Operational Risk: A Survey

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Operational risk has, in a relatively short period of time, risen from non-recognition to prominence as the culprit for spectacular corporate collapses. This paper surveys the mushrooming literature on the subject, covering the definition, classification, characteristics, modeling and management of operational risk. It is concluded that operational risk is a controversial topic that will generate a significant amount of research in the years to come.

I. INTRODUCTION

Operational risk is the risk of losses arising from the materialization of a wide variety of events including fraud, theft, computer hacking, loss of key staff members, lawsuits, loss of information, terrorism, vandalism and natural disasters. It has been receiving increasingly significant attention from the media, regulators and business executives, as financial scandals keep on surfacing (for example, Enron and Parmalt) and because operational loss events have become the major cause of spectacular business failures (for example, Barings Bank and Long-Term Capital Management). The trend towards greater dependence on technology, more intensive competition, and globalization have left the corporate world more exposed to operational risk than ever before. In a particular reference to the banking industry, Buchelt and Unteregger (2004) argue that the risk of fraud and external events (such as natural disasters) has been around ever since the beginning of banking but it is technological progress that has boosted the potential of operational risk. Likewise, Halperin (2001) argues that "operational risk has traditionally occupied a netherworld below market and credit risk" but "headline-grabbing financial fiascos, decentralized control, the surge in e-commerce and the emergence of new products and business lines have raised its profile".[1]

The detrimental consequences of exposure to operational risk cannot be overstated. Blunden (2003) argues that operational risk is as likely to bring a company to its knees as a market collapse, and in many cases it is clearly within management

[1] Market risk results from fluctuations in financial prices, whereas credit risk arises because of the possibility of default by borrowers. Operational risk, therefore, results from almost everything else. To emphasize the importance of operational risk relative to market risk, Parsley (1996, p 74) wonders "what is the use of having state-of-the-art market risk measurement tools if one rogue trader can bankrupt your institution in a matter of weeks". On similar lines, Kingsley et al. (1998) argue that "the value at risk, risk scenario analysis and risk-adjusted performance measures, on which senior managers now rely in much of the financial industry, are potentially misleading if they ignore operational risk".

control, but it is not fully understood or exploited.[2] While market risk has traditionally caught the attention of financial institutions, operational risk is increasingly considered more seriously, perhaps as being more detrimental than market risk and credit risk. Studies of large operational loss events in the U.S. by Cummins et al. (2006) and Wei (2006) show that a bank (or a financial institution in general) can suffer a market value decline in the days surrounding the announcement of a large loss that is significantly larger than the loss itself.

Many reasons have led to the increasing significance of operational risk but, broadly speaking, some recent developments are conducive to the materialization of operational loss events. These include the growth of e-commerce, mergers and consolidations, the use of automated technology, the growing use of outsourcing arrangements, and the increasing complexity of financial assets and trading procedures. Ong's (2002) top three of the updated list of the "top 10 reasons why so many people are interested in operational risk" are (i) it is sexy, hot and completely nebulous; (ii) people think they have already conquered both market risk and credit risk; and (iii) operational risk is a convenient catch-all "garbage dump" for all kinds of possible risks. The greater interest of the regulators in operational risk (enshrined in the Basel II Accord) can be attributed to the changing risk profile of the financial services sector, which has resulted from the growth in e-business activity and reliance on technology. The Basel Committee on Banking Supervision (BCBS, 1999) expresses the view that operational risk is "sufficiently important for banks to devote the necessary resources to quantify".

The objective of this paper is to survey the recent literature on operational risk. The starting point is to define operational risk, which is not straightforward, then the criteria of classifying operational risk are discussed. The controversy concerning the distinguishing features of operational risk is examined, then we move on to a discussion of the importance of, and the problems associated with, operational risk modeling. Two more sections are devoted to the classification of operational risk models and the examination of selected relevant empirical work. Measuring regulatory capital against operational risk is discussed next before moving on to the topic of operational risk management. The final section contains some final thoughts and concluding remarks.

II. THE DEFINITION OF OPERATIONAL RISK

Allen and Bali (2004) note that defining operational risk is easier said than done, and this is perhaps why it is dubbed "Risk X" by Metcalfe (2003). Likewise, Crouchy (2001) suggests that operational risk is a fuzzy concept because "it is hard to make a clear-cut distinction between operational risk and the normal uncertainties faced by the organization in its daily operations". Following the Barings Bank fiasco, the financial industry started to recognize rogue trading and the like

[2] Moosa (2007a) argues that indicative of the misunderstanding of operational risk are four misconceptions that are commonly found in the academic and professional literature. These misconceptions will be discussed later on in this paper.

as a separate risk category, comprising types of risk that could not be classified as either credit risk or market risk. Hence, it was (and still is) rather tempting to define operational risk negatively as any risk that is not market risk or credit risk. Rao and Dev (2006) argue that "it was not uncommon, five years ago, to consider OR as a residual", and that "everything other than credit risk or market risk was, by default, OR".

However, defining operational risk in this negative manner as a residual item is difficult to work with, in the sense that it cannot be used for the purpose of operational risk measurement. Buchelt and Unteregger (2004) agree with this view, asserting that the negative definition of operational risk is hardly suitable for identifying its scope precisely, although it indicates (to a certain extent) what might be meant. However, Medova and Kyriacou (2001) are convinced that thinking of operational risk as "everything not covered by exposure to credit and market risk" remains prevalent amongst practitioners. This view is also held by Jameson (1998) who indicated that the definition most frequently given in telephone interviews was "every risk source that lies outside the areas covered by market risk and credit risk". Viewing it as a residual is probably a reflection of the lack of understanding and the diversity of operational risk.

Early definitions of operational risk appeared in the published literature of major international banks and other bodies in the 1990s before the Basel Committee adopted its official definition that is currently used for regulatory purposes.[3] The Group of Thirty (1993) defined operational risk as "uncertainty related to losses resulting from inadequate systems or controls, human error or management". The Commonwealth Bank of Australia (1999) came up with the broad definition that operational risk is "all risks other than credit and market risk, which could cause volatility of revenues, expenses and the value of the Bank's business". An early definition of operational risk came up in a seminar at the Federal Reserve Bank of New York when Shepheard-Walwyn and Litterman (1998) characterized operational risk as "a general term that applies to all the risk failures that influence the volatility of the firm's cost structure as opposed to its revenue structure". Note, however, the sharp difference between the last two definitions: in the definition of the Commonwealth Bank of Australia, operational risk impinges upon both the revenue and cost sides of the business, but in the definition of Shepherd-Walwyn and Litterman it affects the cost side only. This contrast gives rise to the question if operational risk is one-sided, which is a controversial issue that will be examined in detail later on. Finally, an early definition that identifies internal and external sources of operational risk has been put forward by Crouchy et al. (1998) who suggested that operational risk is "the risk that external events, or deficiencies in internal controls or information systems, will result in a loss- whether the loss is anticipated to some extent or entirely unexpected".

[3] That is, for the purpose of calculating the regulatory capital against operational risk as stipulated by Pillar 1 of the Basel II Accord.

The earlier definitions of operational risk indicate a lack of agreement on what it is all about and probably a severe degree of misunderstanding of the concept.[4] This is also indicated by some other vague and hardly useful definitions that have been put forward. For example, Tripe (2000) suggested that "operational risk is the risk of operational loss", thus describing water as water. Lopez (2002) suggested that operational risk is "every type of unquantifiable risk faced by a bank", which is the antithesis of measuring regulatory capital against operational risk as required by the Basel II Accord. Crouchy (2001) defines operational risk as "the risk associated with operating a business", which amounts to confusion between operational risk and operations risk.[5]

The most common (and reasonable) definition of operational risk first appeared in Robert Morris Associates et al. (1999), who defined operational risk as "the direct or indirect loss resulting from inadequate or failed internal processes, people and systems, or from external events". Initially, the Basel Committee adopted this definition as it was, but reference to indirect losses was eliminated subsequently for the purpose of quantifying regulatory capital, since these losses are difficult to measure.[6] Thus, the BCBS (2004a) defines operational risk as "the risk arising from inadequate or failed internal processes, people and systems or from external events". This definition, which is based on the underlying causes (sources) of operational risk (or rather operational losses), includes legal risk but excludes business and reputational risk.

The BCBS's definition of operational risk has not been accepted without challenge from academics and practitioners. To start with, Turing (2003) describes the definition as "so broad as to be totally unhelpful". Herring (2002) criticizes the definition on the grounds that it omits altogether basic business risk. Thus, while Turing claims that the definition is too broad, Herring argues that it is rather narrow. But then, Cagan (2001) is critical of the Robert Morris Associates et al. (1999) definition on the grounds that it is narrow, although it is much broader than the BCBS's definition. Instead, Cagan argues strongly for an alternative definition that can do a better job in guiding the data collection and risk management processes. She describes a desirable alternative definition as a definition that "encompasses qualitative concerns and can be used as a best practices signpost".

Hadjiemmanuil (2003) describes the Basel Committee's attempt to define operational risk as being "deeply flawed" because "it is not based on generally accepted understanding of operational risk since there is no consensus on this issue

[4] Writing less than ten years ago, Webb (1999) argued that there was no consensus in the industry on a precise definition of operational risk and that such a consensus was unlikely to emerge in the near future.

[5] Operational risk is a broader term than operations risk, the latter pertaining to the operational risk associated with value-driving operations such as foreign exchange trading and settlement.

[6] The BCBS (2001b) classifies losses into "would be included", "should be included", and "would not be included". The first category includes costs incurred to fix an operational risk problem, payments to third parties and write-downs. The second category includes near misses, latent losses and contingent losses. The third category includes the costs of improvement in controls, preventive action and quality assurance, and investment in new systems.

in the banking industry". He also describes the definition as being "opaque" and "open-ended", because it fails to specify the component factors of operational risk or its relation to other forms of risk. The definition, according to Hadjiemmanuil (2003), leaves unanswered many questions concerning the exact range of loss events that can be attributed to operational failures. Thirlwell (2002) argues that the BCBS's definition represents a "measurable view of operational risk if you are trying to come up with something which is quantifiable, but not good if you think about what causes banks to fail".[7]

Vinella and Jin (2005) come up with yet another definition of operational risk, of which (they claim) the BCBS's definition is a special case. They define operational risk as "the risk that the operation will fail to meet one or more operational performance targets, where the operation can be people, technology, processes, information and the infrastructure supporting business activities". They argue that the BCBS's definition is a special case of their "generalized" definition when the failure to meet an operational performance target results in a direct monetary loss. Again, there is no specific mention of the role of external factors in this definition.

Is the definition of operational risk such a critical issue that triggers so much disagreement? One view is that to measure something, we must first define it. But Lam (2003) argues against being "fussy" about the definition of operational risk as it does not serve any purpose as far as operational risk management is concerned. This is why the first step in his "ten steps to operational risk management" is "define it and move on". Lam's underlying argument is that "many institutions do not get off the ground because too much time is spent trying to come up with the perfect definition of operational risk". The problem, however, lies in the concept of a "perfect definition". One thing that we know is that we have to choose between comprehensiveness (idealism) and pragmatism, with the latter seemingly the better choice.[8]

III. THE CLASSIFICATION OF OPERATIONAL RISK

The classification of operational losses (resulting from exposure to operational risk) can be based on three alternative criteria: the causes of operational failure, the resulting loss events, and the legal and accounting forms of consequential losses. In any episode of operational losses, one has to distinguish among the three dimensions of the episode: the cause, the event and the effect (consequence). For example, external fraud (the event) is caused by people (the cause) and results in a legal liability the effect).[9] If the cause is the criterion of classification, it

[7] It is, therefore, a matter of comprehensiveness versus pragmatism. Should the definition be as comprehensive as possible, or should it be sufficiently narrow to allow quantification?

[8] For a comprehensive listing of the definitions of operational risk and comments on them, see Moosa (2007b).

[9] In accordance with the BCBS's definition of operational risk, which excludes indirect losses, the financial effect of a loss event includes all out-of-pocket expenses associated with an operational loss event but does not include opportunity costs, forgone revenue, or costs related to measures implemented to prevent subsequent operational losses (BCBS, 2003c, p 5).

would include people risk, process risk, system (or technology) risk and external risk. For instance, external risk includes external fraud (such as external money laundering), natural disasters (such as floods) and non-natural disasters (such as arson).

An alternative to the cause as a criterion for classifying operational risk is to use event type. One perceived advantage of an event-based classification is that it makes the operational risk manager's task easier, as losses can be considered to materialize in an event. The BCBS has developed a matrix of seven broad categories of loss events that are further broken down into sub-categories and related activity examples. The categories include internal fraud (such as embezzlement); external fraud (such as forgery); employment practices and workplace safety (such as discrimination); consumers, products and business practices (such as money laundering); damage to physical assets such as terrorism); business disruption and system failure such as power outage); and execution, delivery and product management (such as missing legal documents). This classification is similar to the typology of hazards used by the insurance industry.

Peccia (2003) suggests that a classification based on causes is prone to errors and misunderstanding and that a more appropriate schema is the classification of losses by the area of impact on the results, as the ultimate objectives is to explain the volatility of earnings arising from the direct impact of losses on the financial results. The problem is that the causes and effects of operational loss events are often confused. Operational risk types, such as human risk and system risk, constitute the cause (not the outcome) of risk, as the latter is the monetary consequence. However, it will be argued later that classifying loss events by cause rather than consequence makes it easier to distinguish operational loss events from market and credit loss events.

IV. THE DISTINGUISHING FEATURES OF OPERATIONAL RISK

Having gone through the classification of operational risk, it seems that its first feature is bound to be diversity. The diversity of operational risk makes it difficult to limit the number of dimensions required to describe it. Buchelt and Untregger (2004) describe operational risk as "a highly varied and interrelated set of risks with different origins". Milligan (2004) describes operational risk as the risk that "includes everything from slip-and-fall to the spectacular collapse of Barings Bank". Likewise, *The Economist* (2003) describes operational risk as "the risk of all manner of mishaps and foul-ups, from a lost document to a bomb blast". The BCBS (2003c, p 6.) implies the diversity of operational risk by stating that "it can occur in any activity, function, or unit of the institution". Hoffman (1998) implicitly recognizes the characteristic of diversity, arguing that operational risk "transcends all business lines, and span front-, middle- and back-office operations", and that it is "broader that the realm of conventionally insured risks". It would be rather difficult to argue against the proposition that diversity is indeed a distinguishing feature of operational risk.

de Koker (2006) identifies two features of operational risk that distinguish it from credit risk (and market risk). The first is that there is no simple equivalent in the case of operational risk to the concept of risk exposure, in the sense that operational risk is not related closely to any financial indicator. The second of these features is that the distribution of operational risk is more fat-tailed than that of credit risk. Rao and Dev (2006) identify another distinguishing feature of operational risk that pertains to its management, arguing that (unlike credit risk and market risk) operational risk depends more strongly on the culture of the business units. Yet another characteristic is identified by Kaiser and Kohne (2006) who argue that operational risk is more endogenous than market risk and credit risk, which means that the opportunities from risk mitigation are often bigger in the case of operational risk.

While there is no disagreement on the features presented so far, another three features are controversial, including the features of being one-sided, idiosyncratic and indistinguishable from other kinds of risk. To start with, it is typically suggested that operational risk is "one-sided" in the sense that it is an undesired by-product of daily business operations, which implies that the risk-return trade off associated with market risk has no equivalence in the case of operational risk. In his critique of the Basel II Accord, Herring (2002) describes operational risk as being "downside risk". Crouchy et al. (2004) suggest a similar idea, arguing that "by assuming more operational risk, a bank does not expect to yield more on average" and that "operational risk usually destroys value for all claimholders". A similar idea is put forward by Buchmuller et al. (2006) who suggest that "operational risk is usually not taken to create a profit". Lewis and Lantsman (2005) argue that operational risk is one-sided because "there is a one-sided probability of loss or no loss". Alexander (2003b) distinguishes between operational risk, on the one hand, and market risk and credit risk, on the other, by suggesting that operational risk is mostly on the cost side, whereas the revenue side is associated with market risk and/or credit risk. Crouchy et al. (2004) take it for granted that "there is no reward in the form of higher returns from bearing operational risk". As we have seen, the definition of operational risk suggested by Shepheard-Walwyn and Litterman (1998) and the Commonwealth Bank of Australia (1999) indicate that operational risk is one-sided and two-sided, respectively. All of these views mean that while it is possible to obtain a higher rate of return by assuming more market or credit risk, this is not possible with operational risk.

The view that operational risk is one-sided is disputable because the underlying arguments are difficult to buy. By taking on operational risk, firms earn income while being exposed to the risk of incurring operational losses if and when a loss event materializes. No one can dispute the possibility of operational losses in any of the business lines suggested by the Basel Committee, such as underwriting (corporate finance), investment advice (retail banking) and trade finance (commercial banking). Likewise, no one can dispute the proposition that banks expose themselves to operational risk in these business lines because the underlying activities generate income. Why would a bank provide custodial services, for example, given

that this activity involves operational risk? The answer is simple: this activity generates fee income. Hence, it is bizarre to claim that operational risk is not taken for profit.

The argument that operational risk leads to loss or no-loss situations can be demonstrated to be invalid by considering examples from outside the world of business. People accept to be exposed to loss or no-loss situations because they believe that some risks are worth taking, given the potential reward. We take planes although we might find ourselves in loss or no-loss situations when the plane is hijacked or, for some reason, it loses its tail fin (almost certainly a loss outcome in the second case). People still work for banks, knowing that they may find themselves in loss or no-loss situations when armed robbers take hold of a bank. We still take cruise ships, exposing ourselves to situations where we might find ourselves stranded in the middle of the ocean, contemplating the possibility of being eaten by sharks. The same applies to people practicing extreme sports, and just think about those who run with the bulls in the narrow streets of a small Spanish town every summer (lunacy or thrill seeking, involving risk-reward trade off?). In all cases, it is a matter of choice: we deliberately take on risk for the sake of potential reward, and in this sense risk cannot be one-sided. Being in a loss or no-loss situation is the materialization of the unfavorable outcome or the bad side of risk. This argument is even more compelling with respect to the business world. Firms take on operational risk in their day-to-day operations because these operations generate income. Increasing the size of operations and going into new operations lead to more operational risk and more return. Is not this genuine risk-return trade-off?

Turning to the proposition that operational risk is idiosyncratic (in the sense that when it hits one firm, it does not spread to other firms), Lewis and Lantsman (2005) describe operational risk as being idiosyncratic because "the risk of loss tends to be uncorrelated with general market forces". This, the argument goes, is not a characteristic of market risk and credit risk: a market downturn affects all firms, and a default by the customers of one firm affects its ability to meet its obligations to other firms. Danielsson et al. (2001) use the proposition that operational risk is idiosyncratic to criticize the Basel II Accord, arguing that there is no need to regulate operational risk because it is idiosyncratic.

The view that operational risk is idiosyncratic is rather strange, because it implies the following. When a bank incurs losses from loan default or market downturn, its ability to meet its obligations to other banks will be affected, but this is not the case when a bank incurs losses because of the unauthorized activities of a rogue trader. Does this mean that other banks were not affected by the spectacular operational failures of Barings Bank in 1995 and Long-Term Capital Management in 1998?[10] And what about the 1974 (operational) failure of Bankhaus Herstatt, which has led to the establishment of the Basel Committee on Banking Supervision whose

[10] The operational failure of Long-Term Capital Management attracted the attention of the Federal Reserve because of concern about its systemic effects.

activities have contributed to the widespread interest in operational risk? The liquidation of Bankhaus Herstatt adversely affected other banks as it failed to meet its obligations to them. It is true that not all bank failures are systemic, as pointed out by the BCBS (2004b), stating explicitly that apart from the Herstatt case, German bank failures have not been systemic in the sense that they affected individual banks only. But this applies to market risk and credit risk as much as it applies to operational risk. Some credit and market loss events are systemic, but others are not so. Then, one has to remember that bank regulation aims at avoiding catastrophic events with adverse ramifications for other banks. The very requirement of Basel II that banks should hold regulatory capital to protect themselves from rare but fatal operational loss events is indicative of the belief of the Basel Committee that operational risk can be systemic.

The view put forward by Lewis and Lantsman (2005) that, unlike operational risk, credit risk and market risk are systemic because they are related to the state of the economy is also disputable because operational risk too is related to the state of the economy. The underlying idea here is that when the economy is in recession, financial markets decline while the incident of default rises, which means that all firms will suffer the consequences. But this proposition is as valid for operational risk as it is valid for market risk and credit risk. When the economy is in recession, there is more of the risk of legal action associated with employee termination and counterparty bankruptcies. On the other hand, incidents of credit card fraud become more frequent when the economy is booming, as people indulge in credit card-based shopping sprees. Allen and Bali (2004) make the general proposition that operational loss events incorporate cyclical components that are correlated with the systematic risk factors such as macroeconomic fluctuations. Allen and Turan (2007) use equity returns to present evidence on the cyclical components of operational risk. Operational risk is not idiosyncratic because these phenomena, which are related to the macroeconomy, affect all firms.[11]

Another proclaimed feature of operational risk is that it is not distinguishable from market risk and credit risk, in the sense that it may be difficult to separate the loss events attributed to the three kinds of risk. For example, a trader takes a short position on an asset just before a market upturn, which leads to trading losses when the price of the asset rises. This may or may not be a market risk loss event. If the trader takes the position by following the specified trading guidelines, then this is a purely market risk loss event. But if the trader takes this position when the guidelines do not allow short positions on the asset, then this is an operational risk loss event. Likewise, Kaiser and Kohne (2006) argue that "a large number of losses in the credit area cannot be considered as genuine credit risk, as they result from events in the whole area of operational risk". As an example of cases like that, they mention default cases in which the process leading the lending decision is not performed correctly.

[11] Moosa (2007a) argues that operational risk will not be idiosyncratic in the presence of groupthink.

Whether or not an event is to be classified as an operational loss event is (or should be) determined by the causes rather than the consequences of the event. Rebonato (2007, p 88) argues that although trading positions were often part of the chain of events that led to the most notorious losses, they are more often than not "accessories to the crime rather than the ultimate culprits". Kaiser and Kohne (2006) argue that the assignment of loss events to risk types "should basically be driven on the basis of causes". In the Barings case, for example, it was an adverse market move that generated the loss but the cause was operational risk (fraud and inadequate supervision). The distinguishing factor between pure market and credit losses and those linked to operational risk must be the cause (for example, whether or not there is a breach of trading guidelines).[12] Distinguishing operational loss events from credit and market loss events is not as difficult as it is typically portrayed.

V. OPERATIONAL RISK MODELING: IMPORTANCE AND PROBLEMS

Operational risk models encompass a variety of statistical and econometric models designed to measure the regulatory and economic capital to be held against operational risk, as well as models designed to study its causes and consequences. Peccia (2003) argues that modeling operational risk has become important because the environment in which banks operate has changed dramatically. Operational risk modeling is needed to provide the management of a firm with a tool for making better decisions about the desirable level of operational risk to take. Bocker and Kluppelberg (2005) suggest that the only feasible way to manage operational risk successfully is by identifying and minimizing it, which requires the development of adequate quantification techniques. Fujii (2005) points out that quantifying operational risk is a prerequisite for the formulation of an effective economic capital framework. Consiglio and Zenois (2003) emphasize the importance of operational risk models by attributing some widely-publicized loss events to the use of inadequate models rather than anything else. Actually, Giraud (2005) attributes the collapse of Long-Term Capital Management in large part to "model bias in the risk management process". Holmes (2003) argues that even if operational risk modeling is not scientific or reliable, it may force firms to carry more capital and encourage better behavior.

There is also the regulatory requirement of the Basel II Accord that an operational risk model is needed to be in a position to use the advanced measurement approach (AMA), which is attractive because it presumably results in lower

[12] This is why the cause of the loss is a better classification criterion than either the event or the effect. Kaiser and Kohne (2006) argue against the complete assignment of losses to exactly one type of risk, because it is "neither correct nor useful". Instead, they argue for the split of losses amongst different kinds of risk. For example, the portion of credit losses resulting from inadequate collateral management should be assigned to operational risk. The problem here is how to estimate this portion. Moreover, if sound collateral management prevents a would-be defaulter from obtaining a loan, then bad collateral management would be the only cause for the loss, in which case this default would result in a pure operational loss.

regulatory capital than under the other two approaches (the basic indicators approach and the standardized approach). Indeed, it is arguable that one advantage of operational risk modeling is that the resulting models allow the firm to meet the regulatory requirements.

Not everyone is so enthusiastic about the relevance of operational risk modeling to operational risk management, however. Rebonato (2007, p xvi) argues that "although the quantitative approach remains the high route to risk management, a lot of very effective risk management can be done with a much simpler approach", describing the latter as being "a measurable and meaningful approximation to the quantitatively correct answer". In particular, Rebonato is skeptical about the ability of risk managers to move from the probabilistic assessment of risk to decisions. He also argues against the use of internal models for the purpose of meeting regulatory requirements. Likewise, Herring (2002) argues that operational risk models are insufficiently reliable to replicate the approach used with market risk to the case of operational risk. This point has also been made by the Shadow Financial Regulatory Committee (2001), Altman and Saunders (2001) and Llewellyn (2001). Currie (2004) lists the potentially unintended consequences arising from the use of operational risk models for practical risk management purposes, including (i) false reliance, (ii) management of the model rather than reality, (iii) misdirected focus, (iv) misdirected resources, (v) discouragement of the "whistle-blowers", and (vi) blissful ignorance.

It is perhaps the case that objections to the use of the quantitative approach to operational risk management are motivated by the problems encountered by any endeavor to model operational risk. Referring to the modeling techniques suggested by the Basel Committee's advanced measurement approach, Davis (2005, p 1) argues that the implementation of this approach "could easily turn into a nightmare". Hughes (2005) expresses the view that "the challenge on the operational risk side has turned out to be vastly more complex and elusive than originally envisaged". To start with, finding a proper and universally-accepted definition for this kind of risk, is problematical as we have seen. But even if an acceptable definition were available, there are other serious problems.

A serious problem is that of data availability (or rather unavailability). Muzzy (2003) highlights this problem by arguing that "anyone venturing into operational risk management has quickly learned that the process is doomed without robust data". This is because there is in general an absence of reliable internal operational loss data, but that is not all. Publicly-available operational loss data pose unique modeling challenges, the most important of which is that not all losses are reported in public (which means that they will not appear on publicly-available external databases).[13] de Fontnouvelle et al. (2006) argue that if the probability that an operational loss is reported increases as the loss amount increases, there will be a

[13] External operational loss databases report operational loss events that make it to the media, but these represent a tiny fraction of the total number of operational loss events experienced by a typical bank. Credit card fraud is probably the most frequent loss event experienced by banks (see, for example, BCBS, 2003a), but these are not reported in the media, because most of them are not high-profile events.

disproportionate number of very large losses relative to smaller losses appearing in external databases.[14] Allen and Bali (2004) suggest that operational risk databases tend to suffer from underrepresentation of low-frequency, high-severity events. Haas and Kaiser (2004) note that low-frequency, high-severity events, which by definition are much less likely to occur, are often kept confidential (therefore, unreported or misclassified under credit or market risk losses).

One solution to the data availability problem is to augment internal data with external data on the operational losses incurred by other firms. Frachot and Roncalli (2002) discuss why and how internal and external operational loss data are mixed by distinguishing between frequency data and severity data. According to Rao and Dev (2006), data mixing involves two issues: scaling (to account for differences in size) and appropriateness (to account for differences in business structure).[15] While Wei (2007) argues that external data are extremely useful for rare events, making it possible to model the tail distribution, Frachot and Roncalli (2002) put forward the view that mixing internal and external severity data is "almost an impossible task" because no one knows which data generating process is used to draw external severity data. They further argue that merging internal and external data gives spurious results that tend to be over-optimistic regarding the actual severity distribution. Resorting to soft data obtained from scenario analysis and scorecards does not solve the problem, as there is no means of adjusting the calculations for qualitative factors except in "an ad hoc manner" and because such a procedure does not have a solid theoretical foundation (Rao and Dev, 2006). A similar view is held by Peccia (2004) who refers to the use of external data and scenario analysis as "ad hoc patches".

Another problem associated with operational risk modeling arises from the cyclicality of risk and loss events. Allen and Bali (2004) argue that extrapolating the past to measure future risk may be flawed if there are cyclical factors that impact operational risk measures. Although historical data on operational risk gathered during an economic expansion may not be relevant for a period of recession, it is a typical practice to ignore cyclical factors and extend an unadjusted trend line into the future. Allen and Bali (2004) suggest that the cyclical components of operational loss events are correlated with macroeconomic fluctuations, while Allen and Turan (2007) provide evidence on the presence of cyclical components of operational risk.

Yet another problem is the assumption to be made about the correlation of operational loss events. Frachot, Roncalli and Salmon (2004) cast doubt on the validity of the proposition that operational risk losses occur simultaneously, as implied by the Basel II Accord, describing it as being "rather dubious and hardly supported

[14] See Moosa (2007b) on internal and external operational loss databases.

[15] The issues of scaling and appropriateness are dealt with by Na et al. (2005) and Peizer (2003). Na et al. propose a scaling mechanism that can be used to mix internal and external data. Peizier, however, casts considerable doubt on the usefulness of external operational loss data by wondering about the relevance of an exceptional loss incurred by an Indian broker to the operational risk distribution of an asset manager based in Manhattan.

by empirical evidence". Kaiser and Kohne (2006) argue that this assumption is particularly troublesome because a simple summation of high percentile VARs implies the simultaneous occurrence of several worst-case scenarios. The problem, however, is that it is difficult to assess the level of correlation between different risk types and/or business units because of the lack of historical data. Powojowski et al. (2002) express the view that although some correlation exists between operational losses, modeling this correlation is not an easy task. This problem invites subjectivity and bias if banks wish to minimize their regulatory capital against operational risk.

VI. THE CLASSIFICATION OF OPERATIONAL RISK MODELS

In general, operational risk models are classified into top-down models and bottom-up models, both of which rely on historical data. Bottom-up models are based on an analysis of loss events in individual processes, whereas top-down models start at the firm level, moving down to the business lines. Haubenstock and Hardin (2003) argue that the bottom-up approach is preferred because of the degree of subjectivity in the allocation process and the lack of a good risk proxy across businesses. Likewise, Gelderman et al. (2006) argue that a limitation of the top-down approach is that it does not indicate clearly how to manage and control the outcomes of the model, and this is why the bottom-up approach tends to be more prevalent in practice. Allen and Bali (2004) argue that many of the bottom-up models that are designed to measure operational risk from a cost perspective can produce spurious results. For example, if a firm institutes operational risk managerial controls, costs will generally increase, in which case the estimates generated by a bottom-up model would indicate increased risk when it should actually decrease if the controls are effective. Moreover, bottom-up models often suffer from overdisaggregation in that they break production processes into individual steps that may obscure the broader picture. Finally, bottom-up models rely on the subjective data provided by employees who are under scrutiny and therefore have little incentive to be forthcoming. They further note that bottom-up models may be appropriate for the purpose of risk diagnostics and the design of internal managerial controls, whereas top-down models may be effective in estimating economic capital requirements. Currie (2004) calls for the concurrent use of top-down and bottom-up models to calculate operational risk capital requirements.

Smithson and Song (2004) classify operational risk models under three approaches: (i) the process approach, (ii) the factor approach, and (iii) the actuarial approach. In the process approach, the focus is on the individual processes that make up operational activities, which means that models falling under the process approach are necessarily bottom-up models. This approach encompasses causal models, statistical quality control and reliability analysis, connectivity analysis, Bayesian belief networks, fuzzy logic, and system dynamics. In causal networks, historical data are used to work out statistics for the behavior of the components in the past, which makes it possible to identify the problem areas. Statistical quality

control and reliability analysis, which is rather similar to causal networks, is used widely to evaluate manufacturing processes. In connectivity analysis, the emphasis is on the connections between the components of the process.

The second approach is the factor approach, whereby an attempt is made to identify the significant determinants of operational risk, either at the firm level or lower levels (individual business lines or processes). Hence, operational risk is estimated as

$$OR = \alpha + \sum_{i=1}^{m} \beta_i F_i + \varepsilon \tag{1}$$

where F_i is risk factor i. The factor approach covers risk indicators, CAPM-like models and predictive models. In the risk indicators approach, a regression-based technique is used to identify risk factors such as the volume of operations, audit ratings and employee turnover. CAPM-like models, which are also known as arbitrage pricing models and economic pricing models, are used to relate the volatility of returns to operational risk factors. In predictive models, discriminant analysis and similar techniques are used to identify the factors that lead to operational losses.

The third approach is the actuarial approach, whose focus is the loss distribution associated with operational risk. Wei (2007) argues that the actuarial approach seems to be the natural choice to quantify operational risk by estimating the frequency and severity distributions separately.[16] This approach, which will be described in more detail later on, covers the following techniques: (i) the empirical loss distributions technique, (ii) the parameterized explicit distributions approach, and (iii) the extreme value theory (EVT).

VII. EMPIRICAL STUDIES OF OPERATIONAL RISK

The problem of data discussed previously has undoubtedly restricted the ability of researchers to conduct empirical studies on the measurement, causes and consequences of operational risk. This point is made explicit by Wei (2007) who suggested that "quantification of operational risk has been hindered by the lack of internal and external data on operational losses". In this section, a selection of these studies are reviewed.

To deal with the data problem, Allen and Bali (2004) estimate an operational risk model for individual financial institutions using a monthly time series of stock returns over the period 1973–2003. The model is represented by the following OLS regression

[16] Wei (2007) argues for the actuarial approach in preference to other approaches. For example, he suggested that Bayesian networks (proposed by Alexander (2003a), Cruz (2003b), and Giudici and Bilotta (2004)) introduce subjectivity and that copula-based models (proposed by Bee (2005) and Embrechts et al. (2003)) require abundant data.

$$r_t = \alpha_{0,t} + \alpha_{1,t}\Delta x_{1t} + \cdots + \alpha_{22,t}\Delta x_{22t} + \beta_t r_{t-1} + \sum_{i=1}^{4} \gamma_{i,t} FF_{it} + \sum_{i=1}^{3} \pi_{i,t} R_{i,t} + \varepsilon_t \quad (2)$$

where r_t and r_{t-1} are the monthly current and lagged equity returns; Δx_{it} ($i = 1, 2, \ldots, 22$) is the first difference of the 22 variables used to represent credit risk, interest rate risk, exchange rate risk and market risk; FF_{it} represent the three Fama-French (1993) factors as well as a momentum factor; and R_{it} represents three alternative industry factors measured as the average monthly return for each industry sector. The residual term from equation (2) is taken to be a measure of operational risk. The coefficients were estimated using a rolling window of 50 months to yield results indicating that the ratio of the residual (operational risk) to total stock return is 17.7%, with considerable monthly variance. This finding suggests that financial firms have considerable levels of residual operational risk exposure that has been left relatively unmanaged.

de Fontnouvelle et al. (2006) address the problem of sample selection bias using an econometric model in which the truncation point for each loss (that is, the value below which the loss is not reported) is modeled as an unobserved random variable. By using two external operational loss databases to estimate the loss distribution and estimate the capital charge, they conclude that the regulatory capital held against operational risk often exceeds that held against market risk. They also conclude that supplementing internal data with external data on extremely large events could result in a significant improvement in operational risk models.

de Fontnouvelle et al. (2004) used loss data covering six large internationally-active banks as part of the BCBS's (2003a) operational risk loss data exercise to find out if the regularities in the loss data make consistent modeling of operational losses possible. Their results turned out to be consistent with the publicly reported operational risk capital estimates produced by banks' internal economic capital models. Moscadelli (2005) analyzed data from the BCBS's exercise, performing a thorough comparison of traditional full-data analyses and extreme value methods for estimating loss severity distributions. He found that extreme value theory outperformed the traditional methods in all of the eight business lines proposed by the BCBS. He also found the severity distribution to be very heavy-tailed and that a substantial difference exists in loss severity across business lines. In a similar study, Wei (2007) utilized data from the OpVar database to estimate the aggregate tail operational risk exposure, implementing a Bayesian approach to estimate the frequency distribution, while estimating the severity distribution by introducing a covariate. He concluded that "the main driving force of the capital requirement is the tail distribution and the size of a bank".

In another study, Wei (2003) examined operational risk in the insurance industry. By using data from the OpVar operational loss database, he found results indicating that operational loss events have a significantly negative effect on the market value

of the affected firms and that the effect of operational losses goes beyond the firm experiencing the loss event. The conclusion derived from this study is that "the significant damage of market values of both the insurers and the insurance industry caused by operational losses should provide an incentive for operational risk management in the U.S. insurance industry".

In a more recent study, Wei (2006) examined the impact of operational loss events on the market value of announcing and non-announcing U.S. financial institutions using data from the OpVar database. The results reveal significantly negative impact of the announcement of operational losses on stock prices. He also found that the declines in market value to be of a larger magnitude than the operational losses causing them, which supports the conjecture put forward by Cummins et al. (2006). A significant contagion effect was also detected. By using data from the same source, Cummins et al. (2006) conducted an event study of the impact of operational loss events on the market values of U.S. banks and insurance companies, obtaining similar results to those obtained by Wei (2006). They found losses to be proportionately larger for institutions with higher Tobin's Q ratios, which implies that operational losses are more serious for firms with strong growth prospects.

VIII. MEASURING REGULATORY CAPITAL AGAINST OPERATIONAL RISK

The Basel II Accord suggests three methods for calculating regulatory operational risk capital (the capital charge): (i) the basic indicators approach (BIA), (ii) the standardized approach (STA), and (iii) the advanced measurement approach (AMA). As banks become more sophisticated, they are encouraged to move along the spectrum of available approaches, enticed by the prospects of holding a lower capital charge under the AMA. However, the use of the AMA is conditional upon the satisfaction of certain eligibility criteria, as outlined in BCBS (2004a).

No eligibility criteria are required as a prerequisite for using the BIA because this approach represents the "default position", as it is designed for small domestic banks. According to this approach, banks must hold capital against operational risk that is equal to the average of the previous three years of a fixed percentage (α) of positive annual gross income, which means that negative gross income figures must be excluded. Hence

$$K = \frac{\alpha \sum_{i=1}^{n} Y_i}{n} \tag{3}$$

where K is the capital charge, Y is positive gross income over the previous three years and n is the number of the previous three years for which gross income is positive. The parameter α is determined by the Basel Committee.

Accepting the proposition that some financial activities are more exposed than others to operational risk (at least in relation to gross income), the BCBS divides

banks' activities into eight business lines: corporate finance, trading and sales, retail banking, commercial banking, payment and settlement, agency services, asset management and retail brokerage. Within each business line, gross income is taken to be a proxy for the scale of the business operation and hence a likely measure of the extent of operational risk (as in the BIA).[17] The capital charge for each business line is calculated by multiplying gross income by a factor (β) that is assigned to each business line. The total capital charge is calculated as a three-year average of the simple sum of capital charges of individual business lines in each year. Hence

$$K = \frac{\alpha \sum_{t=1}^{3} max\left[\sum_{j=1}^{8} \beta_j Y_j, 0\right]}{3} \tag{4}$$

where β_j is set by the Basel Committee to relate the level of required capital to the level of gross income for business line j.

The BCBS (2004a) suggests that if banks move from the BIA along a continuum towards the AMA, they will be rewarded with a lower capital charge.[18] The regulatory capital requirement is calculated by using the bank's internal operational risk model. One of the objectives of the Basel II Accord is to align regulatory capital with the economic capital determined by the banks' internal models, which can be achieved by using the AMA.[19] Under this approach, banks must quantify operational risk capital requirements for seven types of risk and eight business lines, a total of 56 separate cells, where a cell is a combination of business line and event type. These estimates are aggregated to obtain a total operational risk capital requirement for the bank as a whole, thus ignoring correlation.

The problem is that it is not quite clear what the AMA comprises. For example, Chapelle et al. (2004) define the AMA as encompassing "all measurement techniques that lead to a precise measurement of the exposure of each business line of a financial institution to each category of operational loss event". It is sometimes described as encompassing three versions: the loss distribution approach (LDA),

[17] Using gross income as an indicator of operational risk has been criticized. For example, Herring (2002) argues that gross income has no tenuous link to operational risk, but Dowd (2003) argues that it is the least bad option. Although the BCBS (2001c) has suggested other indicators (such as annual average assets, annual settlement throughput and total funds under management), the Basel II document (BCBS, 2004a) defines regulatory capital in terms of gross income only. When an indicator other than income is used, this is sometimes known as the alternative standardized approach (Moosa, 2007b).

[18] This is indeed a problematical feature of Basel II because only large, internationally-active banks will be allowed to use the AMA. One reason why the U.S. has decided to delay the implementation of Basel II is complaints by small U.S. banks that the Accord would put them in a weak competitive position relative to larger banks.

[19] Economic capital is the amount of capital that a firm (or a unit within the firm) must hold to protect itself with a chosen level of certainty (confidence level) against insolvency due to unexpected losses over a given period of time (for example, one year). Regulatory capital, on the other hand, is the capital prescribed by the regulator. Economic capital is typically determined by an internal model of the underlying firm.

the scenario-based approach (SBA) and the scorecard approach (SCA). The basis of classification here is the nature of the data required to implement the procedure: while the LDA depends on historical data (hence, it is backward-looking), the other two approaches are forward-looking because hypothetical futuristic data is collected from "expert opinion" via scenario analysis and scorecards. For example, Andres and van der Brink (2004) list the three approaches as separate versions of the AMA and go on to illustrate a scenario-based AMA. Likewise, Kuhn and Neu (2004) describe the AMA as being dependent on internal or external data or expert knowledge, meaning that they are separate approaches.

On the other hand, it is sometimes claimed that the scenario-based and scorecard approaches are not really separate versions of the AMA, but rather means for collecting data to supplement the historical data used with the LDA. For example, Currie (2004) describes the AMA as involving the estimation of unexpected losses based on a combination of internal and external data, scenario analysis and bank-specific environment and internal controls. Reference to scenario analysis and internal controls implies that the scenario-based approach and the scorecard approach are used to collect data to supplement the internal and external data used in the LDA. Likewise, Kalyvas et al. (2006, pp 123–124) argue that the AMA measurement system must take into account internal data, external data, scenario analysis, and internal controls and business environment factors. Haubenstock and Hardin (2003) outline the steps involved in the LDA, which is used to calculate the capital charge from internal and external data. Then they list some additional steps, including the development of scenarios for stress testing and incorporating scorecards and risk indicators. The implication here is that the scenario-based approach and the scorecard approach are used to adjust the capital charge calculated by using the LDA. Reynolds and Syer (2003) mention, as separate approaches, the IMA, LDA and SCA, but not the SBA, and the same idea is expressed by Kuhn and Neu (2005). This is in contrast with Fujii (2005) who explains how the "scenario-based advanced management approach (AMA) provides solutions to some of the problems [of the LDA]". Chapelle et al. (2004) argue that while the AMA could encompass any proprietary model, the most popular AMA methodology is by far the LDA.[20]

The Basel Committee seems to accept the two possibilities of regarding scenario-based analysis as a separate version of the AMA and a means of collecting supplementary data for the LDA. In BCBS (2003c), it is stated that scenario-based analysis may be used as an input or may form the basis of an operational risk analytical framework, particularly when internal data, external data and the assessment of the business environment and internal controls are inadequate (that is, when the SBA and SCA are unimplementable). But only the view that the SBA and SCA are used as supplementary procedures is expressed in the 2001 working paper on the regulator treatment of operational risk (BCBS, 2001c). This document describes a

[20] It is not clear how the LDA is by far the most popular methodology, given that it is initially unavailable for regulatory purposes and that it is extremely difficult to implement.

sound (operational) risk management system as involving the use of internal data, relevant external data, scenario analysis and factors reflecting the business environment and internal control system. This is Currie's description of the AMA and also that of Giudici (2004) who interprets this statement as implying that the AMA should take into account internal and external data, scenario-based expert opinion and causal factors reflecting the business environment and control systems. Alternatively, Chernobai and Rachev (2004) argue that the Basel Committee (BCBS, 2001d) suggests five methodologies for the measurement of regulatory capital: (i) the basic indicators approach, (ii) the standardized approach, (iii) the internal measurement approach, (iv) the scorecard approach, and (v) the loss distribution approach. But no matter whether the scorecard and scenario based approaches are separate versions of the AMA or just a means for collecting supplementary data, they both suffer from the problem of subjectivity and bias because the data are collected from the so-called "expert opinion". Rebonato (2007, p 45) argues that if an expert is held responsible when things go badly under his watch, but not correspondingly rewarded if things turn out to be better than expected, it is not difficult to imagine in which direction his predictions will be biased.

In BCBS (2001b), two versions of the AMA are proposed, the LDA and the internal measurement approach (IMA), which is the same classification used by Kalyvas et al. (2006).[21] The difference between the two approaches is that the IMA is used to estimate unexpected loss by relating it to expected loss, whereas the LDA is used to estimate unexpected loss from the total loss distribution. The BCBS (2001b) makes it clear that the loss distribution approach "will not be available at the outset of the New Basel Capital Accord". Initially, the AMA will take the form of the IMA, under which the capital charge for cell ij will be calculated as

$$K = \sum_{i=1}^{8} \sum_{j=1}^{7} \gamma_{ij} E_{ij} P_{ij} L_{ij} \tag{5}$$

where $i = 1, 2, \ldots, 8$ represent business lines and $j = 1, 2, \ldots, 7$ represents event type, E is an exposure indicator, P is the probability of a loss event and L is the loss given event. Thus $E_{ij}P_{ij}L_{ij}$ is the expected loss in cell ij. The parameter γ_{ij} is used to translate expected loss into unexpected loss, such that the capital charge is equal to the unexpected loss (the maximum amount of loss per holding period within a certain confidence interval).[22] The summation over business lines and event types indicates that no allowance is made for correlation because of the

[21] Alexander (2003b) argues that the IMA is rooted in the LDA, in the sense that it provides an analytical solution whereas the LDA uses Monte Carlo simulation. Likewise, Frachot et al. (2001) view the IMA as "an attempt to mimic LDA through a simplified, easy-to-implement way".

[22] The parameter γ will be provided by the regulator for each business line/event type. E is a measure of exposure to operational risk, which the Basel Committee will standradise on the basis of the individual bank data. P and L, which will be provided by banks on the basis of internal models, are respectively the probability of occurrence of a loss event and the proportion of the exposure that will be lost if and when a loss event materializes.

difficulty of estimating a 56×56 correlation matrix. To capture the risk profile of an individual bank which is invariably different from that of the industry as a whole), equation (5) is modified to

$$K = \sum_{i=1}^{8} \sum_{j=1}^{7} \gamma_{ij} E_{ij} P_{ij} L_{ij} R_{ij} \tag{6}$$

where R is the risk profile index (1 for the industry). For a bank with a fat tail distribution, $R > 1$ and vice versa.

The loss distribution approach is described by the BCBS (2001b) as being a "more advanced version of the internal methodology", but the Basel Committee makes it clear that this approach will not be used at this stage. If and when (if at all) it is used, two provisions are designed to make it easier to implement: (i) correlations will not be considered, and (ii) the structure of the business lines and event types will be determined by the bank itself.[23] This approach is different from the IMA in that it allows a direct estimation of unexpected losses without specifying the gamma factor.

Under the LDA, the total loss distribution, from which the capital charge is calculated, is obtained by combining (by using Monte Carlo simulations) the loss frequency distribution and the loss severity distribution. The distributions are selected and parameterized on the basis of historical data and sometimes supplemented by scenario analysis and expert opinion. Typically, the choice falls on the Poisson distribution for frequency and some thick tail distribution (such as the lognormal and gamma distributions) for severity. The capital charge for cell ij is then calculated as being equal to the unexpected loss, which is the difference between the 99.9$^{\text{th}}$ percentile and the mean of the distribution, which means

$$\Pr(L > OpVAR + EL) = 0.001 \tag{7}$$

where EL is the expected loss (the mean of the distribution). This definition appears to be what is embodied in the Basel II Accord as long as the underlying bank can demonstrate that it has adequately provided for expected losses. This is because one of the quantitative standards that the users of the AMA must satisfy is that regulatory capital must be calculated as the sum of the expected loss and unexpected loss unless it can be demonstrated that the expected loss is adequately captured in the internal business practices, in which case regulatory capital is meant to cover the unexpected loss only.[24]

[23] One of the proclaimed advantages of the AMA is that it results in lower capital charges than the basic indicators approach and standardized approach. Failure to allow for the effect of correlation produces higher capital charges than otherwise. There seems to be some contradiction here unless there are other reasons why the AMA would produce lower capital charges. This issue is discussed in detail by Moosa (2007c), who concludes that the subjectivity of the AMA is the most likely reason for this outcome.

[24] Frachot, Moudoulaud and Roncalli (2004) argue that there is ambiguity about the definition of the capital charge, hence suggesting two other definitions: (i) the 99.9$^{\text{th}}$ percentile of the total loss

If correlation among risk categories is assumed to be perfect (that is, losses occur at the same time) the capital charge for the whole firm is calculated by adding up the individual capital charges for each risk type/business line combination. This is what will be done initially if and when the LDA is adopted for regulatory purposes (although it can be used for the calculation of economic capital). On the other extreme, the assumption of zero correlation among risk categories (that is, they are independent of each other) means that the firm-wide capital charge is calculated by compounding all distribution pairs into a single loss distribution for the firm. This is done by calculating the total loss produced by each iteration of the Monte Carlo simulations.

In between the two extremes of assuming perfect correlation and zero correlation is the alternative of allowing for the explicit modeling of correlations between the occurrences of loss events. This indeed is the most difficult procedure. The problem here is that correlation, which is a simple form of the first moment of the joint density of two random variables, does not capture all forms of dependence between the two variables (it is a measure of linear association between the two variables). Another problem with correlation is that it varies over time. This is why it is more appropriate for this purpose to employ the copula, which is used to combine two or more distributions to obtain a joint distribution with a prespecified form of dependence.[25]

In general, the capital charge (that is, regulatory capital or the regulatory capital requirement) is calculated from the total loss distribution by using the concept of value at risk (VAR). However, the use of the concept of value at risk to measure operational risk capital charges has not escaped criticism. For example, Hubner et al. (2003) argue against using a "VAR-like figure" to measure operational risk, stipulating that although VAR models have been developed for operational risk, questions remain about the interpretation of the results. Another problem is that VAR figures provide an indication of the amount of risk but not of its form (for example, legal risk as opposed to technology risk). Moreover, the estimates of VAR can vary substantially with the underlying model. For example, Kalyvas and Sfetsos (2006), who consider the issue of whether the application of "innovative internal models" reduces regulatory capital, find that the use of extreme value theory produces a lower estimate of VAR than the variance-covariance, historical simulation and conditional historical simulation methods.

distribution, and (ii) a definition that considers only losses above a threshold. Evidence for this ambiguity is provided by Wei (2007) who makes it explicit that "banks' capital charge should be equal to at least 99.9% quintile of their entire annual aggregate loss distribution in excess of expected losses". It seems that Wei has missed the qualifying statement "unless it can be demonstrated that the expected loss is adequately captured in the internal business practices".

[25] Rosenberg and Schuermann (2006) show how the copula can be used for the purpose of integrated risk management by constructing joint distribution for market, credit and operational risk. The power of the copula, they argue, lies in its ability to capture a rich dependence structure. However, Wei (2007) argues that a drawback of copula-based models is the data requirement. For a discussion of the pros and cons of copulas relative to correlation, see Moosa (2007b).

Some doubts have been raised about the use of the 99.9th percentile to measure value at risk, which is recommended by the Basel Committee. For example, Alexander (2003b) argues that the parameters of the total loss distribution cannot be estimated precisely because the operational loss data are incomplete, unreliable and/or subjective. This makes the estimation of risk at the 99.9th percentile implausible. Alexander argues that regulators should ask themselves very seriously if it is sensible to measure the capital charge on the 99.9th percentile. Even worse, Rebonato (2007) argues that the 99.9th percentile is a meaningless concept.

While Chernobai et al. (2006) argue that "all statistical approaches become somewhat ad hoc in the presence of incomplete data", they suggest four alternative approaches to the estimation of the frequency and severity distributions by distinguishing between censored and truncated data. Data are censored when the number of observations that fall in a given set is known, but the specific values of the observations are unknown. Data are said to be truncated when observations that fall in a given set are excluded. Thus, censored data affect the estimation of the severity distribution, not the frequency distribution, whereas both are affected by truncated data. The evidence on the effect of truncated data is mixed. Moscadelli et al. (2005) highlight the potential drawbacks of neglecting the existence of thresholds in the measurement process, suggesting that one way to circumvent this problem is to reconstruct the shape of the lower part of the distribution by fitting the collected data and extrapolating down to zero. Mignola and Ugoccioni (2007), on the other hand, argue that neglecting events below the loss data collection threshold does not lead to large errors in the aggregated expected loss quintiles and unexpected loss for threshold values up to fairly large percentiles of the severity distribution.

Generally speaking, operational risk is much more difficult to quantify than market risk and credit risk, which have much more well-behaved loss distributions compared with operational risk. But one may ask the question why it is that operational risk is more difficult to measure than credit risk, given that the concepts on which measurement is based (the concepts of loss frequency and loss severity) are equivalent to concepts of frequency of default and the loss given default. de Koker (2006) points out that despite these similarities, operational risk is difficult to measure because of two characteristics of operational risk that we discussed earlier in this paper: the absence of a good proxy for operational risk exposure and the fat-tail characteristic of the loss distribution.[26]

IX. THE MANAGEMENT OF OPERATIONAL RISK

Operational risk management is an activity that banks, and firms in general, have indulged in for a long time or, as Kennett (2003) puts it, since "year dot". This view is shared by Buchelt and Unteregger (2004) who argue that long before the advent of Basel II, financial institutions had put in place various control mechanisms and

[26] The point on exposure is also raised by Bee (2006) who argues that "unlike losses caused by market or credit events, operational losses are not related to underlying risk factors".

procedures. It is arguable, therefore, that operational risk management is older than credit risk management and market risk management. But just like the term "financial risk", appeared before the term "operational risk", the term "financial risk management" appeared before the term "operational risk management".

It remains true, however, that operational risk management has been a set of fragmented activities designed to deal with a wide variety of operational risks. Given that the concept of operational risk was unknown some ten years ago, it is not surprising that operational risk management is not yet an integrated process that deals with operational risk as a generic kind of risk. Kennett (2003) attributes the trailing of operational risk management behind the management of other kinds of risk to several reasons, including the breadth of operational risk, the fact that it is already managed implicitly, the lack of data, the fact that it affects the whole firm, and the fact that a lot of tools and techniques are "more bleeding edges than cutting edges". But it is often claimed that the advent of the Basel II Accord has contributed to the development of operational risk management. For example, Rao and Dev (2006) argue that the AMA is as much about managing operational risk as of measuring and calculating regulatory capital. They also refer to BCBS (2003d) as listing ten "high-level" basic principles of operational risk management. Likewise, Bolton and Berkey (2005) argue that the "Sound Practices paper provides an excellent outline for designing an op risk management framework that can provide tangible benefits that does not get distracted by the challenges of operational risk modeling".

The process of managing operational risk is different from those of managing market risk and credit risk only in so far as operational is different from the other two kinds of risk. Kaiser and Kohne (2006) argue that the distinctive feature of operational risk may cause significant divergence of the individual steps of operational risk management from the corresponding steps of market and credit risk management. One important difference, however, is that it is much more difficult to implement operational risk management on different hierarchical levels than in the cases of market and credit risk management. Kaiser and Kohne attribute this difficulty to the absence of a portfolio concept for aggregating the individual risk categories that operational risk encompasses.

Kingsley et al. (1998) state the following objectives of operational risk management (i) avoiding catastrophic losses, (ii) generating a broader understanding of operational risk issues, (iii) enabling the firm to anticipate risk more effectively, (iv) providing objective performance measurement, (v) changing behavior to reduce operational risk, (vii) providing objective information so that services offered by the firm take account of operational risk, and (vii) ensuring that adequate due diligence is shown when carrying out mergers and acquisitions. All of these objectives, it seems, fall under the headings "risk avoidance" or "risk reduction" but operational risk management is more than that as it encompasses risk transfer and risk financing. This is why the next issue to discuss is the role of insurance in operational risk management as a means of risk transfer or, more correctly, risk financing.

Insurance has always been used to mitigate various kinds of operational risk, such as the risk of fire (damage to physical assets). Insurance companies have been lobbying regulators to accept the idea of replacing (at least in part) regulatory capital with insurance. Currently, a wide variety of insurance products (policies) are available to banks, which include peril-specific products (such as computer crime cover) and multi-peril products (such as the all-risk operational risk insurance), as well as the traditional deposit insurance. There are, however, doubts about the role of insurance in operational risk management. To start with, banks are (financially) too big for insurance companies, which means that they cannot use insurance effectively to cover all elements of operational risk. Cruz (2003a) identifies other pitfalls with insurance for operational risk, including the following: (i) the limiting conditions and exclusion clauses, which may impede payment in the event of failure; (ii) delays in payment, which could result in serious damage to the claimant; and (iii) the difficulty of determining the true economic value of insurance in the absence of sufficient and appropriate data.

Brandts (2005) casts doubt on the ability of insurance to provide a "perfect hedge" for operational risk, arguing that insurance compensation is often subject to a range of limitations and exceptions. Specifically, he identifies three problems (risks) with insurance: (i) the payment uncertainty resulting from mismatches in the actual risk exposure and the insurance coverage; (ii) delayed payment, which may result in additional losses; and (iii) the problem of counterparty risk resulting from the possibility of default by the insurance company.

Young and Ashby (2003) are skeptical about the ability of insurance products to go far enough in the current operational risk environment. The BCBS (2001b) has expressed doubts about the effectiveness of insurance products, stating that "it is clear that the market for insurance of operational risk is still developing". And although Basel II allows banks using the AMA to take account of the risk mitigating impact of insurance in their regulatory capital calculations, some strict conditions must be satisfied. In general, regulators have a problem with the proposition that regulatory capital can be replaced (at least partially) with insurance. This is mainly because regulators are skeptical about the feasibility of immediate payouts (which is not what insurance companies are known for). There is also fear about the ability of the insurers to get off the hook (completely or partially) through some dubious clauses in the insurance policy.

A controversial issue is the claim that insurance is a key tool of risk transfer, which Kaiser and Kohne (2006), for example, make explicit by stating that "banks transfer risks by buying insurance policies". However, taking insurance does not really amount to risk transfer because the insured would still be exposed to risk. Risk transfer in the strict sense occurs only if a firm outsources the underlying activity to the insurer, which does not sound a good idea. Without that, insurance provides financial cover, should risk assumption lead to losses. Taking insurance, therefore, is not risk transfer but rather (external) risk financing through the insurance company as an alternative to financing it through capital and reserves.

Confusion between risk transfer and risk financing is quite conspicuous in the BCBS (2003b) paper on operational risk transfer across financial sectors. The paper makes it explicit that "banks already transfer operational risk through insurance" (p 6) but then shifts to the use of phrases like "finance those losses". On one page (p 7), it is first stated that "the firm has used insurance to transfer some of the risk of internal fraud loss", but in the following paragraph the word "transfer" is no longer used. Instead, it is stated that "the insurance policy provides benefits that act as a form of contingent capital in the event of an insured loss", while referring to "catastrophic coverage to finance low-frequency, high-severity losses". Actually, the graphical illustration of the use of insurance to cover operational risk does not use the word "transfer" at all. Instead, the title of Graph 1 is "financing of fraud losses over a one-year period, no insurance", whereas the title of Graph 2 is "financing of fraud losses over a one-year period, with insurance". So, is it transfer or financing? Logic and pure common sense tell us that it is financing, not transfer. The authors of the BCBS paper try to stick to the customary term of risk transfer, but it is sometimes quite obvious that this is the wrong term to use, in which case they shift to the correct term of "risk financing".[27]

X. CONCLUDING REMARKS

There is much more disagreement than agreement amongst academics and professionals about the concept of operational risk as well as its causes, consequences, characteristics and management. While there is a consensus on the views that operational risk is diverse and that it is difficult to measure, there are lingering disagreements about the definition of operational risk, its classification and what it should and should not include. A large number of definitions have been suggested, ranging from those that are hardly informative to those that look more like descriptions than definitions, and from those that are very narrow to those that encompass anything that is not related to market risk and credit risk. Strangely perhaps, operational risk is the only risk type that has an official regulatory definition, the Basel Committee's definition (market risk and credit risk do not have official definitions, perhaps because they are straightforward). But this official definition, motivated by regulatory pragmatism rather than comprehensiveness, has been criticized by those who think it is too narrow and those who think it is too broad. Controversy has also arisen about the criteria of classifying operational risk, whether operational loss events should be classified according to cause (people or systems), event (internal fraud or external fraud) or consequence (asset write-down or fines).

[27] As a compromise, it may be possible to argue that insurance can be used to transfer the financial effects of an operational loss event because the firm buying the insurance still experiences the event. The term "risk financing" is more appropriate because the very basic principles of risk management tell us that risk can be dealt with in a number of ways, including risk assumption, risk avoidance, risk transfer, risk reduction and risk financing. Hence, we are talking about risk transfer versus risk financing, which is more appropriate than talking about the transfer of risk versus the transfer of the financial effects of a loss event.

Operational risk is not understood very well, and it seems that there is disagreement about its proclaimed features. Some of the controversial issues pertain to the proclaimed features that it is one-sided, it is idiosyncratic, indistinguishable from other risks, and that it is transferable via insurance. This paper presented strong arguments against what seems to be the conventional wisdom, expressing the views that operational risk is not one-sided, is not idiosyncratic, is not indistinguishable from other risks, and that it is not transferable via insurance.

There are also controversies about why and how operational risk should be modeled and measured. But the most controversial issue is whether or not operational risk should be regulated, as required by the Basel II Accord. To start with, there is disagreement about the need for bank regulation in general, which is based on the undisputable fact that banks command special importance in the domestic and world economy, hence avoiding bank failures should be an objective of the regulators. However, there is significant skepticism about the role of regulation as a means of achieving financial stability. For example, Kaufman and Scott (2000) argue that regulatory actions have been double-edged, if not counterproductive. Koehn and Santomero (1980) suggest that regulation does not necessarily accomplish the declared objective of reducing the probability of bank failure and that a case could be put forward for the proposition that the opposite result can be expected. Benston and Kaufman (1996) assert that most of the arguments that are frequently used to support special regulation for banks are not supported by either theory or empirical evidence. They also share the view that an unregulated system tends to achieve an optimal allocation of resources. When it comes to Basel II as a form of bank regulation, Barth et al. (2006) conclude that Basel II is some sort of "one size fits all" kind of regulation, which they seem to be very skeptical about. Their empirical results reveal that raising regulatory capital bears no relation to the degree of development of the banking system, the efficiency of banks and the possibility of experiencing a crisis.

Risk-based regulation (including Basel II) has been criticized severely. Danielsson et al. (2002) demonstrate that, in the presence of risk regulation, prices and liquidity are lower, whereas volatility is higher, particularly during crises. They attribute this finding to the underlying assumption of the regulator that asset returns are exogenous, which fails to take into account the feedback effect of trading decisions on prices. Danielsson (2003) argues that while the notion that bank capital be risk sensitive is intuitively appealing, the actual implementation (in the form of Basel II) may boost financial risk for individual banks and the banking system as a whole. Danielsson and Zigrand (2003) use a simple equilibrium model to demonstrate "what happens when you regulate risk", showing that even if regulation lowers systemic risk (provided that not too many firms are left out by the regulatory regime, which is what will happen under Basel II), this can only be accomplished at the cost of significant side effects.

The management of operational risk (and financial risk in general), as envisaged by Basel II, has been criticized by Rebonato (2007) on the grounds of differences between regulators and risk managers. While regulators are concerned

about catastrophic events (represented by the 99.9th percentile of the loss distribution), there is more to risk management than rare events because banks are also concerned about the daily risk-return trade-off. Risk managers, therefore, should not do things the same way as the regulators. If we accept the logic of this argument, the proclaimed novelty of the Basel II Accord of aligning regulatory capital with economic capital is not a good idea after all. Regulatory capital is supposed to protect banks from catastrophic events, whereas economic capital is what is needed to run banks efficiently. Even more important, the argument goes, regulators should not force banks to devote resources to the development of internal models to calculate "numbers of dubious meaning" for regulatory purposes. The recommendation is: keep it simple or let banks decide whether or not they want to develop internal models. It would take a lot of people some convincing to dispute the validity of this view.

Having gone through a somewhat detailed discussion of various aspects of operational risk, the inevitable conclusion is that operational risk is truly a controversial topic, which has led to the emergence of a new strand of research that did not exist some ten years ago. This survey, it is hoped, will serve as a concise introduction to the topic as more and more academics and practitioners develop taste for it.

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XII. NOTES ON CONTRIBUTOR

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