKASSE SJAELLAND	DANMARK
STANDARD CHARTERED BANK	UNITED KINGDOM
SYDBANK A/S	DANMARK
UBS AG	SWITZERLAND
UMWELT BANK	GERMANY
VAN LANSCHOT NV	THE NETHERLANDS
VESTJYSK BANK	DANMARK
ZAGREBACKA BANKA	CROATIA

## APPENDIX I

### 1.1A Overview of Regulatory Capital Requirements

The new internationally agreed-upon standards, Basel III, are currently being applied with a phase-period, which will end in January 2019 for some requirements. Differently from Basel II, the new requirements envisage a consistent increase in the quantity and quality of hard minimum capital requirements that financial institutions shall satisfy at all times. This, needless to say, was established in order to enhance banks' loss-absorbing capabilities and to bolster creditors and customers' confidence. Theoretically, these precautions should also decrease the intervention of regulatory authorities, as banks will have more capital to face potential threats. Moreover, Basel III introduced three additional capital buffers over and above the minimum capital requirements. Two of them, namely the Capital Conservation Buffer (*CCoB*) and the Countercyclical Buffer (*CCyB*), have a system-level dimension and can be used to absorb losses during stress periods (usable buffer). The time-variation feature of these buffers is meant to pursue the extensive macroprudential goals of enhancing systemic stability and smoothing the financial cycle. The third buffer, the *G-SII* buffer, is addressed to the banks judged by the Financial Stability Board to be globally systemic, i.e. to be essential from a system-wide point of view. This further buffer aims at guaranteeing a higher resilience standard for banks whose failure would be enormously disruptive to the financial system and no equity capital is required for the countercyclical buffer and the systemic risk buffer.

### 1.2A Fully loaded equity

Each bank has to define its individual equity target. This target should range between 14.5% and 22% plus additional capital requirements shown in the cloud of the figure 1A. Let us consider a bank with 14.5% buffer. Accordingly, an institution that must hold just this percentage is regarded as not being systematically important and no equity is required for the countercyclical buffer and the systemic risk buffer. Nonetheless, a bank like this may not exist in reality, since possibly at least one of the equity requirements in cloud may be triggered. Therefore, a more realistic picture would suggest a minimum of at least 16% for a non-systematically important bank and a higher percentage increase for systematically important institutions as well.

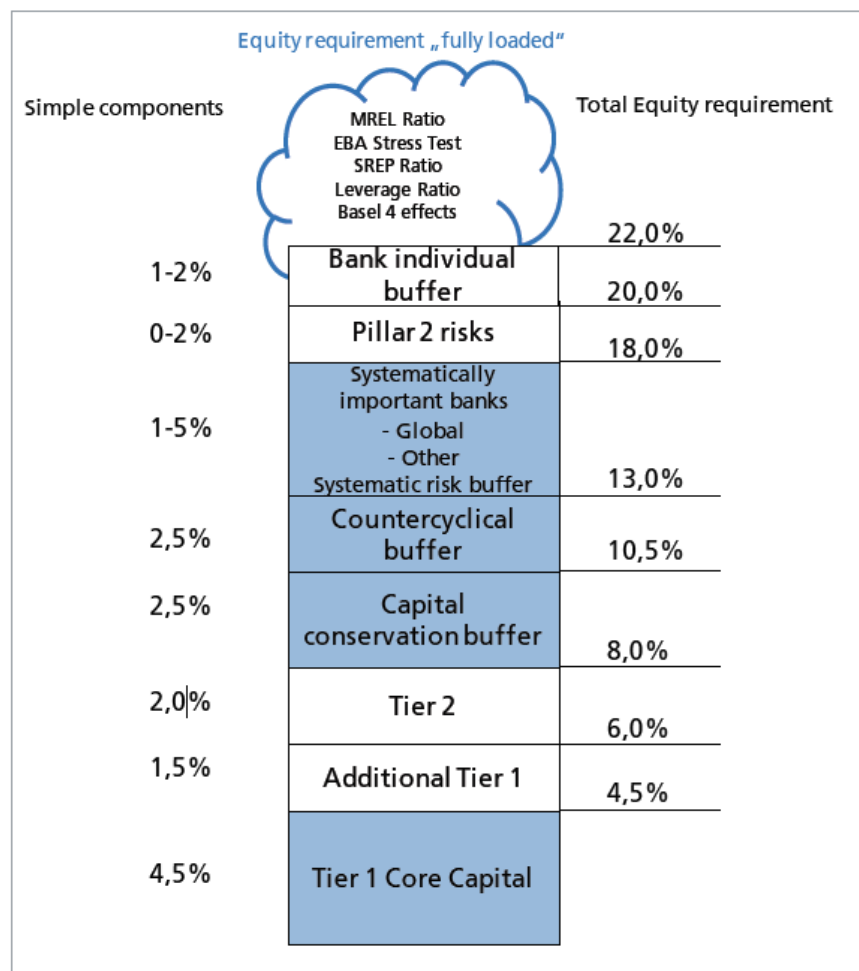


Figure 1A. Fully loaded equity Requirement. (ALM Forum, 2015)

Most of the times, the equity requirement of banks is argued as a percent of risk weighted assets (*RWA*). This is a deficient consideration, since the equity requirement for risks in the trading book and for operational risks is absent. As a result, banks may have differing equity requirements even if their risk weighted assets are the same (*CRR*, 2013). In Basel III, the total absolute equity requirement of banks was increased by a substantial change of the parameters in the *RWA* calculation and a substantial increase of the required equity for trading positions. As a consequence, 8% of the equity requirement before 2009 is not even closely comparable to 8% equity requirement in 2015.

Additionally, with Basel 4 the parameters for standardized approaches (credit risk, market risk and operational risk) are going to be more risk sensitive and will serve as a mandatory floor upon which more sophisticated approaches will be constructed (*BCBS*, 2015). Notably, the standardized parameters will tend to the current *IRB* approaches, which will eventually boost the “parameter effect” of the required equity by further 30% compared to 2009. With Basel III, the most relevant changes regard, on the one hand,



the disappearance of Tier 3 category as eligible capital completely, while on the other hand, the introduction of precise criteria for the eligibility of Tier 1 and Tier 2. The system distinguishes also between so-called going-concern capital with the feature to offset losses incurred and assure the continuing existence of the institute. The going-concern capital is further divided into common equity Tier 1 (core Tier 1 / *CET1*) and so-called additional core capital (additional Tier 1). In the *CRR* (Articles 26 to 31) we may find a description of what is actually included. Specifically, it comprehends only the ordinary shares issued by the bank, share premium, retained earnings, disclosed reserves and funds for general bank risks. Furthermore, 14 criteria are defined that have to be met without exception if additional equity qualities shall be created.

In addition to common equity also additional core capital may be eligible as part of the core capital. In this case too there are 14 criteria defined by the *CRR* (*CRR* Articles 51 to 55).

The gone concern capital (supplementary capital / Tier 2) has the objective of compensating losses in case of bankruptcy. Again *CRR* defines 14 criteria for the eligibility of supplementary capital, including a minimum term of 5 years, the subordination to not-ranking creditors and the independence of dividend payments from the issuer's creditworthiness. The importance of supplementary capital is significantly reduced, because its ability to protect creditors in case of insolvency has proved to be rather limited. In principle, in the *CRR* a minimum capital requirement of 8% remains, the requirements for the composition, however, were considerably tightened. While under Basel 2 only 2% common equity was required, under Basel 3 at least 4.5% common equity must be available from 2015 onwards..

In addition to the minimum capital requirements, the *CRR /CRD* regulations provide for capital buffer requirements, which should be built especially in periods of excess credit growth and can be reduced in times of crisis. The additionally required various capital buffers have to be of *CET 1* quality. The following buffers have to be available, whereas with regard to the level, transition periods are provided until the full extension in 2019:

- Capital conservation buffer: 2.5 % mandatory for all institutions, step-by-step introduction as from 1.1.2016, full rate as from 1.1.2019. (Art. 129 CRD IV).
- Counter-cyclical buffers: 2.5%, step-by-step introduction as from 1.1.2016 (CRD IV Article 130, 135-140).

- Buffer for systemic risks: Systemic risk buffer as from 1.1.2014 possible (CRD IV Article 133 and 134).
- Capital buffer for global systemically important institutions (G-SII): 1–3.5 %, step-by-step introduction as from 1.1.2016. (Article 131 and 132 CRD IV).
- Capital buffer for other systemically important institutions: 0-2.0 %, possible as from 1.1.2016; no looping-in necessary (Article 133 and 134 CRD IV).
- Supervisory review and evaluation process (SREP) (Article 22 and 123 as well as the annexes V and XI of Directive 2006/48/EG)

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