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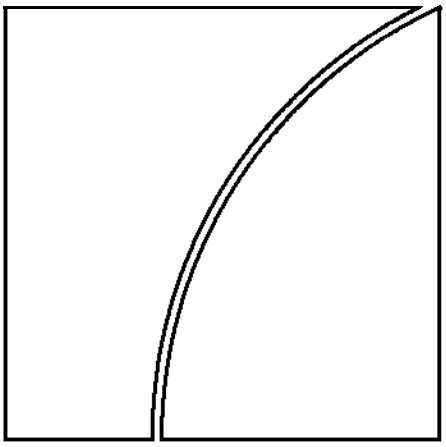

Findings on the interaction of market and credit risk

May 2009

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Executive summary

For many reasons, both historical and practical, market and credit risk have often been treated as if they are unrelated sources of risk: the risk types have been measured separately, managed separately, and economic capital against each risk type has been assessed separately. The development of credit risk transfer markets and the moves to mark-to-market accounting for portions of held-to-maturity banking book positions, however, have blurred distinctions between them and raise questions regarding approaches that treat the two types of risks separately. Market participants have argued that there are significant diversification benefits to be reaped from the integrated measurement and management of market and credit risks. The recent financial crisis, however, has illustrated how the two risks may reinforce each other and that in such stress situations illiquidity can worsen losses further. From a supervisory perspective, these developments raise important questions related to how the two types of risks can be defined and what relationships exist between them, how they should be aggregated and how precisely their joint risk is measured, what role liquidity plays in their interaction and under what conditions securitisation – as one driver of the above developments – can work as a risk management approach.

Against this background, but before the start of the ongoing financial crisis, the Basel Committee on Banking Supervision established a working group under its Research Task Force to study the interaction of market and credit risk (the **IMCR group**). The group's mandate was to undertake research that contributes to the understanding of the interaction between market and credit risk in the context of risk measurement and management. Working group members' research efforts are documented in a number of individual and jointly authored working papers that are available from the authors or their home institutions. This paper summarises the findings of the IMCR group's efforts, focusing on the main lessons for supervisors and on the answers to the questions mentioned above. Many of the projects were underway or largely completed prior to the crisis that began in August 2007. Even though many issues that have become apparent since its start are not directly reflected in the group's research agenda, the paper highlights the aspects of the findings that are particularly relevant for it, for example by contributing to the understanding of its causes and propagation mechanisms. This "Findings" paper is organised around four related sets of conclusions.

The first set of conclusions deals with **conceptual distinctions and empirical relationships** between market and credit risk. Market risk and credit risk are often distinguished by identifying the latter with (actual or expected) default. (A straightforward way to define default is the failure to meet a contractually pre-determined obligation.) As the same economic factors tend to affect both types of risk, drawing a clear distinction between them in practical risk measurement and management is, however, very difficult. Even if distinct factors could be separately associated with the two types of risk, the factors often interact significantly in determining asset values, and therefore risk measurement and management needs to explicitly account for their joint influence. In practice, market and credit risk are often distinguished in relatively simple ways on the basis of instruments, market liquidity, accounting treatments or holding periods. Care should be exercised to ensure that such pragmatic distinctions do not lead risk managers to ignore important risks that emanate from the interactions between market and credit risk.

The important interactions between market and credit risk and their form lead to the second set of conclusions, which summarises some central research results by the IMCR group.

These concern errors in **aggregating the two types of risk** and the issue of whether diversification benefits can be identified.[1] Ideally, an integrated risk modelling approach would be preferable to account for material interactions between market and credit risk. This requires, inter alia, that all gains and losses are captured in a consistent way across the two types of risk. Compared to approaches often encountered in practice, adjustments may be necessary, for example to not only consider losses on held-to-maturity loan portfolios but also (interest) earnings. Moreover, in certain portfolios market and credit risk are related in a non-linear way. Since this means that they are inextricably linked, conventional approaches that estimate each risk type separately and then aggregate them (such as "top-down" risk aggregation approaches), which are widely used in the industry, may lead to sizable biases in overall risk estimates. For example adding the separately estimated risk components may not be conservative, as often thought, because non-linear interactions may lead to compounding effects.[2] Examples of positions in which such compounding effects may be present include foreign currency loans, adjustable rate loans (including sub-prime mortgage loans) or matching long and short positions in OTC derivatives. There may also be cases in which diversification benefits are underestimated. On balance, the IMCR results suggest a rather "cautionary tale". Claims about the presence of diversification benefits between market and credit risk should be regarded with great caution if they are not derived from an integrated ("bottom-up") approach.

Successful management of market and credit risk often relies on liquid markets to hedge risks and unwind positions, as the ongoing financial crisis has abundantly illustrated. Therefore, the third set of conclusions addresses the role of market **liquidity** for the relationships between market and credit risk. (Other liquidity concepts such as funding liquidity were not considered by the IMCR group.) Liquidity conditions interact with market risk and credit risk through the horizon over which assets can be liquidated. In particular, deteriorating market liquidity often forces banks to lengthen the horizon over which they can execute their risk management strategies. As this time horizon lengthens, overall risk exposures increase, as does the contribution of credit risk relative to market risk. The liquidity of traded products can vary substantially over time and in unpredictable ways. Theoretical IMCR research indicates that such liquidity fluctuations, all else equal, should have a larger impact on prices of products with greater credit risk. Conversely, as the current financial crisis illustrates, valuation uncertainties or other shocks that enhance actual or perceived credit risks can have adverse effects on liquidity and put in motion a downward spiral between market prices and liquidity of traded credit products (see for example the case of tranches from collateralised debt obligations based on sub-prime loans).

Securitisation transforms credit risk into market risk by pooling loans and issuing tradable claims against the pool. It is a risk management and funding tool that relies on the liquidity of primary markets for placing asset-backed securities. The final set of conclusions selects a few research results relating to securitisation in this sense, without addressing many of the other problems currently discussed in this area. Securitisation offers potential benefits by allowing banks to focus on intermediation and (only) selected risk bearing to better manage their loan portfolios. The current financial crisis has, however, demonstrated problems that can arise in securitisation. Work undertaken by members of the IMCR group illustrates that widespread mis-pricing and distorted investments can occur if the incentives of underwriting banks and investors are improperly aligned. As a consequence the markets for risk sharing

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[1] Diversification in this context is taken to mean that the overall risk is lower than the sum of the separately measured different risk components.

[2] Compounding describes a situation in which the overall risk is greater than the sum of the separately measured different risk components.

and funding can become illiquid, exposing the banks to significant risks. Insufficient knowledge about pricing parameters, such as credit correlations, further increase the risks associated with risk management strategies that rely on securitisation.

Findings on the interaction of market and credit risk

1. Introduction

For many reasons, both historical and practical, market and credit risks have often been treated as if they are unrelated sources of risk: the risk types have been measured separately, managed separately, and economic capital against each risk type has been assessed separately. The development of credit risk transfer markets and the moves to mark-to-market accounting for portions of held-to-maturity banking book positions, however, have blurred distinctions between them and raise questions regarding approaches that treat the two types of risk separately. Market participants have argued that there are significant diversification benefits to be reaped from the integrated measurement and management of market and credit risks. The recent financial crisis, however, has illustrated how the two risks may reinforce each other and generate large losses if not managed jointly in the appropriate fashion. It has also illustrated the significant role that illiquidity can play in such stress situations.

From a supervisory perspective, these developments raise important questions. Can one usefully define and distinguish the two forms of risk? What relationships exist between them? Are present risk management and aggregation approaches precise in measuring and managing their combined risk? How should risk aggregation within the economic capital framework recognise the links between the two risk categories? How should regulation and supervision account for these relationships? What role does market liquidity play in the interaction of them? Finally, given the importance of securitisation for the developments described above, what are the conditions under which this bank risk management and funding tool can deliver its main benefits?

Against this background, but before the start of the ongoing financial crisis, the Basel Committee on Banking Supervision established a working group under its Research Task Force to study the interaction of market and credit risk (the IMCR group). The mandate of the group was to conduct research that would lead to an improved understanding of the interaction between market and credit risk and how this interaction is related to risk measurement and management.

The IMCR group operated between 2006 and 2008. Working group members studied many specific issues related to the interaction of market and credit risk and their research efforts are documented in a number of individual and jointly authored working papers.[3] The papers are available from the authors themselves or their sponsoring institutions. The group also held a public conference in December 2007, which featured a selection of its own projects, academic and industry contributions, and kept it abreast of relevant risk management developments in the banking sector.[4]

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[3] These papers are Alessandri and Drehmann (2007), Åsberg and Shahnazarian (2008), Breuer et al (2008), Cuenot et al (2006), Drehmann et al (2008), Fiori and Iannotti (2008), Guo et al (2007), Hasan et al (2009), Jiangli et al (2007), Kobayashi (2007), Kobayashi et al (2008), Kupiec (2007), Masschelein and Tsatsaronis (2008, 2009), Raunig and Scheicher (2008), Scheicher (2006) and Tarashev and Zhu (2008).

[4] The conference was hosted by the Deutsche Bundesbank in Berlin, Germany. The program and the presented papers are available for downloading at http://www.bundesbank.de/vfz/vfz_konferenzen_2007.en.php#interaction.

This paper summarises the main findings of the IMCR group. In so doing, it focuses on the answers to the questions mentioned above, which have emerged from the group's different streams of work. It is organised around four related sets of conclusions. The first set of conclusions deals with some conceptual issues, in particular regarding the distinction between market and credit risk. They lead to the second set of conclusions, which summarises some central research results of the group. These concern problems in aggregating the two types of risk and whether diversification effects can be identified. The third set of conclusions addresses the role of market liquidity for the relationships between market and credit risk. The final set of conclusions involves selected results related to securitisation. Even though the bulk of the work was already completed before the onset of the current financial crisis, the report highlights the aspects of the group's findings that are particularly relevant for it, for example by contributing to the understanding of its causes and propagation mechanisms.

2. Conceptual issues: Distinctions and relationships between market and credit risk

Market risk and credit risk can be distinguished on the basis of identifying the latter with (actual or expected) default. A straightforward way to define default is the failure to meet a contractually pre-determined obligation. As the same economic factors tend to affect both types of risk, drawing a clear distinction between them in practical risk measurement and management is, however, very difficult. Even if distinct factors could be separately associated with the two types of risk, they often interact significantly in determining asset values, and therefore risk measurement and management needs to explicitly account for their joint influence. In practice, market and credit risk are often distinguished in relatively simple ways on the basis of instruments, market liquidity, accounting treatments or holding periods. Care should be exercised to ensure that such pragmatic distinctions do not lead risk managers to ignore important risks that emanate from the interactions between market and credit risk.

Economic risk, as contrasted with operational or legal risk, for banks refers to uncertainty about the future (economic as opposed to accounting) value of assets and liabilities. Very often distinctions are made between market and credit components of economic risk and their respective risk drivers.

In fact, market and credit risk can be distinguished by relating the latter to some notion of default, be it the actual occurrence of default or changes in the expectations about the probability of default. A straightforward way to define default is the non-delivery of a contractual obligation by the obligor counterparty. Starting from this view on credit risk, market risk can then be described as fluctuations in value (or expectations about future fluctuations) that relate to changes in relative prices (such as exchange rates, commodity

A selection of these papers is currently considered for a special issue of the *Journal of Banking and Finance*. Some of the papers have also been issued as Bundesbank discussion papers (see http://www.bundesbank.de/vfz/vfz_diskussionspapiere_2008.en.php).

prices, etc), in the discount factor (ie interest rates and risk premia) or in the level of cash flows, which are not nominally pre-determined by contract.[5]

This (and other) distinction(s) should not be overstated, however, as default may be affected by fluctuations in asset prices.[6] Market and credit risk tend to be driven by the same economic factors. For example, stock and bond values both change with the macroeconomic environment, shifts in general asset prices (including the yield curve) and specific business prospects, managements and capital structures of the companies concerned. Still, the effect of each of these factors on a firm's stock price will typically be different from its effect on the firm's bond price.

The identification of common risk drivers foreshadows important interactions between market and credit risk. As a consequence, it is very difficult to distinguish these two risks clearly in practical risk measurement and management. Even in cases when each risk can be associated with different risk drivers these may be correlated. In some situations models that treat market and credit risk as independent may be adequate whereas in other situations accurate risk measurement will require that the joint influence of common or correlated risk drivers be explicitly recognised when measuring these risks. Research of the IMCR group provides evidence for these interactions both at the "macro" level of the economy as a whole and at the "micro" level of the sensitivity of individual bank risk to different risk drivers.

At a "macro" level, empirical results from research conducted by group members highlight dynamic aspects of linkages between market and credit risk. Correlations between macroeconomic variables and asset prices reflecting the impact of interest rates, default rates and charge-offs, equity prices, and prices of default-sensitive instruments are significant from both a statistical and an economic point of view.[7] Furthermore, the interactions between these variables become more apparent when examined through their dynamic responses to different shocks. For instance, empirical results for Italy suggest that a shock in the short-term interest rate (as caused, for example, by a tightening of monetary policy) has a larger effect on firm default rates when the credit risk model accounts for feedback from interest rates on equity prices and other proxies of market risk.[8]

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[5] For illustration the criterion of pre-determined or open-ended cash flows can be applied to some standard financial instruments. According to it, an investment in stocks represents only market risk because dividends are not pre-determined by contract. By contrast, holdings of bonds issued by the same company would be subject to credit (and market) risk because the timing of the repayment of coupon and principal amounts is specified in the contract. Masschelein and Tsatsaronis (2009) present a more comprehensive discussion of these points and illustrate the relative importance to distinguish between the two components in the context of a list of common financial instruments.

Another often mentioned distinction between the two types of risk relates to aspects of the distributions used. It is said that credit risks are characterised by skewed distributions and jumps in underlying risk drivers. It happens, however, that interest rate and equity options – instruments typically more associated with market risks – exhibit similar features, such as volatility skew and jumps.

[6] Cuenot et al (2006) also raise points about the difficulty to distinguish between market and credit risk.

[7] See Hasan et al (2009). They also examine interactions between risk factors in terms of the risk profile of individual institutions. They find evidence of significant cross-factor influences affecting the risk of individual banks as reflected in the conditional volatility of their share prices. Åsberg and Shahnazarian (2008) estimate the relationship between three macroeconomic factors (short term interest rate, consumer price index, industrial production) and the aggregate default probability for Swedish listed companies. They show that the interest rate has a significant positive impact on the default probability for companies.

[8] See Fiori and Iannotti (2008), who examine these interactions in a factor augmented vector auto-regression (FAVAR) model incorporating a large number of macroeconomic and financial variables for the Italian economy. The estimated responses of sectoral corporate default rates to a 50 basis points increase in the

At the "micro" level, a study of the IMCR group of the relationship between credit default swap (CDS) spreads and equity prices provides evidence consistent with the hypothesis that market and credit risks emerge from similar risk drivers. The study finds a close positive correlation between the risks of CDS portfolios and equity portfolios for the same companies.[9]

The prior analysis that identifies common risk drivers and strong interactions among market and credit risk measures suggests some caution towards simple ways to distinguish the two types of risk on the basis of specific characteristics of exposures. First, little distinction can be made on the basis of the identity of instruments. While exposure profiles of some instruments may be predominantly composed of market or credit risk, there are many assets that combine elements of both types of risk. Second, separating the two on the basis of the existence of liquid markets is problematic. Tradable assets are often treated as being mainly subject to market risk. This method of identification may mask important features of credit risk in that few models explicitly account for the risk that market liquidity conditions may change and inhibit the ability to hedge or trade a position (see Section 4). What was once identified as a liquid tradable position perceived to be predominantly subject to market risk may become a held-to-maturity position with a risk profile dominated by credit risk.[10] Third, accounting treatments may also not be a reliable way to distinguish between market and credit risk, as for example the fair-value accounting option can be used for loan portfolios and more frequently traded credit instruments tend to be marked-to-market.

Finally, there are significant dangers of associating market and credit risk too closely with the intended use or holding period of an investment, as indicated by the booking of specific positions in the trading or banking book. In particular, the trading portfolio of banks is often treated by practitioners as being primarily (if not exclusively) subject to market risk even though unexpected defaults may occur, for example, in a traded bond portfolio. As evidenced by the recent financial crisis, this is clearly a mis-conception. Underestimation of the credit risk embodied in structured products, inter alia, resulted in large writedowns by financial institutions. This includes credit-related event risk in the trading book.[11] Given the significant and increasing importance of credit risk in the trading book, the Basel Committee has addressed it in Basel II and currently goes further in the context of its trading book review.[12]

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monetary policy rate increase six-fold when one incorporates in the model proxies for market risk and their dynamic interactions with other risk drivers. Similarly, Åsberg and Shahnazarian (2008) find that forecasts of aggregate default rates can be improved by including short-term interest rates as potential drivers.

[9] See Raunig and Scheicher (2008). The positive correlation is also supported by economic theory, as CDS and equity are both options on a firm and therefore related to the same fundamentals. Identifying it empirically (for the same holding period) should, however, not be read as an encouragement to hedge CDS positions with equity positions or vice versa. First, there is quite some heterogeneity in the empirical relationship across firms. Second, there is significant time variation in correlations. Third, the paper analyses correlations in value-at-risk measures and not in price measures, as used for hedging purposes.

[10] The generally lower liquidity of credit instruments compared to more mature instruments characterised by a large market risk component and changing liquidity conditions for traded credit instruments over time induce subtle problems in the joint assessment and management of market and credit risk that are addressed in Section 3 and, in particular, Section 4 below.

[11] Reports by market participants point to another example of significant credit risk in the trading book. In jurisdictions where newly purchased distressed assets cannot be booked in the banking book, these are typically booked as trading assets, are marked-to-market and managed accordingly.

[12] Basel Committee on Banking Supervision (2006) states in paragraph 718(xcii) that a "…bank must have an approach in place to capture in its regulatory capital default risk of its trading book positions that is incremental to the risk captured by the VaR-based calculation…" for market risk. The Committee developed this "incremental default risk charge" further in its ongoing trading book review and recently proposed to extend it to a more general "incremental risk charge" (IRC) (see Basel Committee on Banking Supervision (2009a) and

Similarly, it would be wrong to ignore the market risk from changes to the discount rate in a loan portfolio. Subsection 3.2 below addresses the issue of interest rate risk in the banking book from the perspective of interacting market and credit risk and the potential for diversification effects.

For practical reasons, however, distinctions between market and credit risk still play a significant role in risk measurement and management practices. But such practices should not lead risk managers to ignore the common and interdependent features of market and credit risk, as they need to be taken into account to measure and manage overall economic risk appropriately.

3. Aggregation issues: Diversification versus compounding between market and credit risk

> *Ideally, an integrated risk modelling approach would be preferable to account for material interactions between market and credit risk. This requires, inter alia, that all gains and losses are captured in a consistent way across the two types of risk. Compared to approaches often encountered in practice adjustments may be necessary, for example to not only consider losses on held-to-maturity loan portfolios but also (interest) earnings. Moreover, in certain portfolios the two types of risk are related in a non-linear way. Since this means that they are inextricably linked, conventional approaches that estimate each risk type separately and then aggregate them up* (such as "top-down" risk aggregation approaches), which are widely used in the industry, *may lead to sizable biases in overall risk estimates. For example, adding the separately estimated risk components may not be conservative, as often thought, because non-linear interactions may lead to compounding effects. There may also be cases in which diversification benefits are underestimated. Claims about the presence of diversification effects between market and credit risk, however, should be regarded with great caution if they are not derived from an integrated ("bottom up") approach.*

Despite the relationships between market and credit risks discussed in the previous section, applied risk measurement often proceeds in a compartmentalised fashion. The frequently used "top-down" approach first aggregates each risk type across positions and then only combines them at a higher level, often in a linear way. Since it therefore neglects a multitude of market-credit risk interactions, the question arises whether such an approach may lead to appreciably biased estimates or whether overall economic risk is still well approximated. A series of IMCR research papers suggest that the potential for biased risk assessments is substantial and that an integrated, "bottom-up" approach – combining market and credit risk measurement from the level of individual exposures and building it up to the level of portfolios and the bank as whole – may be able to avoid biases.[13] This section starts with cases in which compartmentalised approaches may lead to the underestimation of risk. Then

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Basel Committee on Banking Supervision (2009b)). The draft guidelines clarify the high-level principles mentioned above and provide guidance on the parameterisation of models that banks would be expected to use in the calculation of the IRC. The need to better capture credit risk in trading books of banks and securities firms was also recognised in the report by the Financial Stability Forum (2008) on how to enhance the resilience of financial systems in response to the ongoing financial crisis (recommendation II.4). This was one of the recommendations approved by G7 Ministers and Governors for implementation within 100 days.

[13] See Alessandri and Drehmann (2007), Breuer et al (2008), Drehmann et al (2008) and Kupiec (2007).

cases are reported in which they would overestimate risk. After reporting an analysis in which both cases can emerge, practical challenges to the integrated measurement of market and credit risks are discussed.

3.1 Compounding effects

A commonly held view suggests that simply summing up the separately measured risk components under the top-down approach leads to "conservative" estimates of overall risk. The argument is that the summing of components assumes perfect correlation between market and credit risks. But if they are imperfectly correlated, then diversification effects are ignored and total risk overestimated.[14]

This intuition, however, does not necessarily hold when market and credit risk interact in a non-linear fashion. Non-linear interaction emerges when losses from default on an instrument depend on movements in market risk factors, or conversely, when changes in the values of instruments due to movements of market risk factors depend on whether there is a default or rating migration. In these circumstances, the two types of risk are inextricably linked, and attempts to measure them separately and then combine them can lead to substantial biases.[15]

In fact, IMCR research shows cases in which the combined risk is actually higher than the sum of the components ("compounding effects", the opposite of diversification effects).[16] A particularly clear example is foreign currency loans, which constitute a sizable part of lending in certain countries. Consider a bank lending in foreign currency to domestic borrowers. These positions contain market risk (exchange rate risk) and credit risk (default risk of borrowers). Now assess the two risks separately. When for example the domestic economy slows, ceteris paribus, the probability of domestic borrowers defaulting increases. When the domestic currency depreciates, ceteris paribus, the value of the loan in domestic currency increases as it is denominated in foreign currency. So, on the surface one could think that the two effects offset each other. But this reasoning would neglect the strong relationship between exchange rate changes and default risk in this type of contract. The ability of a domestic borrower to repay a loan in foreign currency depends in a non-linear way on fluctuations in the exchange rate (unless the domestic borrower has other revenues in the foreign currency in which the loan is denominated). A home currency depreciation has a particularly malign effect on the repayment amount and therefore repayment probability of a

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[14] Diversification in this context is taken to mean that the overall risk is lower than the sum of the separately measured different risk components. Whether diversification effects can be identified also depends on the risk measure being used, and how it is used. Diversification effects are generally not guaranteed when risk is measured using value-at-risk. When risk is measured using coherent risk measures, such as expected shortfall, diversification effects are guaranteed provided that the total risk (encompassing all risk sources) of each business unit of the bank is estimated separately and then added up across business units. (This follows from the fact that one property of a coherent risk measure is that it is sub-additive. See Artzner et al (1999) for the properties of coherent risk measures.) In this context, business units are broadly defined as non-overlapping subportfolios that together constitute the bank's total portfolio. If risk is instead computed separately for different risk types, ie market and credit risk, and then added together, then even with coherent risk measures, diversification effects are not guaranteed. As discussed in depth in this subsection, it is then possible for the true risk of the portfolio to exceed the sum of its estimated market and credit risk.

[15] By contrast, if all instrument values are a linear function of the credit and market risk factors, then the risks are not inextricably linked and separate computation of credit and market risk will be conservative provided that coherent measures of risk are utilised, as discussed in Breuer et al (2008).

[16] See notably Breuer et al (2008) and also Kupiec (2007). Compounding describes a situation in which the overall risk is higher than the sum of the separately measured different risk components.

foreign currency loan by an unhedged domestic borrower, which tends to be stronger than the valuation effect mentioned above.[17]

An analysis of foreign currency loans in Austria indicates that simply adding up the separately measured exchange rate and default risk components underestimates the actual level of risk several times. For example, for a B+ rated obligor the integrated risk measurement approach leads to an overall risk that is 1.5 to 7.5 times larger than the risk derived from a compartmentalised approach (each risk measured separately and then added up). This bias becomes more pronounced for portfolios with lower ratings and vice versa.

The box describes a number of other examples where nonlinear interactions between credit and market risk allow for the possibility of compounding effects to occur. It shows that the case of foreign currency loans is not just a peculiar exception. The possible emergence of compounding effects and the fact that adding up separately measured market and credit risk components may not lead to conservative estimates of overall economic risk are of high practical relevance.

Box: Further examples of portfolios where compounding effects may emerge

(i) Adjustable rate loans

Adjustable rate loans have coupons that change as interest rates change. Therefore, if the coupons on the loans adjust frequently (or in the limit continuously), then the interest rate risk of the loan is passed on to borrowers, and therefore, assuming the loans do not default, they have no market risk for the bank.

If credit risk is computed separately from market risk, then the credit risk of the loans is computed while holding interest rates constant. This treatment of credit risk can miss an important interaction between market and credit risk. For example, if probabilities of default are increasing in interest rates, then holding rates constant can easily lead to an understatement of the true probability of default and hence the sum of market and credit risk, when computed separately, would lead to an understatement of total risk.

(ii) Carry trades and foreign currency loans

The carry trade is an investment strategy that borrows funds in a low interest rate currency, and then lends the funds at a high interest rate in another currency. For example, suppose a UK investor does the carry trade by borrowing from a Japanese bank at a fixed rate in yen, and then invests the proceeds in pounds sterling.

If the Japanese bank computes its market risk and credit risk separately, then market risk is computed assuming the UK counterparty cannot default, in which case the only source of market risk for the Japanese bank is due to fluctuations in the yen term structure.

If credit risk is computed under the assumption that interest rates and exchange rates do

[17] There is some relation to analyses of "wrong way risk" or "wrong way exposure", which emerged after the Asian financial crisis. Such studies assess the credit exposure of a position whose value depends on the movement of market risk variables, for example exchange rates, as in Levy and Levin (1999) or Finger (2000). The issue addressed in this section differs. It does not address how to compute a credit risk exposure, but rather how to compute the combined market and credit risk of a portfolio for which nonlinear interactions between market and credit risk factors are present.

not fluctuate, then the credit risk estimates do not depend on the potential for fluctuations in interest rates and exchange rates.

If the probability that the borrower defaults and losses given default depend on whether the carry trade is ex-post profitable for the UK investor, then separate treatment of market and credit risk can lead to total risk being underestimated, because credit risk treatment which holds exchange rates and interest rates constant can lead to an understatement of credit risk.

(iii) Matching long and short positions in OTC derivatives

If a bank buys an over-the-counter (OTC) derivative from one counterparty and sells an exactly offsetting OTC derivative position to another counterparty, then assuming that the counterparties do not default, the bank has no market risk because the losses on one position are exactly offset by gains on the other position.

Assuming the market values of the OTC derivatives do not change (or are marked to market and re-collateralised daily), then if one party defaults, its deliverable can be purchased on the market at the same price. Therefore, there is no credit risk.

However, if market risk variables move and one of the counterparties defaults at the same time, then movement of the market risk variable and the default together generate a loss for the bank.

A historical example of this mechanism is what happened to foreign currency forwards during the Russian crisis in August 1998. Western banks held dollar/rouble forwards with Russian banks and exactly opposite positions with Western customers. These portfolios were fully hedged against moves in the dollar/rouble exchange rate. Furthermore, for a given exchange rate, default risk was irrelevant to these positions. If some counterparty defaulted, it was always possible to get the currency deliverable to the other counterparty on the market at no loss at the given exchange rate. In August 1998 adverse credit events and market moves occurred simultaneously. The Russian counterparties defaulted and at the same time the rouble floated and its value dropped dramatically. The dollars deliverable to the Western customers had to be purchased on the market, and the roubles banks received in return had lost much value. This led to considerable losses for the banks involved.

3.2 Diversification effects

Highlighting positions or portfolios in which compounding effects between market and credit risk occur does not mean that the opposite, diversification effects, is not possible in other circumstances or portfolios.[18] Research by the IMCR group demonstrates this for the

[18] For example, Breuer et al (2008) derive sufficient conditions for diversification effects to appear under coherent risk measures when risks are computed by risk category and then aggregated. In the case of two risk categories, these conditions require that a portfolio can be decomposed in two subportfolios, where each one depends on only one risk category. In such situations, the malign non-linear interactions between market and credit risk described in Subsection 3.1 above can by definition not occur. Earlier research by Rosenberg and Schuermann (2006) uses a top-down approach to risk aggregation that rules out malign interactions by assumption. Under these circumstances for a set of large bank holding companies they estimated significant diversification effects between market and credit risk. As noted in Subsection 3.3, when risk is measured using

interactions between interest rate and credit risk in the banking book, taking the example of a representative UK bank.[19] This bottom-up analysis highlights the importance of modelling the whole banking book including assets, liabilities and interest sensitive off-balance sheet items. The interaction of interest rates and default probabilities tends to create non-linear effects that are difficult to capture outside an integrated model of overall economic risk.

The main mechanisms at work are described by means of a stress test simulation based on a model calibrated to data from the UK and starting from a shock to interest rates. On the negative side for bank profits, higher interest rates lead to more borrower defaults and decreased net-interest income because of a margin compression between short term borrowing and long term lending. Over time, however, banks regain their profitability as assets re-price and lending margins recover as higher interest rates and credit risk are passed on to borrowers. The consideration of loan revenue (and deposit cost) developments is of course an important difference to standard credit risk models that focus on the probability of loan losses.

Using a stylised set of assumptions, the model calibrated to the profile of a typical UK bank is then used to assess aggregate risk and required capital.[20] The results suggest significant diversification benefits between interest rate and credit risk in the banking book. In fact, the gains of passing on interest rate and credit risk changes to borrowers over time are estimated to be so large that the economic capital set against interest rate and credit risk together is lower than the capital that would have to be set against credit risk considered in isolation. One implication of these results is that non-linear interactions between market and credit risk do not necessarily lead to compounding effects (see Subsection 3.1), while compartmentalised measurement of market and credit risk could still lead to sizable mistakes in the assessment of overall risk in the banking book. The analysis provides an example in which there are large diversification benefits, but recognition of these benefits requires that all risk and profit sources are measured on a consistent basis. A key feature driving the diversification results in this model is the assumption that lending margins revert to long/run equilibrium levels and the recognition that earnings on banking book positions can, over time, offset market and credit risk stress scenario losses.

3.3 Value of and obstacles to integrated risk measurement

Further research from the IMCR group suggests that the value of integrated risk measurement and modelling goes beyond whether specific positions or portfolios exhibit either diversification or compounding effects between market and credit risk. Mis-measurement of overall risk may go in both directions; overestimation and underestimation, even for the same portfolio structure.[21]

From a longer term perspective, all the research results reported in this section underscore the importance of risk measurement on the basis of integrated, bottom-up, rather than compartmentalised approaches. Given the strong and complex interactions between market

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bottom-up approaches that do not rule out malign interactions by assumption, diversification effects can be present and as in Rosenberg and Schuermann can be large.

[19] See Drehmann et al (2008).

[20] See Alessandri and Drehmann (2007). This stylised representation does, however, not derive loan values through discounting with the yield curve ("marking to market"), thereby omitting a potentially important source of valuation effects.

[21] See Kupiec (2007).

and credit risk, the different biases identified can only be avoided through integrated approaches. Market information suggests, however, that integrated risk modelling is currently only observed in specific, usually trading-related areas such as securitisation and credit derivatives businesses. Moreover, the recent survey by the Senior Supervisors Group finds that some banks that are more severely affected by the current financial crisis had difficulties in integrating certain market and credit risks across business lines, whereas firms that are less affected had not.[22]

The practical challenges of moving to a fully integrated measurement and management of economic risk, however, are currently substantial. A first major obstacle to integrating market and credit risk measurement and management is that the metrics typically used for each of them are not fully comparable, with market risk models capturing a full distribution of returns and credit risk models focusing on losses from default and neglecting gains. For example, market risks are often measured using value-at-risk from "dirty" mark-to-market valuation changes on a portfolio. These valuation changes include profits and losses that arise from changes in modelled pricing factors, but they typically exclude trading fee revenues, accrued interest and dividends on trading book positions, and specific position returns (specific risk) that are not measured in the value-at-risk model. As the measurement time horizon lengthens, not only will appropriate value-at-risk estimation methods change, but the importance of accrued fees, interest and dividend earnings and specific risk can become important components of the economic profit and loss position on the trading book. Similarly, as the time horizon lengthens, it becomes important for market risk economic capital estimates to account for expected returns on portfolio positions and funding interest costs.[23] On the credit risk side, few credit risk or capital models attempt to model the full profit and loss distribution on held-to-maturity positions. Typically models estimate credit losses and ignore the interest earnings on performing credits and interest costs to fund the portfolio.[24]

Second, the arguably most important obstacle to the further integration of market and credit risk assessments is the different horizons over which risks are measured. This is clear from current practices, despite the increased tradability of credit risk through the expansion of securitisation and related financial innovations over the last decade. (Section 4 below discusses the related topics of market liquidity and assets' liquidity horizons.) Finally, it should be mentioned that an integrated model makes very significant demands on data and technological infrastructure.

In sum, an integrated approach must measure market and credit risk components on a consistent basis; account for profits as well as losses, recognise all sources of income and impose a common horizon. In practice, few models of market or credit risk fully respect these requirements. In this light, an IMCR study constructs a model, similar in structure to the models used in practice, but fully consistent in horizon and revenue recognition and

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[22] The Senior Supervisors Group (2008) states that some firms that are more adversely affected by the crisis "could not easily integrate market and counterparty risk positions across businesses, making it difficult to identify consolidated, firm-wide sensitivities and concentrations" (p 4). In contrast, firms that tended to avoid significant challenges were able to integrate the two types of risk.

[23] See Kupiec (2007) and references therein.

[24] Drehmann et al's (2008) analysis discussed above showed how important developments in interest earnings can be. In contrast, the tools that are often used are so-called "default-mode" credit models that rely on the estimated probabilities of default. The securitisation trend over recent years has, however, diminished the scope for differences in measuring market and credit risk, as securitisation transforms the latter into the former. For example, tranches of structured products do not default but exhibit higher or lower payments. (In terms of the definitions of market and credit risk in Section 2 they do not have contractually pre-determined payments.)

compares the integrated risk measures to the ones derived from compartmentalised approaches.[25] The model recognises default and migration credit risks as well as market risk that arises from volatility in the risk free term structure and spread factors that determine discount rates for different rating classes of loan exposures. When it is calibrated to reflect a typical portfolio profile of BBB-rated obligors, estimates suggest that the compartmentalised approaches for estimating risk can underestimate economic capital in some cases by a factor of two while in others they may overstate it by as much as 60%. The bias in compartmentalised capital estimates relative to the integrated model depends on how the compartmentalised capital estimates are constructed relative to horizon, revenue recognition and recognition of portfolio funding costs.

Against the claims by the industry about substantial diversification benefits to be reaped from integrating market and credit risk, the results of the IMCR group rather suggest a "cautionary tale". Supervisors confronted with the aggregation methodologies of banks (such as in the calculation of economic capital, for example) should be alert to the fact that diversification benefits are by no means a foregone conclusion. Careful supervisory validation of estimated diversification effects is fully justified, especially when they are derived from top-down methods and involve simple correlations.[26] In fact, market information indicates that top-down is the dominant approach among banks. Supervisors need to require bank risk managers to explain and justify diversification effects in terms of the interactions between market and credit risk components of overall risk, which may not always be linear and easily captured by (linear) correlation measures. For specific positions or portfolios in which particularly malign non-linear interactions between market and credit risk components exist, supervisors may even require risk managers to explain the absence of compounding effects.[27]

An important area for future research remains a systematic study of how prevalent the compounding effects in the aggregation of market and credit risks described above are relative to the diversification effects often stressed by market participants.

4. Liquidity issues: The role of the liquidity horizon for the interaction between market and credit risk

Liquidity conditions interact with market risk and credit risk through the horizon over which assets can be liquidated. In particular, deteriorating market liquidity often forces banks to lengthen the horizon over which they can execute their risk management strategies. As this time horizon lengthens, overall risk exposures generally increase, as does the contribution of credit risk relative to market risk. The liquidity of traded products can vary substantially over time and in unpredictable

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[25] Kupiec (2007).

[26] Most often the underlying models for aggregation purposes are based on normally distributed returns or in the banks that follow more advanced approaches on the Gaussian copula. The output, however, may be subject to considerable model uncertainty because of individual component risk measurement inconsistencies, the instability of estimated correlations or an inappropriate assumption of Gaussian copula aggregation (for example because of non-linear or asymptotic dependencies between risks).

[27] A related but different point can be made about bank-internal information flows that emerged during the ongoing financial crisis. Assessments of vulnerabilities in mortgage investments made by credit officers for the bank's own originated loans seem to have sometimes failed to reach the trading areas of the same institution which were dealing with similar exposures to loans originated by other banks.

ways. Such liquidity fluctuations, all else equal, should have a larger impact on prices of products with greater credit risk. Conversely, as the current financial crisis illustrates, valuation uncertainties or other shocks that enhance actual or perceived credit risks can have adverse effects on liquidity and put in motion a downward spiral between market prices and liquidity of traded credit products.

Banks' exposures to market and credit risk depend on their risk management strategies. Because many strategies rely on liquid markets for hedging, or for unwinding positions to limit losses on exposures that cannot be hedged, asset market liquidity is an important determinant of banks' overall risk profile. Additionally, since liquidity is time varying, and markets typically become less liquid when risk increases appreciably, recent events make abundantly clear that how liquidity interacts with other sources of risk needs to be better understood. This section first describes which aspects of liquidity the IMCR group considered. It then discusses how changing market liquidity can alter the relative balance of market and credit risk in bank portfolios. Next it provides an example of how changing market liquidity is associated with interactions between market and credit risk. Last it addresses the reverse direction, how increased uncertainty and risk impairs market liquidity, and links it to observations from the current financial crisis.

The focus of the IMCR group was primarily on market liquidity and not on funding liquidity or any other liquidity concept. Market liquidity conditions determine the liquidity horizon, which measures the amount of time required to unwind a position without unduly affecting the underlying instrument prices (including in a stressed market). Unanticipated shocks to market liquidity conditions can change a bank's liquidity horizon and alter the blend of market and credit risk in its portfolio. This occurs for two reasons. First, over very short horizons, in normal circumstances, defaults tend to be largely idiosyncratic.[28] Therefore, in well diversified portfolios, losses due to unexpected defaults are expected to be negligible over short horizons. The dominant risk in credit portfolios over short horizons is expected to materialise through mark-to-market price changes, not defaults. Such valuation changes are likely to be categorised as market risk, especially if the positions are in the trading book. If instead the positions are not marked to market and held to maturity, the risk might not be measured at all. Over longer horizons, defaults are driven by changes in macroeconomic conditions that are not diversifiable. Therefore, risk from unexpected defaults becomes relatively more important.

A second reason for why the liquidity horizon affects the blend of risk is that market risk and default risk may grow at different rates through time. For example, common models of default risk tend to assume that, over modest horizons, the probability of default grows approximately linearly with time. By contrast common value-at-risk models of market risk assume that risk increases with the square root of time. Therefore, for assets with typically short liquidity horizons, such as stocks, most of the risk occurs through changes in market prices over the liquidity horizon.[29] Other assets, such as bonds and CDS, trade far less and are likely to have longer liquidity horizons and consequently a larger share of credit risk.[30]

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[28] The current crisis in the sub-prime mortgage market is an example when defaults are not idiosyncratic, even over short horizons.

[29] In reduced-form credit risk models, the probability of default over short holding periods is approximately equal to the default intensity times the holding period, and is hence linear in time. In structural models, such as Black and Cox (1976), when the default boundary is equal to the bond face value the probability of default is tiny over very short holding periods and then linearly increasing in the holding period of a position. The square root formula for market risk holds for normally distributed returns. For fat-tailed return distributions the price risk is proportional to the α-th root of the holding period, where α is the tail index.

The impact of both changes in the liquidity horizon and changes in credit risk on the overall risk of a portfolio is explored in a simulation study carried out by the IMCR group.[31] According to this research, a drying up of liquidity associated with an increase in the liquidity horizon from two weeks to six months would have the same effect on the value-at-risk of a portfolio of A3-rated assets as a downgrade of these assets by two notches from A3 to Baa2 over a two-week liquidity horizon.[32] In an alternative scenario in which the lengthening of the liquidity horizon and the rating downgrade both occur at the same time, the combined impact on the value-at-risk is 2.3 times stronger than the sum of both effects measured separately, showing that nonlinearities can also have strong effects in the interaction of credit and liquidity risk.

Although credit risk generally becomes more important relative to market risk over longer time horizons, this does not imply that positions that are held for short horizons are immune from credit risk. It rather means that the credit risk may manifest itself through price changes over short horizons (see above). It also shows well how difficult it has become in practice to sharply distinguish market from credit risk (see Section 2). If banks held these loans on balance sheet and they were not traded, their default would have affected the banks' P&L only over time. By holding CDOs that referenced the loans, however, the perceived losses due to credit risk were rapidly priced in and realised.

Given the importance of liquidity horizons for the relative balance of market and credit risks in bank portfolios, the IMCR group has also performed empirical research on the trading activity in markets for certain credit-risky instruments. These studies indicate that the liquidity in these markets is generally inferior relative to a variety of other markets, such as stock markets on public exchanges or major money and foreign exchange markets. In line with other research, they find, for example, that in a sample of 3,755 US corporate bonds only 15% traded at least once a week over the period 2005–06, while less than half were traded once every four weeks.[33] A similar message comes from the analysis of market quotes for single-name CDS spreads. In a sample of 161 of the most liquid (obligor) names almost 5% may not have a spread quoted on any given day, and it takes on average six calendar days before a new quote appears for the same contract.[34]

The ratio of default and (normally distributed) market risk losses is also proportional to the square-root of the holding period. Since the ratio goes to 0 as the holding period goes to 0, over short horizons market risk is relatively more important, while over longer horizons losses due to default become more important.

30 There are a number of reasons why the markets for a firm's corporate bonds, loans, or other defaultable instruments are often less liquid than the market for its stocks. These include that bonds and loans often have customised features which may make them especially attractive to particular investor clienteles while at the same time reducing the size of the base of investors that want to trade the bond. Additionally, because bonds are less levered than stocks, their value is less sensitive to information about the firm, and hence there is less reward for trading bonds based on differences in information. Finally, for many years bond trading was less transparent than stock trading, and this too had the effect of reducing bond market liquidity.

31 Masschelein and Tsatsaronis (2008).

32 In general, the overall risk of a portfolio tends to increase with the liquidity horizon. Risk-free zero coupon government bonds are an exception though. If these bonds are held to maturity, their price at maturity is certain and they have no nominal risk, but their price before maturity is unknown ex-ante, and hence they are riskier when held over short horizons than if held to maturity.

33 Guo et al (2007). This is even much less frequent than, for example, the case for small cap stocks in the US. It should also be noted that the sample selection is likely to be biased towards the larger and more frequently traded corporate bond issues.

34 Masschelein and Tsatsaronis (2009).

An important feature of financial markets is that liquidity can change in unpredictable ways. Asset prices will reflect this in the form of risk premiums. When the horizon over which an asset is liquefiable changes, asset prices will move in relation to their risk exposures, since investors require larger risk premiums for being exposed to certain risks for longer. Theoretical IMCR research adds that changes in liquidity should have a larger effect on the prices of assets that, all else equal, have more credit risk.[35] This is an illustration of how liquidity that is time-varying causes market and credit risk to interact.

The relationships between market liquidity and different risks need not only go in one direction: from fluctuations in liquidity to changes in exposures to market and credit risk. Often, dramatic changes in liquidity are preceded by changes in risk and in risk perceptions. For example, further IMCR research shows that changes in risk and uncertainty about valuation models can cause liquidity conditions in markets to deteriorate, which in turn lengthens liquidity horizons, and reinforces the market and credit risk faced by market participants, leading to even more exaggerated price movements.[36]

Market reports about the crisis paint a similar, though more detailed, picture. Investors lost faith in the model-implied and rating-related prices for a number of structured products, such as complex CDOs.[37] As a consequence, investors required increasingly higher premiums reflecting their declining appetite for the risks embodied in structured products. This happened on top of deteriorating fundamentals, such as rising interest rates, declining house prices and a general slow down in the US economy, which also caused rising default correlations. All these factors launched a downward spiral between market prices and liquidity in structured product markets. The implied lengthening of the respective liquidity horizons contributed to the risk of higher price fluctuations and defaults. Against this background, it turned out that the actual liquidity horizons of some important credit instruments, such as CDO tranches, were much longer than market participants had anticipated, so that loss-generating positions could either not be unwound at all or liquidated only at a large additional cost.

Overall, IMCR studies suggest that banks' exposures to market risk and credit risk vary with liquidity conditions in the market, and liquidity conditions in turn are also determined by perceptions of market and credit risk. Going forward, this finding suggests that banks and regulators need to think about a framework that better integrates all three types of risk. From a practical perspective, a promising way for banks to account for this type of interaction may be through the use of stress tests, where the impact of deteriorating market liquidity conditions is explicitly examined and their impact on measured risk accounted for. The assessment and development of stress testing tools is, however, outside the scope of the IMCR group.[38] A more structured approach through the joint modelling of liquidity and other

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[35] See Kobayashi (2007). In the current turmoil one could argue that particularly large price impacts were observed for AAA-rated CDO tranches. This fact, however, does not necessarily contradict the above statement, as it could also result from a particularly large miss-pricing of highly rated tranches.

[36] Kobayashi et al (2008). To explore the connection between uncertainty and liquidity, they explicitly capture liquidity risk using a search-based model and also apply a robust control method that is one of the techniques of stochastic control.

[37] Model risk and uncertainty are also addressed in Section 5.

[38] The Research Task Force of the Basel Committee held a conference on stress testing methodologies of individual banks, in particular on the links between macro risk drivers such as GDP and micro risk measures such as probability of default, in Amsterdam in March 2008. It was hosted by the Netherlands Bank. Some of the research papers presented there will appear as a special issue of the *International Journal of Central Banking*. The Financial Stability Forum (2008) generally recommends under point II.14 to "strengthen stress testing guidance".

factors that drive value may well become more important in the future. It is particularly important for risk management methods and business models that rely on liquid markets for their success. This issue is revisited in the following section in the context of securitisation. The more general need to strengthen liquidity management and its regulatory treatment is recognised by the Basel Committee, which issued a sound practice guidance on this in September 2008.[39]

5. Selected issues related to securitisation

Securitisation allows banks to manage market and credit risk by selling them selectively rather than holding or hedging the total risk. It holds potential benefits by allowing banks to focus on intermediation and selective risk bearing. It relies heavily, however, on the liquidity of primary markets for placing asset-backed securities. The current financial crisis has demonstrated problems that can arise in securitisation. Research illustrates that widespread mis-pricing and distorted investments can occur if the incentives of underwriting banks and investors are improperly aligned. As a consequence the markets for risk sharing and funding can become illiquid, exposing the banks to significant risks. Insufficient knowledge about pricing parameters, such as credit correlations, further increase the risks associated with risk management strategies that rely on securitisation.

By transforming credit risk into market risk and pricing default, the growth of securitisation over the recent years has made it increasingly more important to better understand the interaction of market and credit risk. This section contributes, inter alia, a few points to the current debate on the problems of securitisation that came to the surface through the ongoing financial crisis. Since the remit of the IMCR group is limited to the interaction of market and credit risk, the discussion is very selective and does not address many other important issues in this area.[40]

As noted in Section 2, market and credit risk are both driven by the same underlying economic forces, but how they interact depends on a bank's business model and risk management strategy. Securitisation is fundamentally different from traditional bank lending because banks, after having originated the loans, hold them only for a short time before the loans are sold or before the associated risks of the loans are sliced into tranches and then sold. In other words, with securitisation banks manage the credit and market risks of securitised loans by selling both to the market. When structured appropriately, securitisation is economically valuable because (i) it allows a bank to manage credit and other risks of its loan portfolio and optimise its risk profile and (ii) it allows a bank to focus on financial intermediation activities, such as borrower screening and monitoring, which are areas where banks should have a comparative advantage, and it allows a bank to move away from risk-

[39] See Basel Committee on Banking Supervision (2008) and also Financial Stability Forum (2008), recommendation II.9.

[40] A summary of the main problems is contained in the report by the Financial Stability Forum (2008). Other broad discussions are contained in Ferguson et al (2007), Senior Supervisors Group (2008), Ashcraft and Schuermann (2008), or Institute of International Finance (2008).

bearing (where it may have little comparative advantage) toward risk-sharing with other market participants, including other banks.[41]

The recent experience suggests, however, that incentive problems at various stages of the securitisation process can lead to severe mis-pricing and distorted investments. For example, if the incentives of originators are not sufficiently aligned with those of the holders of risk then banks' intermediation function, including screening and monitoring of borrowers, can be severely impaired. Once these problems become apparent to the wider market, risk sharing markets become dysfunctional or even disappear. If securitisation markets become illiquid, banks can be exposed to heightened risk from exposures to both credit risk (defaults), for example as loans can no longer be securitised, and to market risk from changes in the mark-to-market value of the securitised assets. In addition, when risk-sharing markets become illiquid, the signals from prices can become distorted or even disappear, rendering risk measurement especially challenging.

Because securitisation relies on the presence of liquid markets for sharing the risks of securitised assets, it is important that securitisation practices help to promote the liquidity of risk sharing markets, for example by solving the above problems. Economic research suggests that an important element in aligning the incentives between underwriters and investors is that banks retain a sufficiently strong economic interest in the securitised assets they sell. In general, this would mean retaining some exposure to securitisation cash flows whose payoffs are especially sensitive to how well the bank performs its origination, monitoring and servicing activities.[42]

A further requirement for well functioning markets is that investors in securitisation instruments should have a firm understanding of the associated risks. Recent events exposed deficits in this understanding that were partly related to problems with the availability of information and to the complexity of certain securitisation structures that obscured the links between the performance of the underlying assets and the price of the instruments. For example, the price of CDO tranches is very sensitive to unobservable factors such as forward-looking perceptions of credit default correlations. For more complex structures (re-securitisations, synthetic transactions etc), the sensitivity to unobservables is even more severe, making such products very difficult to hedge or price.

Analysis in selected IMCR studies illustrates the importance of underlying assumptions in the pricing of credit risk transfer instruments with the examples of single name CDS and CDS index tranches that have become an industry reference point.[43] Depending on the particular model assumptions adopted, the implied parameters that are used to price the assets may

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[41] See Jiangli et al (2007). In addition, Cerasi and Rochet (2008), a paper which was presented at IMCR's conference in Berlin, discusses these issues.

[42] In some settings, appropriate incentives are provided when originators retain the first loss tranche. In recent years these tranches were increasingly sold by originators. Still, even this may not necessarily be sufficient in either theory or practice. For example, many originators retained the equity tranche of their securitisations and the financial crisis still broke out. Moreover, some argue that such a "skin in the game" approach could be circumvented through hedging with CDS, although it is not clear that there are enough reference entities in CDS markets to offer viable hedging options for most CDOs. Alternative techniques used by underwriters with a similar purpose are to equip structured products with excess collateral or save some of the interest rate proceeds in a special account. All three techniques would make underwriters bear some losses when underlying assets default. In addition, it is important to note that such techniques would not address all of the incentive issues that have been identified during the recent crisis. For example, conflicts of interest in the activities of credit rating agencies would not be affected.

[43] Scheicher (2006) and Tarashev and Zhu (2008). Some securitisations embed credit derivatives, but similar valuation problems apply to securitisations that do not.

differ substantially, suggesting that there may be substantial basis risk when using these implied parameters for hedging. On balance, valuation and risk measurement in the context of structured finance instruments is subject to high levels of model uncertainty, which should be explicitly incorporated in the analysis of the risk associated with these positions.[44] Failure to fully take account of this uncertainty, in particular in complex forms of securitisation, was one of the contributing factors to the crisis.

[44] See also Financial Stability Forum (2008), recommendation II.12.

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