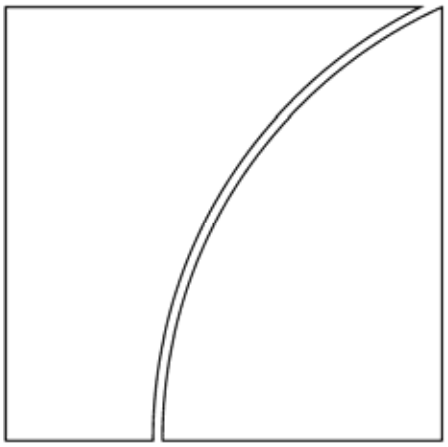
BANK FOR INTERNATIONAL SETTLEMENTS

BIS Quarterly Review

March 2008



International banking and financial market developments

BIS Quarterly Review
Monetary and Economic Department

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Special features

Notations used in this Review

e	estimated
lhs, rhs	left-hand scale, right-hand scale
billion	thousand million
…	not available
.	not applicable
–	nil
0	negligible
$	US dollar unless specified otherwise

Differences in totals are due to rounding.

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Overview: markets reprice to reflect risks to growth

After a relatively calm December that saw markets broadly unchanged, accumulating evidence of a real-side slowdown prompted a broad-based repricing of growth risk and associated shifts in policy expectations in January. While tensions in the money markets eased somewhat during the period under review, weak US macroeconomic data releases, combined with further large-scale bank writedowns and concerns about financial guarantors, increased the perceived chances of global financial stress spilling over into the real economy.

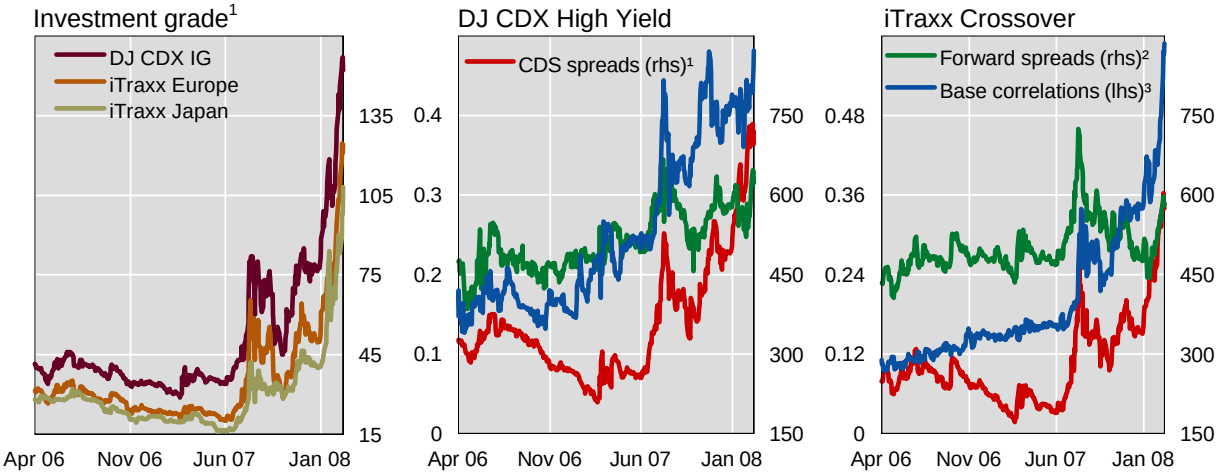
When investors realised that the economic fallout from the credit crisis might not be confined to the United States, asset markets sold off across the board. Credit spreads, which had in fact reflected concerns about broader economic weakness for some time, reached new peaks against the background of growing financial sector strains. Global equity markets saw sharp declines in January as well, as investors revised downwards their expectations of future profitability. However, equities rebounded in February, outperforming credit markets, supported by repeated US monetary policy action. Investors, in turn, were quick to price in additional easing by the US Federal Reserve and by other central banks, anticipating further evidence of slowing growth. Long-term inflation-linked government bond yields declined, and more so than nominal yields, pushing up break-even inflation rates in the United States.

While price reactions to credit market stress had previously been more pronounced among industrialised economies, concerns over a more widespread growth slowdown clearly began to weigh on many emerging financial markets over the period. Equity markets, including those that had shown previous resilience, recorded the most pronounced weakness.

Credit markets deteriorate further

Global credit markets once again experienced considerable volatility and saw spreads rise sharply across the board, as further large writedowns of credit exposures by major financial institutions and continued negative news from the US housing sector deepened concerns about a weakening macroeconomy. Between end-November and 22 February, the US five-year CDX high-yield index spread rose by 204 basis points to 696, while corresponding investment grade spreads moved by 76 basis points to 152. Spreads had narrowed early in the period, before rising precipitously from 10 December, with investment

Credit spread indices



[1] Five-year on-the-run CDS mid-spread, in basis points. [2] Implied five-year CDS spread five years forward, calculated at flat money market rates and with a recovery rate of 40% assuming continuous time and coupon accrual, in basis points. [3] Implied default correlation based on the prices for 0–10% loss tranches of the DJ CDX HY and iTraxx Crossover indices respectively.

Sources: JPMorgan Chase; Markit; BIS calculations. Graph 1

grade names underperforming lower-quality credit (Graph 1, left-hand and centre panels). European and Japanese indices broadly mirrored the performance of their US counterparts. The five-year iTraxx Crossover CDS index climbed 227 basis points to 575, while investment grade spreads rose by 71 basis points to 124. Spreads on the iTraxx Japan index also widened considerably, to around 108 basis points, up 66 from the start of the period. All five indices had moved to the widest levels since their inception back in 2004 on or around 22 January, before reaching even higher peaks by late February (Graph 1, left- and right-hand panels).

Higher expectations of default ...

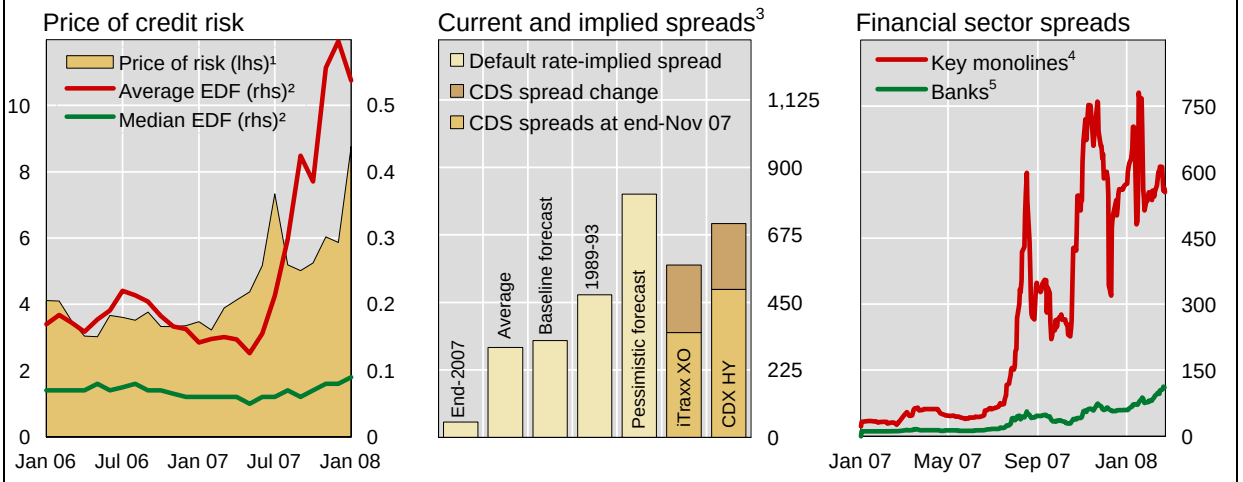
By the end of the period under review, credit spreads had thus risen to levels that would compensate buy and hold investors for a relatively sharp increase in realised default rates from their current near record low levels (Graph 2, centre panel). Expectations of a cyclical increase in defaults were also apparent from rising default correlations implied by tranched index products, which pointed to a rise in the weight attached by investors to systematic as opposed to firm-specific risk factors. Implied forward spreads, in turn, suggested that much of this added risk was anticipated for the near term, reflecting longer-term expectations of an eventual reversion in default rates as well as counterparty risk concerns (Graph 1, centre and right-hand panels).

At the same time, as various risk premia are known to account for sizeable fractions of observed spreads, realised spread levels were unlikely to fully reflect the risks of an economic downturn. While risk tolerance remained at depressed levels (Graph 2, left-hand panel), high-yield credit continued to trade some 350 basis points below the highest comparable cash spreads reached in 2001–02. And spreads remained well below the levels that would fully compensate buy and hold investors were pessimistic forecasts of future defaults to be realised (Graph 2, centre panel).

... reflect weak economic data ...

After a short lull in December, credit market sentiment deteriorated once again in the new year, following the release of data in early January indicating

Price of risk, default rates and sectoral credit spreads



[1] Ratio of risk neutral to empirical probabilities of default. Empirical probabilities are based on Moody's-KMV EDF data. Estimates of risk neutral probabilities are derived from US dollar CDS spreads (document clause MR) and estimates of the recovery rate. The reported ratio is the value for the median name in a large sample of BBB-rated and non-investment grade entities. [2] In per cent. [3] Implied spreads from Moody's global cumulative speculative grade default rates based on a recovery rate of 40%, constant hazard rates, and a risk premium of zero. Calculated for end-2007 one-year default rates, average five-year default rates (1983–2006), five-year cohort default rates (1989–93), and Moody's default rate forecasts up to end-2012; in basis points. [4] CDS spreads for seven financial guarantors. [5] CDS spreads for a sample of 25 commercial, investment and universal banks from Europe and the United States (average Markit rating of AA).

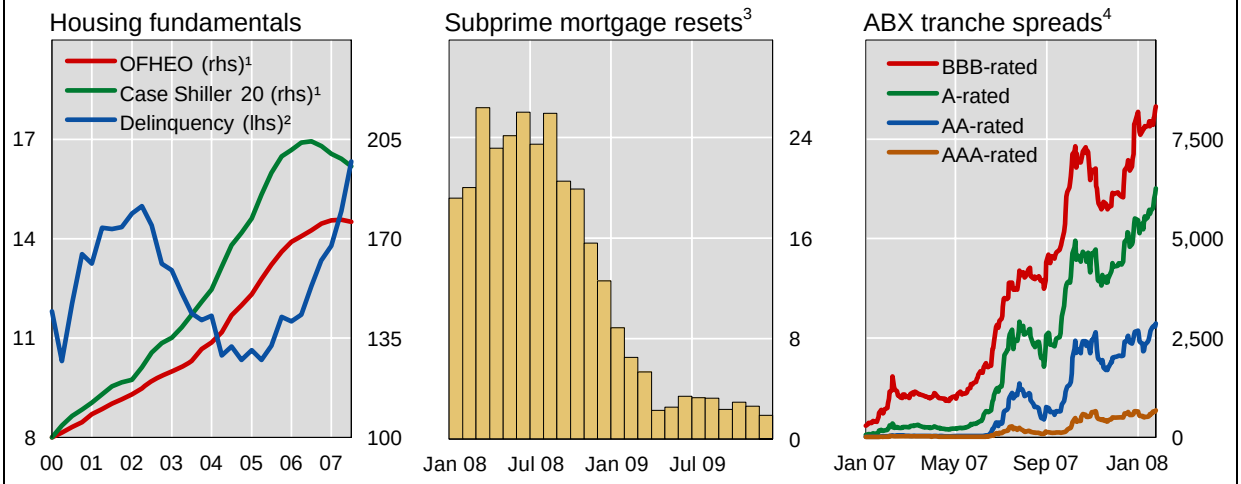
Sources: Bloomberg; Markit; BIS calculations. Graph 2

weak growth in the US manufacturing sector and disappointing labour market developments. With some $250 billion worth of subprime loans estimated to see their first interest rate resets in 2008, a further weakening in house prices and rising unemployment expected to feed into even higher delinquencies, mortgage markets sold off once again. The ABX.HE indices, which reference securities backed by subprime mortgage loans, saw their spreads widen beyond the peak levels established in November. By 22 February, aided by falling Libor rates, prices for the 07-1 BBB– index had thus declined to imply total writedowns of all underlying bonds by late 2009 (Graph 3).

... and continuing financial sector strains

One catalyst for the renewed credit market weakness was continued uncertainty about the ability of the financial system to provide and allocate credit. Parts of the credit market remained largely dysfunctional, with asset-backed issuance volumes down, high-yield bond markets effectively closed, and large backlogs of leveraged loan deals still awaiting financing. Against this background, bank balance sheets continued to be under pressure and financial sector spreads saw renewed widening from mid-January (Graph 2, right-hand panel), adding to perceptions of systemic risk (see box on pages 6–7). Citigroup posted a fourth quarter loss on 15 January, due in part to additional writedowns of $18 billion on mortgage-related exposures. This was followed, during subsequent weeks, by similar news from other financial institutions both within and outside the United States. Although its impact on capital positions was partially offset by injections from sovereign wealth funds and other investors, this new round of large-scale writedowns brought the global total of such charges to around $150 billion. Since a number of earnings announcements also included significant increases in provisions related to

US mortgage markets



¹ House price indices; 2000 Q1 = 100. ² Subprime loan delinquencies as a percentage of total subprime loans; seasonally adjusted. ³ Profile of first-time mortgage resets on outstanding subprime adjustable rate mortgages; in billions of US dollars. ⁴ JPMorgan Chase home equity (ABX.HE 2007-1) closing on-the-run spreads, in basis points.

Sources: Bloomberg; Datastream; Deutsche Bank; JPMorgan Chase. Graph 3

banks' consumer activities, and with spreads on commercial mortgage as well as leveraged loan products widening, projected losses outside the residential mortgage business appeared to be on the rise. This pointed to further strains for financial sector balance sheets and tighter credit conditions ahead.

Signs of improvement in ABCP markets

These strains occurred despite signs of improvement in some markets, such as those for asset-backed commercial paper (ABCP). Spreads narrowed from the highs reached at the end of 2007 and, helped by a number of bailouts of troubled structured investment vehicles (SIVs) by their sponsoring institutions, volumes saw a series of weekly expansions after several months of contraction. The maturity profile of outstanding paper also improved, though at the cost of declining volumes in February, highlighting the continued fragility of the market (Graph 4).

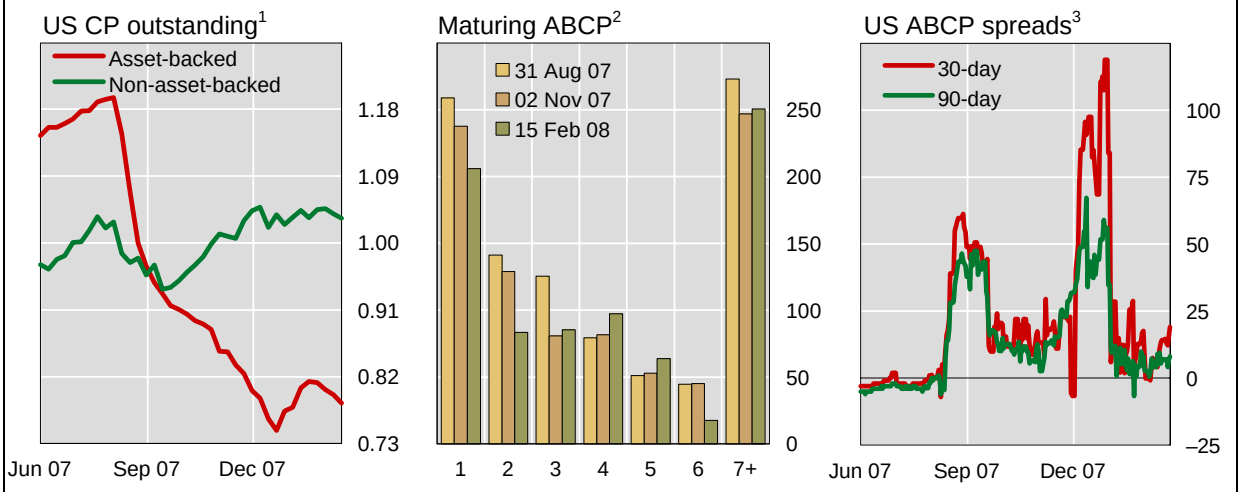
Concerns about monoline downgrades ...

Looming downgrades of monoline financial guarantors proved to be another factor weighing on credit markets. Mark to market losses on insurance written on structured instruments had accumulated in the second half of 2007, triggering large-scale spread increases and reviews of the credit ratings assigned to these companies (Graph 2, right-hand panel). Standard & Poor's had downgraded ACA, a smaller guarantor, from A to CCC in December, giving rise to fears about counterparty risk when the company was unable to meet resulting margin calls. In response, markets increasingly focused on potential downgrades of the bigger AAA-rated monolines, which insure some $2.4 trillion worth of public and structured finance debt.

... and associated writedowns ...

As the ratings of such guaranteed securities tend to be contingent on those of the financial guarantor, rating actions on large monolines were expected to translate into broad-based downgrades of insured bonds and tranches. Related concerns materialised on 18 January, when Fitch downgraded Ambac by two notches from AAA, and also later in the month, when the ratings of SCA and FGIC were cut by the same rating agency. Some 290,000 monoline-insured issues, mostly municipal bonds, were downgraded

Asset-backed commercial paper (ABCP) markets



[1] In trillions of US dollars. [2] Maturity of outstanding ABCP, weeks after data; in billions of US dollars. [3] ABCP yield minus the corresponding Libor rate, in basis points; ABCP yields for A1+ rated issues.

Sources: Federal Reserve Board; Bloomberg; BIS calculations. Graph 4

as a result. Reflecting these and anticipated future downgrades, municipal paper spreads moved to levels which partially discounted existing monoline guarantees. In turn, associated drops in market values and writedowns on monoline-insured exposures to senior structured finance tranches added to losses already incurred by banks and other investors.

... contribute to market volatility ...

Nervousness about feedback effects between these developments and the economic outlook reached a peak later in the month, fuelling volatility across all major asset markets. On 22 January, US investment grade spreads gapped up in early trading, before rallying to close a relatively modest 7 basis points up from the previous trading day. These moves followed not only a long holiday weekend in the United States during which financial markets in other regions had fallen sharply, but also a surprise 75 basis point inter-meeting cut in the federal funds target to 3.5%, which represented the largest one-day change since 1994 and the first one between scheduled meetings since 17 September 2001. High-yield spreads closed 30 basis points wider, but well off their widest intraday levels. Spreads retreated from these peaks during the following days, helped by another 50 basis point adjustment in the federal funds rate on 30 January and congressional approval of a significant fiscal stimulus package in the United States. However, markets remained volatile into February, reflecting further indications of an economic slowdown throughout the major industrialised economies and a continuous flow of financial sector news. This included additional monoline downgrades as well as related recapitalisations and restructuring plans, reports by a large insurer about increased loss estimates for exposures similar to those of the monolines, and renewed concerns about unwinds of structured instruments. By late month, in a sign of an increasing investor focus on interactions between growth risk and financial sector health, spreads on many major credit indices had thus widened beyond their previous peaks, underperforming other asset markets in the process.

... and unwinds of structural exposure

Market perceptions of systemic risk in the banking industry

Nikola Tarashev and Haibin Zhu

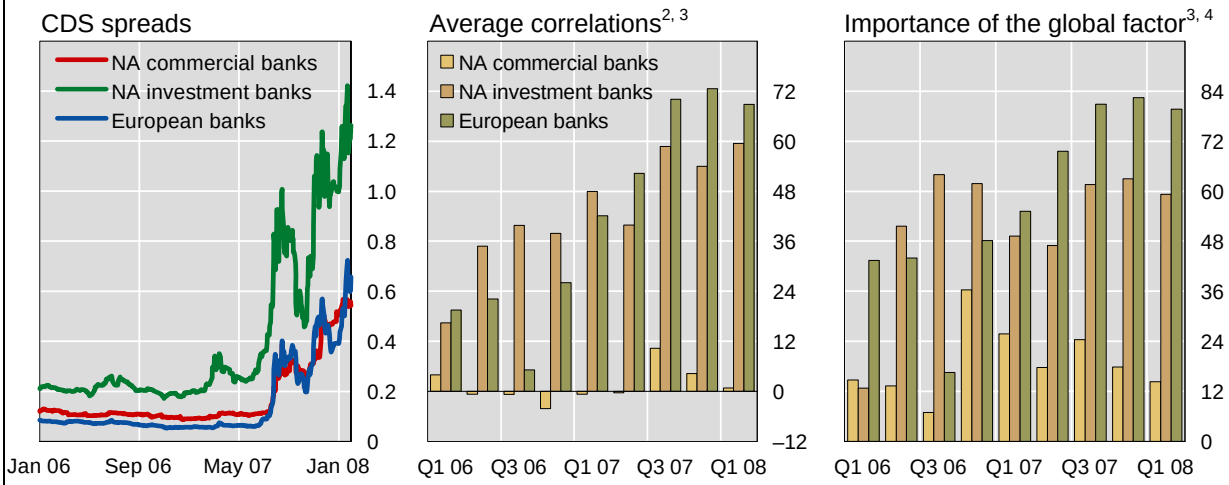
Since the onset of the financial turmoil in the third quarter of 2007, many banks have experienced significant strains, mainly as a result of substantial losses on mortgage-related exposures. To assess the impact of these developments on investors' perceptions of "systemic risk" in the banking industry, this box analyses the credit default swap (CDS) spreads for a sample of large internationally active banks. The main finding of the analysis is that increases in both the level and the co-movement of CDS spreads over the last six months suggest a marked rise in estimated prices of insurance against systemic distress.

CDS spreads represent market prices of insurance against the failure of individual institutions to meet their debt obligations. Thus, the average level and the co-movement of spreads are directly related to perceptions of systemic risk. However, being the price of insurance, CDS spreads reflect not only assessments of the *actual* credit risk associated with a particular institution but also the market *premium* for bearing this risk.① Importantly, in periods of stress and uncertainty, much, if not most, of the level and co-movement of spreads might be driven by attitude towards risk as opposed to by assessments of risk.

The *level* of CDS spreads jumped with the onset of the financial turmoil and has been on an upward trend since then, despite temporary declines that were partly driven by central bank actions (Graph A, left-hand panel). Average spreads increased the most for North American investment banks, from 0.5% in July 2007 to a temporary peak of 1% in August 2007 and then to 1.4% in January 2008. For North American commercial banks and European universal banks, CDS spreads increased by relatively less and have not differed much from each other over the last six months.②

For any given level of CDS spreads, an increase in their *co-movement* implies that the market perceives a greater likelihood of *joint* defaults and, thus, higher systemic risk. This box measures this co-movement via estimates of asset-return correlations, which rose in the third quarter of 2007 for all three banking segments, albeit by a varying amount (Graph A, centre panel). An increase in asset-return correlation since the beginning of 2006 is noticeable for European banks and North American investment banks, from roughly 20% to about 60–70%. By contrast, over the whole period, correlations remained quite low for the sample of North American commercial banks.

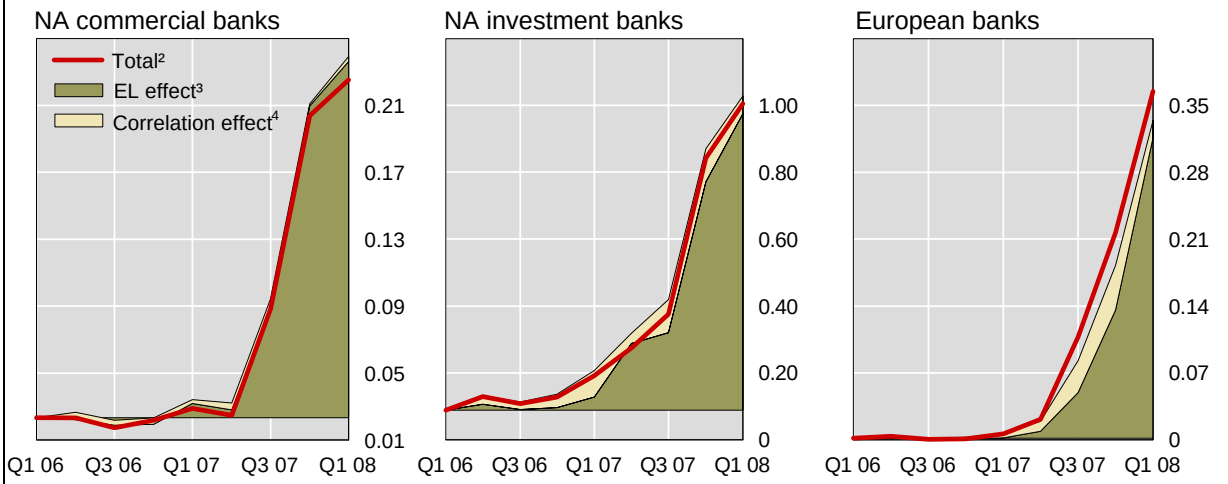
Measures of systemic risk[1]



[1] In per cent. The sample comprises eight commercial and six investment banks headquartered in North America and 11 universal banks headquartered in Europe. [2] Three-month backward-looking asset-return correlations. [3] For the estimation procedure, see N Tarashev and H Zhu, *BIS Working Papers*, no 214, 2006. [4] The share of asset-return volatility that is accounted for by the single most important factor of the asset returns of all 25 banks.

Sources: Markit; authors' calculations. Graph A

Price of insurance against distress[1]



[1] Based on the same data sample as Graph A, in per cent. [2] Risk neutral expectation of credit losses that equal or exceed 15% of the corresponding banking sector's liabilities in 2006 (per unit of exposure to these liabilities). The size of the assumed exposure to a particular bank is proportional to that bank's total outstanding liabilities in 2006. [3] Cumulative effect of changes in risk neutral ELs on the price of insurance against distress. In each quarter, correlations are held fixed at their levels in the previous quarter. [4] Cumulative effect of changes in asset-return correlations on the price of insurance against distress. In each quarter, ELs are held fixed at their levels in the previous quarter.

Sources: Bankscope; Markit; authors' calculations. Graph B

Factor analysis of this co-movement suggests that the differences in asset-return correlations across banking segments are largely driven by an (unobservable) *global* risk factor – ie a factor which, by construction, is common to all the returns in the sample (Graph A, right-hand panel). Since the third quarter of 2007, this factor has accounted for an estimated 80% of the volatility of European banks' asset returns, up from 20% in mid-2006. For North American investment banks, this share has remained relatively stable, at roughly 60% since 2006. In comparison, North American commercial banks' exposure to the same global factor has been much lower.

Both the level and the co-movement of bank spreads suggest that the CDS market has factored in an increase in the price of systemic risk from its very low levels in 2006 and the first half of 2007. This is illustrated by Graph B, which plots the "price of insurance against distress", defined as the implied cost of protection against credit losses that equal or exceed 15% of a sample of banks' total liabilities.[③] This price is dissected into a component that reflects changes in average expected losses (ELs) and another component that reflects changes in asset-return correlations.

The price of insurance against sector-wide distress has generally increased over the last two years but at rates that have varied over time and across banking segments. Driven purely by rising ELs associated with individual institutions, this price rose almost eightfold for the North American commercial banks in the sample, from about 0.03% of their liabilities between the beginning of 2006 and mid-2007 to 0.23% most recently (Graph B, left-hand panel).[④] The corresponding rise for the sample of European banks has been more pronounced, from negligible levels to 0.36%, driven by increases in both ELs and asset-return correlations (Graph B, right-hand panel). Finally, since the beginning of 2006, ELs and asset-return correlations have underpinned the steady growth in the price of insurance against distress at the North American investment banks in the sample. This price is estimated to currently stand at 1% of the institutions' total liabilities (Graph B, centre panel), considerably higher than that for the other two sectors.

[①] In technical terms, CDS spreads reflect so-called "risk neutral" measures of expected losses (ELs). [②] The available time series of CDS market data precludes a useful comparison between recent spread levels and levels realised during previous periods of market stress, eg 2001–02. [③] In qualitative terms, the results in Graph B are robust to changing this threshold between 10 and 30%. [④] The interaction between EL and correlation effects implies that these two effects need not add up to the total price of insurance against distress.

US recession concerns spark equity sell-off in January

Equity markets were subject to much the same concerns as their credit counterparts, with weak US macroeconomic data and more bad news about financial sector exposures contributing to a global sell-off in January. By 22 January, the S&P 500 was down 11% for the month, the worst performance over a similar period since October 2002 (Graph 5, left-hand panel). Equity markets in Japan and Europe also reacted to the deteriorating situation in the United States, losing 17% and 15% over the same period respectively. Equity prices bottomed out around 22 January, following the unanticipated reduction in US short-term interest rates and news of possible capital injections into the monoline insurers. Markets rebounded somewhat in late January, but subsequently gave up much of these gains in February, as further evidence of economic weakness emerged.

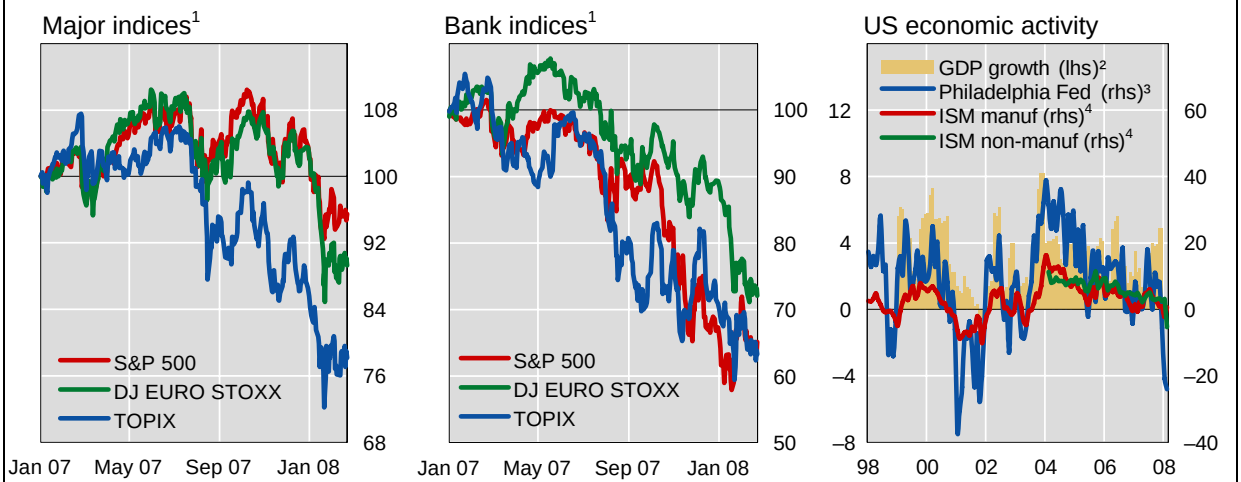
Weak real-side activity in the United States ...

Concerns that the slowdown in the United States might turn out to be more severe than expected came to the forefront in the period under review, as evidence of weaker real economic activity accumulated. Equity markets in the United States were volatile but stable overall in December, with the S&P 500 closing on 26 December up 1% for the month. However, a weak durable goods orders number and an unexpected rise in jobless claims the following day led to a 1.4% decline in the index, and marked the beginning of a downward trend in equity markets. Weak purchasing managers' and employment data releases in early January further soured the mood of investors. Then, on 17 January, the Philadelphia Fed manufacturing index hit its lowest level since 2001, pushing the S&P 500 Index down 2.9% on the day, or more than 9% for the month (Graph 5, left-hand panel).

... culminates in a global equity sell-off ...

This build-up of bad news concerning the US economy culminated in a global sell-off in equity markets on 21 January, a day when US markets were

Equity markets and the US economy



[1] In local currency; 2 January 2007 = 100. [2] Quarterly growth rate in 2000 US dollars, in per cent. [3] Philadelphia Federal Reserve index of general business conditions. [4] Institute for Supply Management manufacturing and non-manufacturing reports on business; actual figures minus 50.

Source: Bloomberg.

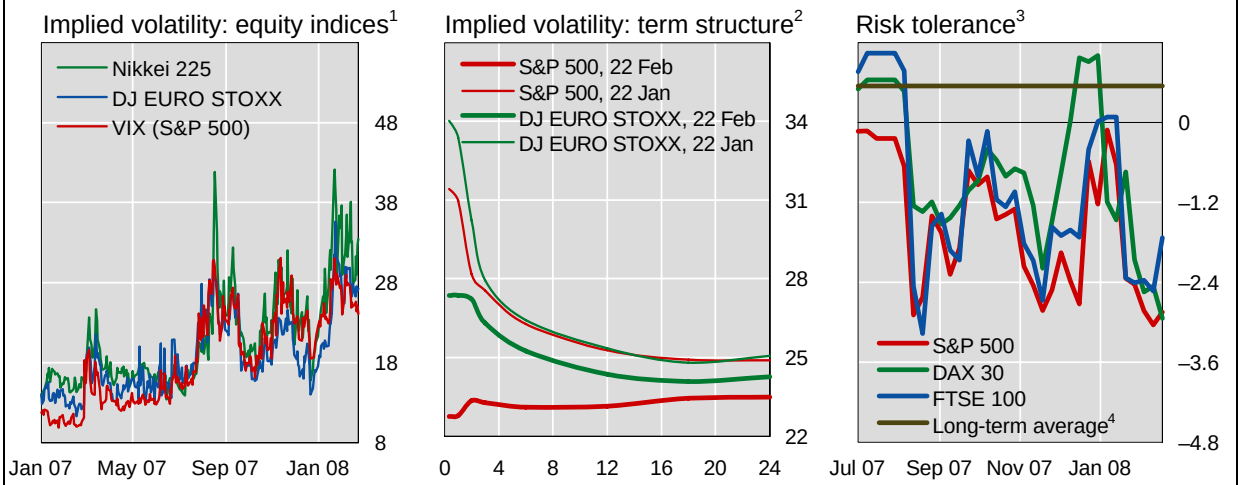
Graph 5

closed. Most major markets saw declines, with the DJ EURO STOXX index down by 6.5%, the largest daily drop since the inception of the index at end-1991, and the TOPIX index down 3.6% and an additional 5.7% the following day. Banks and insurance companies were hit the hardest, reflecting in part concerns over the health of the monoline insurers that followed on the announcement by Fitch that Ambac had been downgraded the previous Friday. Futures prices on the S&P 500 indicated that investors expected a similar rout when markets resumed trading, on 22 January. The unanticipated cut by the Federal Reserve in short-term interest rates on the morning of 22 January, before markets opened in the United States, seemed to temporarily stabilise markets. Equities sold off in the morning hours, but later recovered somewhat, leaving the S&P 500 down 1% from its Friday close. Markets rallied over the following week until the gains were all but eliminated by additional evidence of macroeconomic weakness in the service sector and more bad news about the monoline insurers on 5 February. By 22 February, the S&P 500 Index was up 3% from its 22 January low, but still down 8% for the year.

... and a decline in investors' tolerance for risk

Market-based indicators of investors' tolerance for risk showed sharp declines as equities sold off and volatility increased in January. Option-implied market volatility in the United States, which had risen for most of the month, jumped on 22 January to as high as 31%, a level last seen in mid-November, and considerably higher than the 2004–06 average of 14% (Graph 6, left-hand panel). To some extent, market participants considered this a relatively short-term phenomenon, with readings of the term structure of implied volatility taken on that day dropping off fairly quickly at longer maturities (Graph 6, centre panel). That said, investors still expected volatility levels above 22% for the foreseeable future, almost double the levels reached in early 2007. By

Equity market volatility and risk tolerance



[1] Volatility implied by the price of at-the-money call option contracts on stock market indices, in per cent. [2] Volatility implied by the price of at-the-money call and put option contracts on stock market indices, in per cent. The horizontal axis refers to the maturity of the options, in months. [3] Derived from the differences between two distributions of returns, one implied by option prices, the other based on actual returns estimated from historical data; weekly averages of daily data. [4] Average of the principal component of the risk tolerance indicators for S&P 500, DAX 30 and FTSE 100 over the period March 2005 to end-June 2007.

Sources: Bloomberg; Chicago Mercantile Exchange; Eurex; London International Financial Futures and Options Exchange; BIS calculations. Graph 6

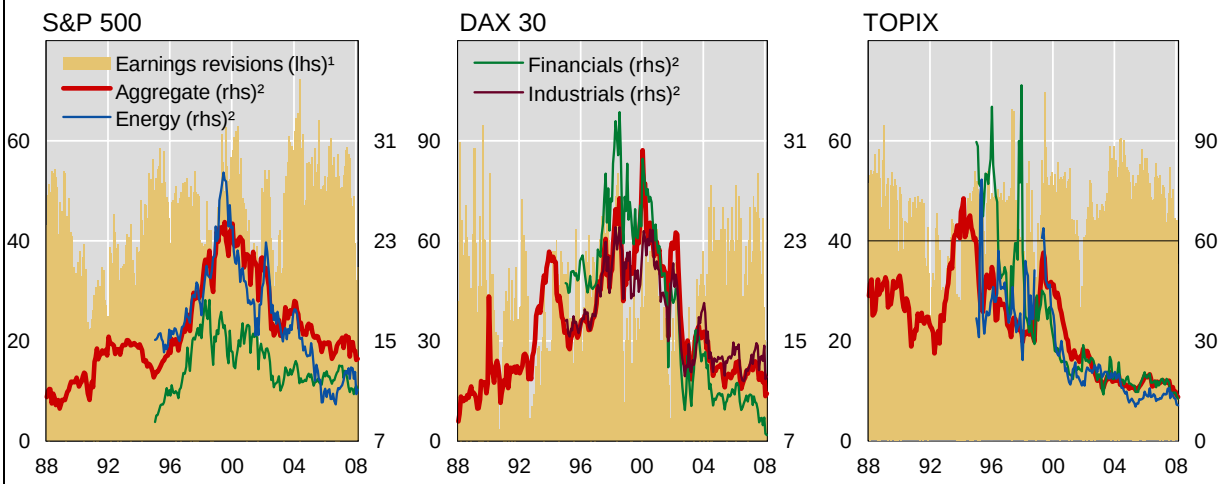
22 February, they had revised these expectations only slightly. Investors' tolerance for risk, measured by differences in the statistical distribution of actual equity returns and expected returns implied by option prices, deteriorated during the sell-off. Indeed, the mid-February readings for US and German markets sank to their lowest levels since the credit crisis began in August (Graph 6, right-hand panel).

Incoming data on fourth quarter 2007 US corporate earnings did little to soothe equity investors during the period. Cumulative earnings per share fell by 17% (year over year, share-weighted basis) in the fourth quarter, considerably more than the 2.5% decline in the previous quarter. Overall growth was dragged down by particularly poor results in the consumer durables industry (–167%) and the financial sector (–108%), the latter reflecting large writedowns by commercial banks during the quarter. Excluding financials, the growth in cumulative earnings per share was positive, at 18%. The string of announcements in mid-January detailing banks' earnings losses and related capital injections tended to exert downward pressure on financial sector equity prices, which were hit particularly hard during the period under review. By 22 February, indices for banks had declined by 12% in the United States, 21% in Europe and 19% in Japan, from their end-November levels (Graph 5, centre panel).

Equity valuations fall to mid-1990s levels

Forward-looking valuation measures have fallen along with global equity indices, despite analysts' increasingly pessimistic forecasts of future earnings growth. Diffusion indices of 12-month forward earnings per share turned down significantly in the current and previous quarter in both the United States and Europe, reaching levels not seen since 2002 (Graph 7, left-hand panel). Yet these downward revisions in earnings did not keep pace with the decline in equity prices, driving down forward-looking valuation measures in the three

Earnings expectations and equity market valuations



[1] Diffusion index of monthly revisions in 12-month forward earnings per share, calculated as the percentage of companies for which analysts revised upwards their earnings forecast plus half of the percentage of companies for which analysts left their forecast unchanged; to adjust for analysts' systematic overestimation of earnings. [2] Ratio of the stock price and the 12-month forward earnings per share.

Sources: I/B/E/S; BIS calculations. Graph 7

major markets. By end-January, the P/E ratio for the S&P 500 Index reached 13, its lowest level since 1995. This represents a significant fall from the levels over 20 reached during the dotcom boom, but is in line with its 1988–97 period average (Graph 7, left-hand panel).

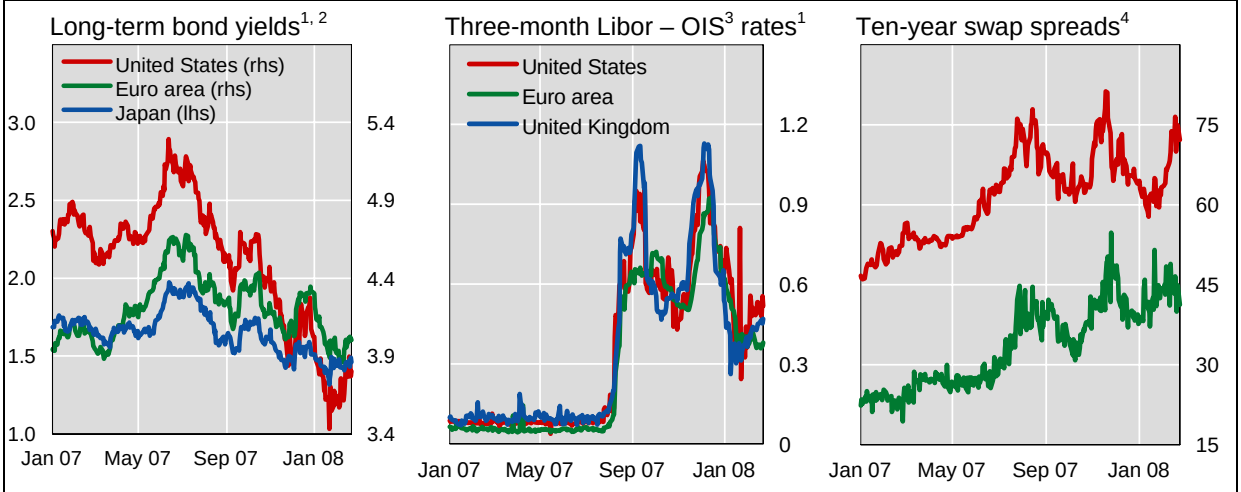
Government bond yields follow equities lower

After rising moderately up to late December, long-term government bond yields plummeted in January amid the ongoing global reassessment of risky assets. The slowdown in US real economic activity and increasing safe haven flows from equity markets, against the backdrop of the FOMC rate cuts in early December and late January, drove down 10-year US Treasury nominal yields from a recent high of 4.28% on 26 December to 3.43% on 22 January (Graph 8, left-hand panel). Yields remained relatively unchanged for the next three weeks, despite the additional cut on 30 January, but then drifted higher to 3.80% on 22 February. Long-term yields in the euro area followed the trend of those in the United States, declining by 12 basis points from end-November to 4.0% on 22 February, while long-term rates in Japan declined by 2 basis points to 1.46%.

Tensions in money markets ease

The disruptions in money markets, which started in August 2007, seemed to worsen in December (see Upper and Michaud in this issue for discussion). News of losses by banks continued to dribble out to the market, putting upward pressure on spreads between Libor and overnight indexed swap (OIS) rates, a measure of some combination of counterparty credit and liquidity risks in money markets (Graph 8, centre panel). Central banks responded with a coordinated effort, announced on 12 December, to provide ample term liquidity to the financial markets (see Borio and Nelson in this issue for discussion); by mid-January, Libor-OIS spreads had come in from their December highs. Swap spreads, which had widened considerably during the early months of the crisis,

Interest rates and spreads



[1] In per cent. [2] Ten-year government bond yields; for the euro area, German bund. [3] For the euro area, EONIA; for the United Kingdom, SONIA. [4] In basis points.

Sources: Bloomberg; BIS calculations. Graph 8

fell in the United States during much of the period, reaching lows on 15 January last seen in June (Graph 8, right-hand panel). While this was consistent with an easing of money market tensions, swap spreads again trended higher up to mid-February.

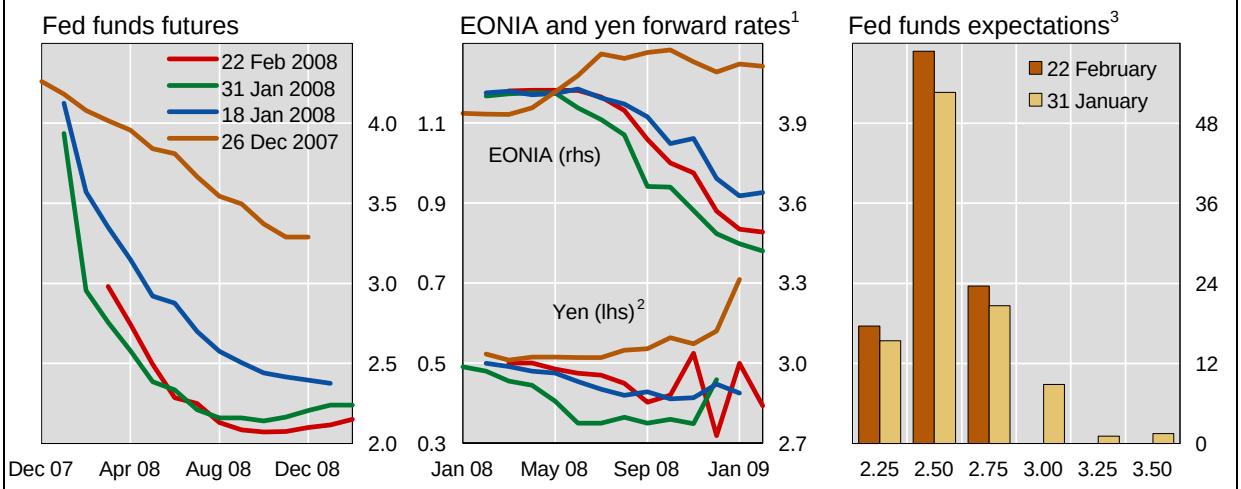
As equity markets skidded through early January, market participants began to expect greater monetary easing in the United States. These expectations were reinforced following a speech by the Chairman of the Federal Reserve on 10 January, indicating that the Fed was prepared to take "substantive additional action as needed" in the face of the deteriorating outlook for US growth. Fed funds options around that time implied that investors expected at least a 50 basis point cut, with a high probability of a 75 basis point cut, at the scheduled FOMC meeting on 30 January. Market participants seemed to interpret the unanticipated cut in short-term interest rates on 22 January as evidence that the FOMC regarded the downside risks to growth and financial stability as more severe than the risk of higher future inflation. Accordingly, the market reacted by pricing in even more monetary easing in 2008, particularly in the first half of the year (Graph 9, left-hand panel). Fed funds options in the days following the rate cut fully anticipated the further 50 basis point cut at the regularly scheduled FOMC meeting on 30 January. Moreover, fed funds futures on 31 January priced in further cuts, putting short rates at 2.75% by end-March, and possibly as low as 2% by the end of 2008. By 22 February, markets were pricing in a 59% chance of a 50 basis point cut at the 18 March FOMC meeting (to 2.5%), and end-of-year expected short rates had fallen further.

Aggressive monetary policy action reflects downside risks to growth

The mounting evidence of an economic slowdown in the United States contributed to relatively sharp declines in real yields on index-linked bonds in January (Graph 10, left-hand panel). Following a brief rise in December, real

Forward curves and fed funds expectations

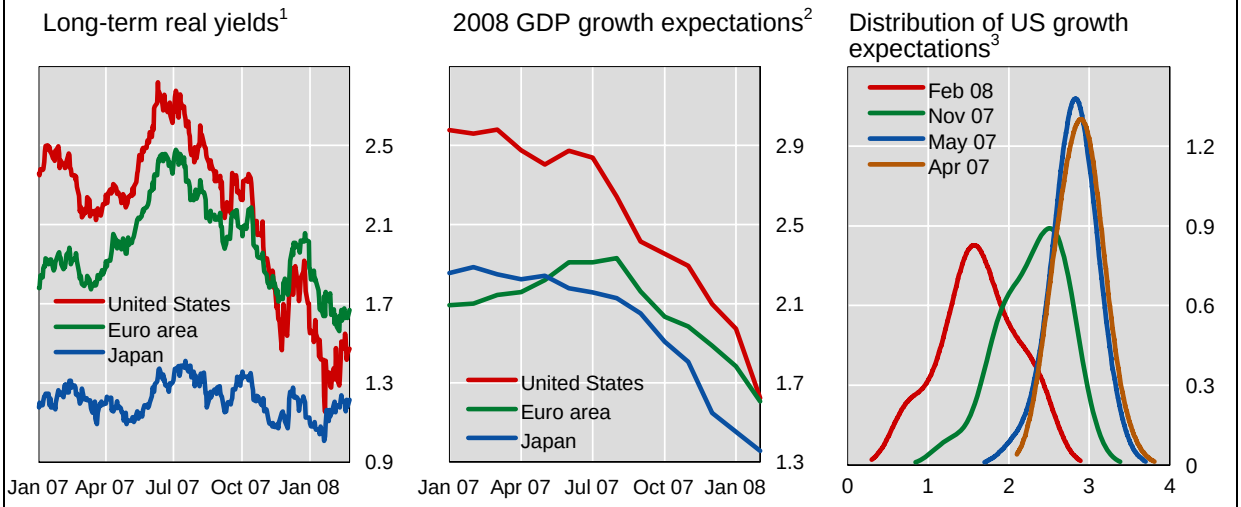
In per cent



[1] Implied one-month rates. [2] Calculated from OIS rates. [3] Probabilities of changes in the fed funds target rate implied by prices of fed funds options, relative to the 18 March 2008 meeting. The horizontal axis indicates the fed funds expected target rate and the vertical axis indicates the probabilities.

Sources: Bloomberg; BIS calculations. Graph 9

Real yields and growth expectations



[1] Ten-year yields on index-linked government bonds, in per cent; for the euro area, based on French government bonds linked to euro area inflation. [2] Forecasts as published monthly by Consensus Economics, in per cent; observations are positioned in the month in which the forecast was made. [3] Based on the individual contributor's forecasts as published monthly by Consensus Economics; fitted using a normal kernel density function; the horizontal axis indicates the GDP growth rate, in per cent.

Sources: Bloomberg; © Consensus Economics; national data; BIS calculations. Graph 10

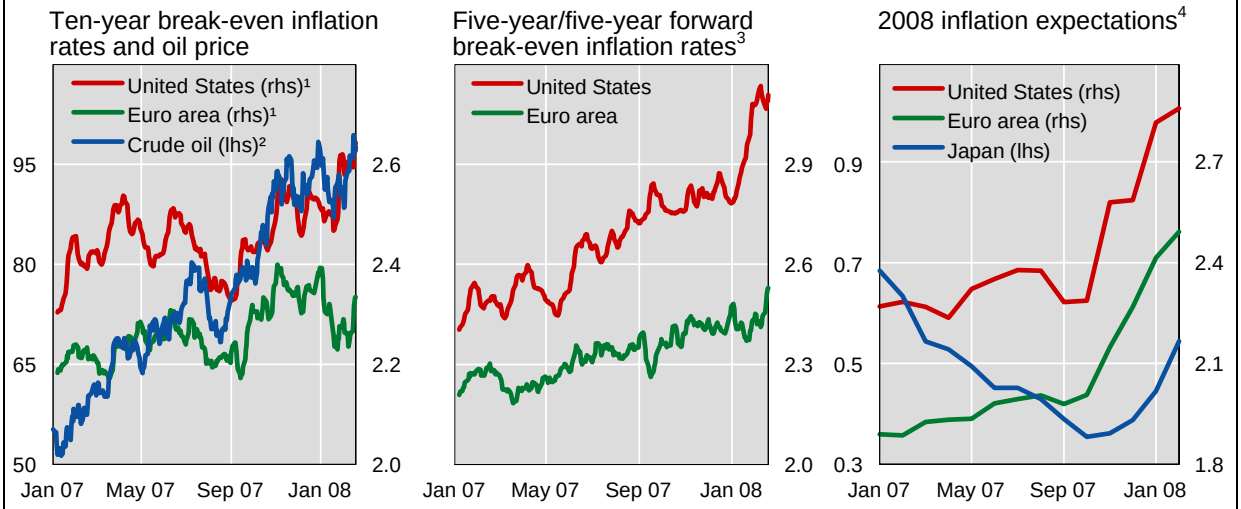
yields in the United States continued their downward trajectory which had been evident since July, falling to as low as 1.15% on 23 January. Similarly, real yields in the euro area fell to 1.64% on 23 January, from 1.83% at end-November. This was mirrored in analysts' expectations of 2008 GDP growth, which were further revised downwards in January and February, falling to as low as 1.62% in the United States and to 1.61% for the euro area (Graph 10, centre panel). In the United States at least, these forecasts have become more dispersed, suggesting greater uncertainty about future growth (Graph 10, right-hand panel).

Nominal yields rose more than real yields after late January, as investors increasingly focused on the possibility of higher future inflation, particularly in the United States. Even as analysts revised upwards their 2008 inflation forecasts (Graph 11, right-hand panel), 10-year break-even inflation rates in the United States changed little between end-November and mid-January, hovering near 2.5% (Graph 11, left-hand panel). However, boosted in part by rising oil prices, break-even inflation jumped in late January following the second cut in interest rates by the Federal Reserve, and trended upwards to 2.64% by 22 February. Longer-term expectations implied by five-year forward break-even inflation rates five years ahead, which are less likely to be influenced by transient shocks, rose even more sharply (Graph 11, centre panel).

Euro area inflation expectations remain anchored

Relative to the United States, expectations of future inflation in the euro area, as indicated by break-even inflation rates, remained relatively anchored for much of the period under review. Although up by roughly 25 basis points since May 2007, five-year forward break-even inflation five years ahead had remained near 2.4% between end-November and mid-February (Graph 11, centre panel). In the weeks prior to 22 January, incoming data releases

Break-even inflation rates, oil price and inflation expectations



[1] Nominal minus real 10-year bond yields, in percentage points. [2] Brent, in US dollars. [3] Five-year forward break-even inflation rates five years ahead, calculated from estimated zero coupon spot break-even rates; in per cent. [4] Forecasts as published monthly by Consensus Economics; observations are positioned in the month in which the forecast was made; in per cent.

Sources: Bloomberg; © Consensus Economics; national data. Graph 11

seemed to indicate that downside growth risks were becoming stronger in the euro area, leading investors to put a lower probability on rate increases by the ECB. Despite a higher than expected euro area inflation estimate of 3.2% on 31 January, the highest reading in 14 years, worse than expected growth in the euro area service sector in January seemed to convince investors that future rate cuts had become more likely. This view was reinforced following the ECB statement on 7 February which indicated that the downside risks to growth had indeed become more of a concern. Accordingly, market participants lowered their expectations of future rates (Graph 9, centre panel), while break-even inflation rates edged higher (Graph 11, centre panel).

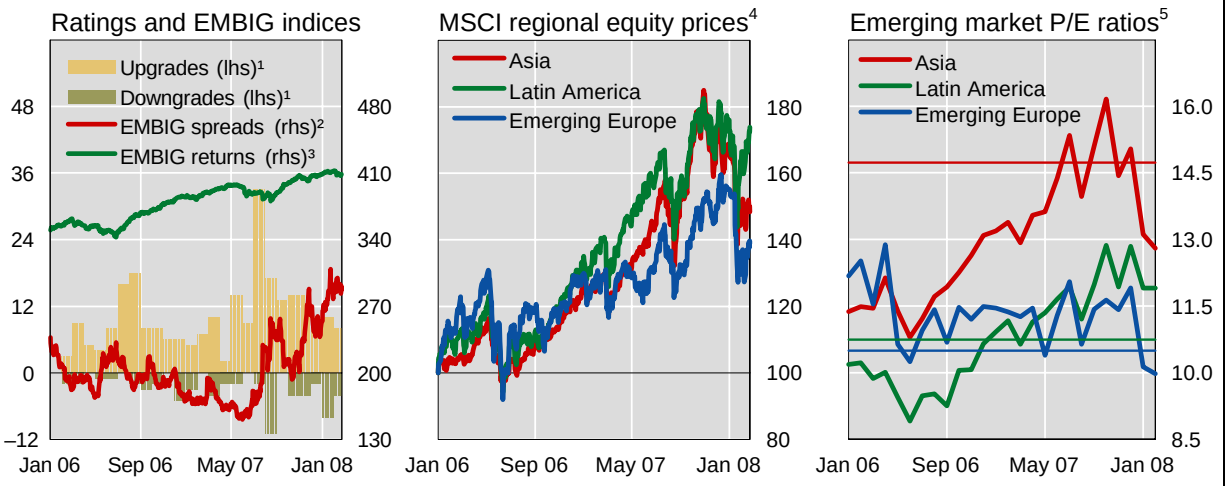
Investors question emerging market decoupling

While price reactions to credit market stress had previously been more pronounced among industrialised economies, concerns over a more widespread growth slowdown clearly began to weigh on many emerging financial markets over the period. Emerging market equity prices, in particular, fell across the board in January, suggesting that risk tolerance and earnings expectations were coming under pressure. This included countries and markets that had previously been among the most resilient.

Emerging market spreads widen ...

Spreads on the EMBI Global emerging market bond index widened from lows around 240 basis points in late December to a high of 309 on 23 January, before falling back to near 287 basis points by 22 February. The index returned some 0.7% between end-November and late February and remained relatively stable in yield terms for much of the period, suggesting that part of the observed spread movement was offset by changes in US Treasury yields. Positive rating changes continued to outweigh negative ones, although the margin was declining, signalling that domestic macroeconomic fundamentals

Emerging market assets



[1] Monthly long-term foreign and local currency sovereign rating changes from Fitch, Moody's and Standard & Poor's. [2] EMBI Global index; sovereign spread over government bond yields, in basis points. [3] EMBI Global index; cumulative total returns. [4] In local currency; 31 December 2005 = 100. [5] P/E ratios based on consensus forecasts of one-year operating earnings; MSCI indices; the horizontal lines indicate the long-term averages.

Sources: Bloomberg; Datastream; JPMorgan Chase; BIS calculations. Graph 12

were providing relative support in an environment of increased uncertainty about global growth (Graph 12, left-hand panel).

... and equity markets weaken ...

Equity markets, including those that had shown previous resilience, saw more pronounced weakness. Between end-November and 22 January, the MSCI emerging market index lost some 15% in local currency terms and was still down about 7.5% by late February, despite markets recovering in the wake of the two US interest rate decisions. Asian equities and, to a lesser extent, those from emerging Europe were hit particularly hard (Graph 12, centre panel).

... as investors question market decoupling

Investors appeared to challenge previous assumptions regarding the remoteness of Asian and emerging European equity markets from problems facing the United States, suggesting a change in investor emphasis from direct to indirect sources of risk to growth and earnings. While Mexican exports had long been viewed as vulnerable to a US downturn and smaller Latin American economies were expected to suffer from slowing remittance flows, Asian markets were seen as more sensitive to global growth and commodity price trends. European emerging markets, in turn, were known to be exposed to the risk of slower growth in the major European economies. On this basis, the relative weakness of Asian and emerging European equity markets seemed consistent with expectations of a cyclical adjustment in earnings in the wake of slowing global growth. At the regional level, index valuations masked significant differentiation across individual countries (Graph 12, right-hand panel). Thus, having started the recent correction at elevated levels, price-earnings multiples for countries such as Brazil, China and India continued to be above their historical averages.

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Highlights of international banking and financial market activity[1]

The BIS, in cooperation with central banks and monetary authorities worldwide, compiles and disseminates several datasets on activity in international banking and financial markets. The latest available data on the international banking market refer to the third quarter of 2007. The discussion on international debt securities and exchange-traded derivatives draws on data for the fourth quarter of 2007.

The international banking market

Activity in the international banking market continued to expand in the third quarter of 2007, amidst growing tensions in global financial markets. The three sections below focus on developments in the interbank market using the three sets of international banking statistics collected by the BIS. The first tracks the movements in the most recent quarter, with particular emphasis on activity in banks located in the United Kingdom. The next section provides an analysis of the evolution of international banks' US dollar funding needs. The data suggest that European banks have, since 2000, increasingly borrowed from other banks to finance their growing net long positions vis-à-vis non-banks, which may have contributed to problems in the interbank market as refinancing became more difficult. The third section looks at bilateral interbank exposures of various national banking systems using the BIS consolidated banking statistics. Relative to Tier 1 capital, international interbank exposures differ significantly across systems, with European banks generally exhibiting higher ratios than US banks.

Global flows and the London interbank market

BIS reporting banks' cross-border claims continued to expand in the period under review. Total claims rose by $1.1 trillion in the third quarter of 2007, to reach $32 trillion. An expansion in interbank claims accounted for $661 billion of the overall increase, despite the growing squeeze in various segments of the

[1] Queries concerning the banking statistics should be addressed to Patrick McGuire and Goetz von Peter and queries concerning international debt securities and derivatives statistics to Naohiko Baba.

market. In recent quarters, the rate of expansion in international bank credit rose to its highest level in 20 years. The year-on-year growth in total claims, which has been accelerating steadily since 2002, reached 22% in the most recent quarter, a level last seen prior to the 1987 stock market sell-off. As discussed in more detail in the box on pages 24–5, economic slowdowns and episodes of financial turmoil in the past were often preceded by periods of accelerating growth in international bank credit, particularly in interbank lending.

The top panels of Graph 1 map the net flow of funds via the international banking system in the third quarter of 2007. The largest arrow, representing a net flow of funds ($172 billion) from the United States to the United Kingdom, was in part driven by changes in interbank positions (top right-hand panel). US dollar-denominated claims booked by banks in the United States on banks in the United Kingdom expanded by $89 billion in the most recent quarter, driving the overall estimated net interbank flow of $71 billion. The BIS locational banking statistics by nationality, which do not provide a vis-à-vis country breakdown, suggest that much of this reflected inter-office activity of UK-headquartered banks.[2]

Changes in positions vis-à-vis non-banks also contributed to the overall net transfer of funds from the United States to the United Kingdom (Graph 1, top left-hand panel).[3] Banks in the United Kingdom reduced their claims on non-banks in the United States by $26 billion, reflecting a drop in loans ($39 billion) and equity claims ($23 billion).[4] This contributed to the first significant decline ($56 billion) in their net claims on these non-banks, which had been growing steadily since 2002. Overall, net claims of banks in the United Kingdom (including islands) on non-banks (worldwide) have grown by an estimated $1 trillion since end-1999, much of which was denominated in US dollars.[5] At the same time, their net liabilities to banks increased by a similar amount, a sectoral transformation which is shown in Graph 1 (bottom left-hand panel).[6] Growing net liabilities to banks in Switzerland, the euro area, Asian offshore centres and oil-exporting countries have presumably been used to

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[2] Data reported by the United States indicate a $72 billion increase in claims on own offices abroad booked by UK-headquartered banks located in the United States.

[3] This includes loans to corporate borrowers and non-bank financial institutions as well as investment in debt and equity securities. Across all reporting countries, debt security claims on non-banks have grown from $1.2 trillion (or 35% of total claims on non-banks) in the first quarter of 2000 to $4.3 trillion (or 37%) in the third quarter of 2007.

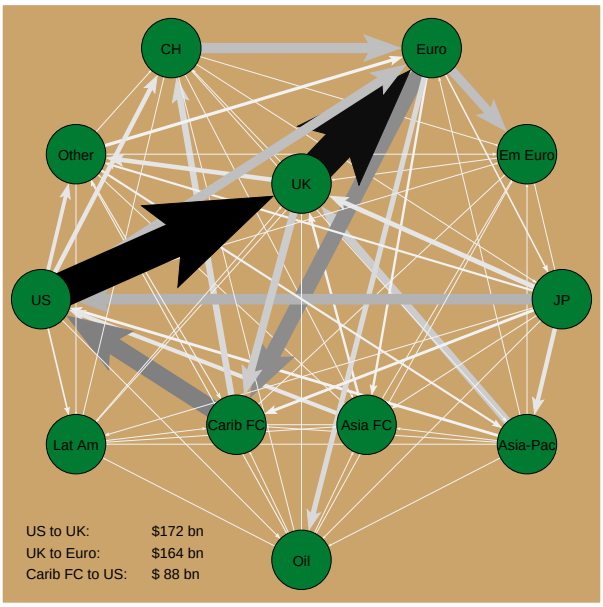
[4] This was partially offset by greater investment in debt securities ($37 billion), which possibly reflected a shift into US Treasury securities. While impossible to identify precisely, the BIS consolidated banking statistics indicate that claims on the US public sector booked by French, German and UK banks rose by an aggregate $71 billion.

[5] On a gross basis, banks in the United Kingdom reported $3 trillion in claims on non-banks in the third quarter of 2007, roughly half of which was denominated in US dollars.

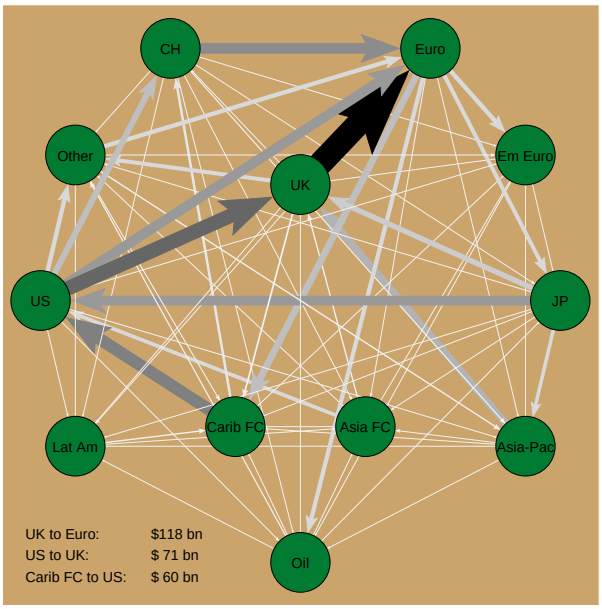
[6] Liabilities to banks include positions vis-à-vis own offices, other banks and official monetary authorities. In the BIS statistics, uncollateralised interbank positions cannot be distinguished from collateralised (ie repo) transactions.

Net flows of funds through the international banking system[1]

Total net flows[2] during 2007 Q3

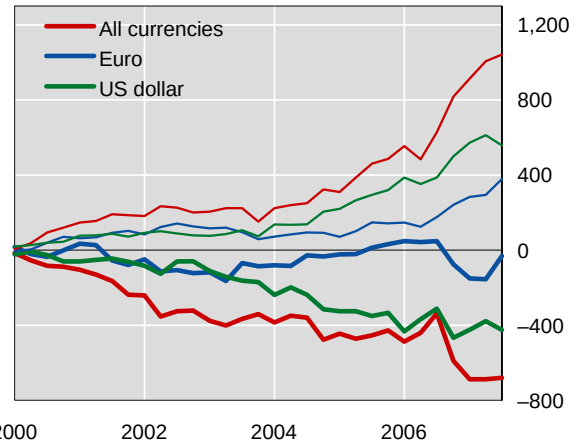


Interbank net flows[2] during 2007 Q3

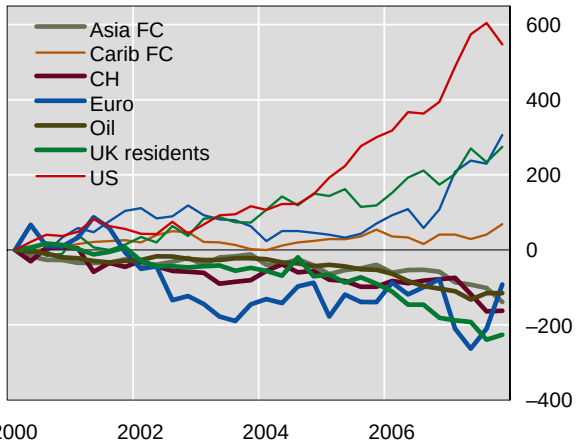


Cumulative net flows through banks in the United Kingdom[3]

By currency and sector



By counterparty and sector



Asia FC = Asian financial centres (Hong Kong SAR, Macao SAR and Singapore); Asia-Pac = China, India, Indonesia, Korea, Malaysia, Pakistan, the Philippines, Taiwan (China) and Thailand; Carib FC = Caribbean financial centres (Aruba, the Bahamas, Bermuda, the Cayman Islands, the Netherlands Antilles and Panama); CH = Switzerland; Em Euro = emerging Europe (Bulgaria, Croatia, Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia, Slovenia, Turkey and Ukraine);
Euro = euro area member states excluding Slovenia; JP = Japan; Lat Am = Argentina, Brazil, Chile, Colombia, Mexico and Peru; Oil = OPEC member states (excluding Indonesia) plus Russia; Other = Australia, Canada, Denmark, New Zealand, Norway and Sweden; UK = United Kingdom, Guernsey, the Isle of Man and Jersey; US = United States.

[1] Exchange rate adjusted flows, expressed at constant end-2007 Q3 exchange rates. [2] The thickness of an arrow is proportional to the amount of net bank flows between countries/groups, and is comparable across panels. An arrow points from A to B if net flows in this direction are positive, calculated as net interbank claims (assets minus liabilities) of banks in A on banks in B, plus net claims of banks in A on non-banks in B, minus net claims of banks in B on non-banks in A. (This last component is missed if B is not a reporting country.) The graph does not show intraregional flows or reporting banks' lending to domestic residents. See also P McGuire and N Tarashev, "Tracking international bank flows", *BIS Quarterly Review*, December 2006. [3] UK as defined above, in billions of US dollars. Thick lines refer to interbank net flows, thin lines to non-bank net flows.

Source: BIS international locational banking statistics on a residence basis. Graph 1

finance their net claims on non-banks, primarily in the United States (Graph 1, bottom right-hand panel).

US dollar funding in the interbank market

The sectoral transformation taking place in banks in London is analysed in more detail in this section, with an eye towards identifying the national banking systems involved. Market commentary has suggested that European banks had difficulty obtaining US dollar funding as the tensions in the interbank market grew in the second half of 2007. The BIS locational statistics *by nationality* allow for a (partial) reconstruction of the global balance sheets of banks of a given nationality, thus providing some information, albeit incomplete, on these banks' net funding requirements in a particular currency.[7]

US banks channel US dollars to the interbank market ...

Overall, these data suggest significant differences in the global funding patterns of European and US banks. The top panels of Graph 2 portray aggregated net claims, broken down by sector, booked by offices of US and European banks located in various reporting countries (as detailed in the lower panels).[8] As shown in the top left-hand panel, US banks have borrowed US dollars from non-banks, and have channelled these funds to unaffiliated banks through the interbank market. By the third quarter of 2007, their total net claims on other banks (excluding inter-office claims) reached $442 billion, up from virtually nil in 1999.

... to fund European banks' investment in non-banks

At the same time, European banks have borrowed from other banks to fund US dollar claims on non-banks (Graph 2, top right-hand panel). Since 1997, their net liabilities to banks, which include both uncollateralised loans and repo financing, have grown to more than $800 billion, much of this to unaffiliated banks and official monetary authorities. European banks have booked a substantial portion of their claims on non-banks from their offices in London (Graph 2, bottom right-hand panel), with German, UK and, to a lesser extent, Dutch and Swiss banks increasing their net claims the most. German banks' US dollar-denominated net claims on non-banks grew from $50 billion in 2000 to $463 billion in the most recent quarter.

These diverging positions of US and European banks suggest that the latter face relatively large US dollar funding requirements, which may help in understanding the liquidity squeeze in the interbank market during the second half of 2007. Interbank borrowing tends to be short-term, whereas banks' investment in non-banks is of varying maturities. While the associated term risk may have been hedged, the build-up of European banks' US dollar liabilities to other banks presumably used to fund their US dollar non-bank assets may

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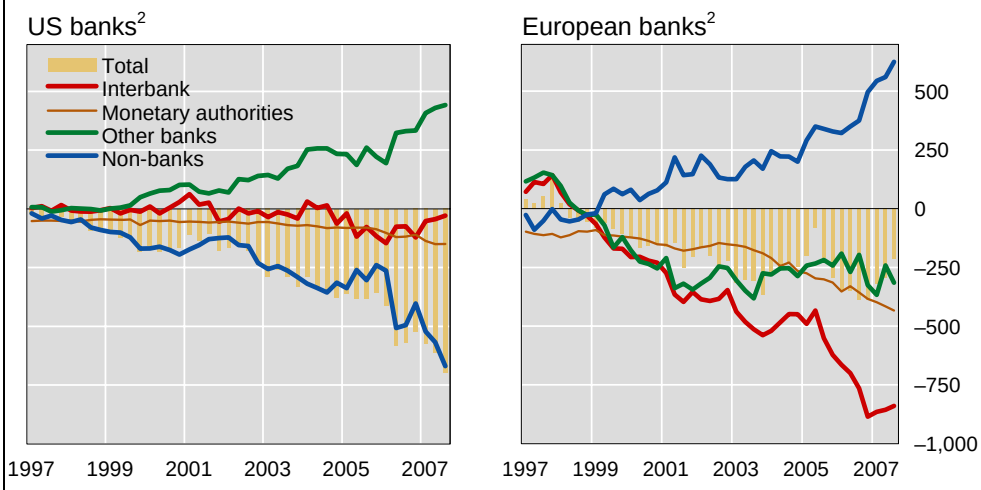
[7] The *BIS locational statistics by nationality* provide a breakdown of banks' total cross-border positions (in all currencies) and positions vis-à-vis residents (in foreign currencies), broken down by the *nationality of the parent bank* in each reporting country. Positions are further broken down by sector (non-bank, other bank and inter-office) and by currency, but not by vis-à-vis country.

[8] These data should be interpreted with caution since they exclude US dollar-denominated claims on residents booked by offices in the United States and claims on all counterparties booked by offices in non-reporting countries. The figures presented in Graph 2 tracking net claims on "other banks" exclude inter-office borrowing. However, the US dollar positions reported by France and Germany do not distinguish these from inter-office positions, and are treated as positions vis-à-vis "other banks".

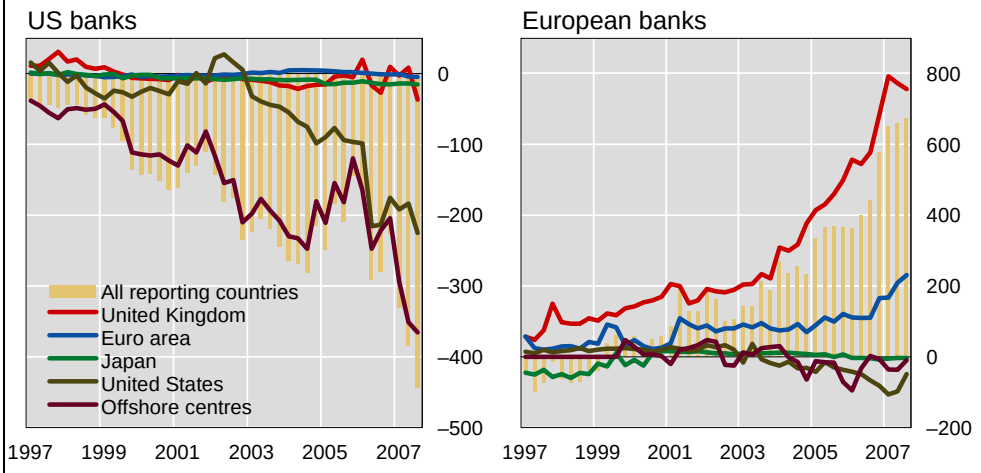
Funding in the US dollar interbank market

In billions of US dollars

Net claims,[1] by bank nationality



Net claims[1] on non-banks, by location of booking office



[1] Net claims are calculated as cross-border claims minus cross-border liabilities. The interbank component is further broken down into inter-office claims (not shown), claims on other banks and claims on official monetary authorities. [2] Net claims of banks' offices located in all BIS reporting countries are aggregated by the parent country indicated in the panel heading.

Source: BIS locational banking statistics by nationality of ownership of reporting banks. Graph 2

have required a frequency of rollovers in the interbank market that became difficult to maintain as market tensions increased.

Global interbank exposures

From the preceding focus on funding and liquidity risk, this section shifts the discussion to an analysis of counterparty risk in the interbank market. From this perspective, the BIS consolidated statistics on an ultimate risk basis (UR basis) provide relevant information at the level of national banking systems, including both cross-border and local positions.[9] These statistics can be used to track

[9] The ultimate risk reporting concept, combined with the sectoral breakdown, provides a rough estimate of *bilateral* interbank exposures of national banking systems. For example, on a UR basis, interbank claims reported by the United States vis-à-vis the United Kingdom provide an estimate of US banks' global claims on UK banks (as opposed to US banks' claims on banks

bilateral exposures of national banking systems (regardless of the location of their respective offices), thus shedding light on the overall structure of global interbank exposures at the onset of the turmoil.

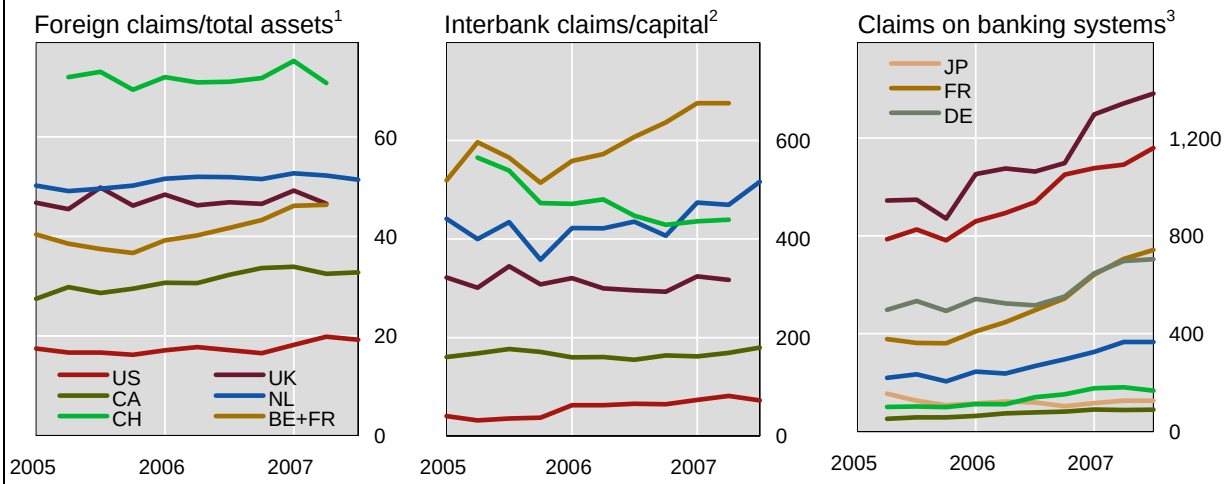
Foreign exposures can be large relative to total assets ...

The size of foreign exposures differs substantially across banking systems. UK and German banks' foreign claims (UR basis) are the largest, both standing at $4.1 trillion, followed by French banks ($3.2 trillion), Swiss, Dutch and Japanese banks (over $2 trillion each) and US banks ($1.7 trillion). Scaling these foreign exposures by banks' total assets (ie including domestic assets) yields a more comparable measure for gauging the importance of international business across different national banking systems (Graph 3, left-hand panel). So measured, foreign exposures have been relatively stable, but these ratios differ greatly across banking systems. For example, foreign claims account for less than 20% of US banks' total assets, for 30–50% of Canadian, UK, Belgian and French banks' total assets, and for over 50% of Swiss and Dutch banks' total assets.

... and relative to Tier 1 capital

Exposures to other national banking systems make up a significant share of banks' total foreign exposures. Scaled by Tier I capital, US banks' interbank exposures are relatively small, at roughly 72% of their Tier I capital, albeit up from 40% in 2005 (Graph 3, centre panel). At the other end of the spectrum are Belgian and French banks, with their combined international interbank

Global exposures of selected national banking systems



Banks headquartered in CA = Canada; CH = Switzerland; DE = Germany; FR = France; JP = Japan; NL = Netherlands; UK = United Kingdom; US = United States; BE+FR = Belgium and France (Belgian and French banks are combined). The ratios in the left-hand and centre panels are computed using total assets and Tier 1 capital respectively of internationally active banks reporting the consolidated banking statistics. Semiannual balance sheet data (CH, FR, UK) are converted to quarterly frequency by interpolation (cubic spline) up to the most recent available quarter. Data are not adjusted for exchange rate changes, since currency breakdowns are not reported in the consolidated banking statistics.

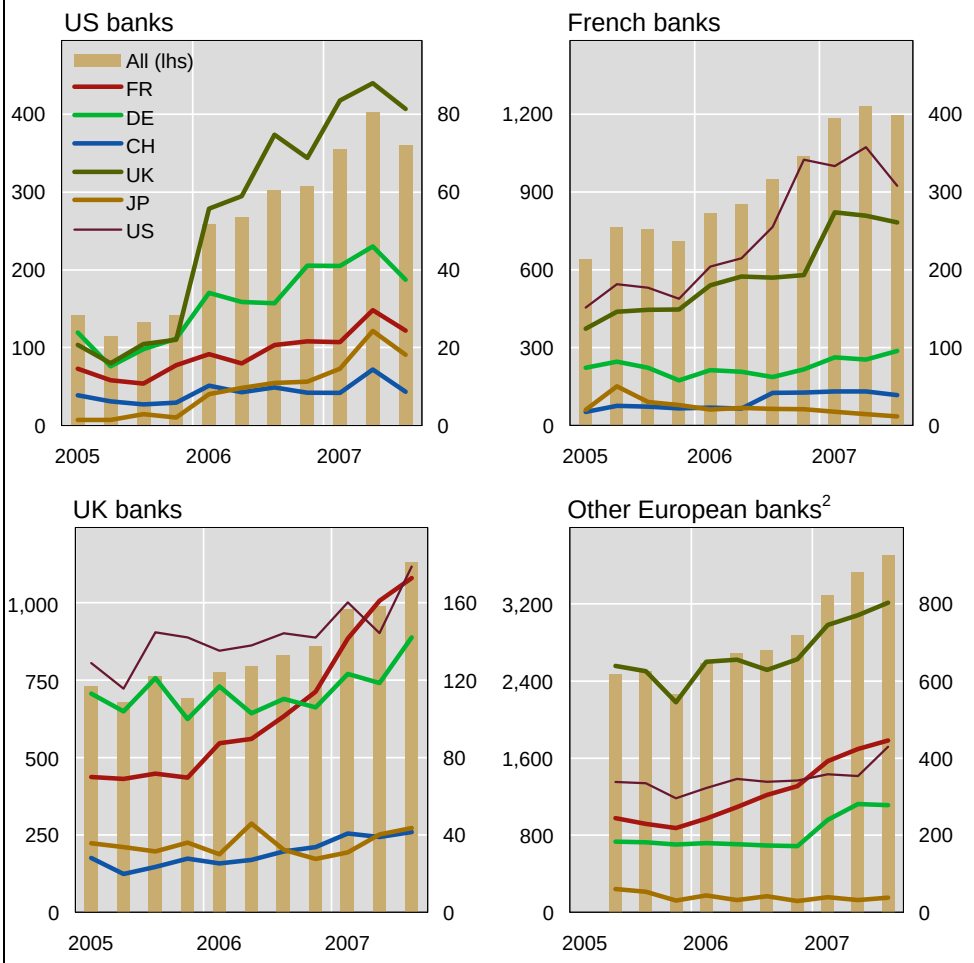
[1] Foreign claims reported by banks of the nationality identified in the legend, as a percentage of their total assets. [2] Foreign claims on banks reported by banks of the nationality identified in the legend, as a percentage of their Tier 1 capital. [3] Foreign claims by domestically owned banks in all reporting countries on the national banking systems identified in the legend, in billions of US dollars.

Source: BIS consolidated banking statistics on an ultimate risk basis. Graph 3

located in the United Kingdom, as in the BIS consolidated statistics on an immediate borrower basis (IB basis)).

Bilateral interbank exposures of selected banking systems[1]

By bank nationality, in billions of US dollars



[1] Consolidated foreign claims of reporting banks headquartered in selected countries (panel headings) vis-à-vis banks of the nationality indicated by the legend, where nationality is defined by the residence of the ultimate obligor. Interbank claims on a consolidated basis exclude inter-office positions. Data are not adjusted for exchange rate changes. [2] Belgian, Dutch, German, Italian, Spanish and Swiss banks. Spanish and Swiss banks began reporting these data in 2005 Q2.

Source: BIS consolidated banking statistics on an ultimate risk basis. Graph 4

exposures nearly seven times their Tier I capital, followed by Dutch and Swiss banks at more than four times.

Since 2005, banks have built up increasingly large positions vis-à-vis some national banking systems. Foreign claims on US banks, reported by banks headquartered outside the United States, have increased since the second quarter of 2005 from $785 billion to almost $1.2 trillion (Graph 3, right-hand panel). This amounts to 15% of total foreign claims on the entire banking sector. Claims on UK banks have grown significantly as well, reaching nearly $1.4 trillion by the third quarter of 2007, or 18% of total foreign claims on banks. The underlying *bilateral* exposures driving these movements are shown in Graph 4. By the second quarter of 2007, French banks' claims on US and UK banks had grown to $357 billion and $270 billion, respectively.

Cyclical growth in the interbank market

Patrick McGuire and Karsten von Kleist

Growth in international bank credit varies significantly over time. Using the BIS locational banking statistics, this box assesses the growth in international banking activity around periods of major stress in global financial markets and changes in underlying real economic activity. The exercise suggests that growth in international bank claims has in several cases accelerated in the years prior to a significant financial shock, particularly in the US dollar segment of the interbank market, before decelerating after the shock occurs.

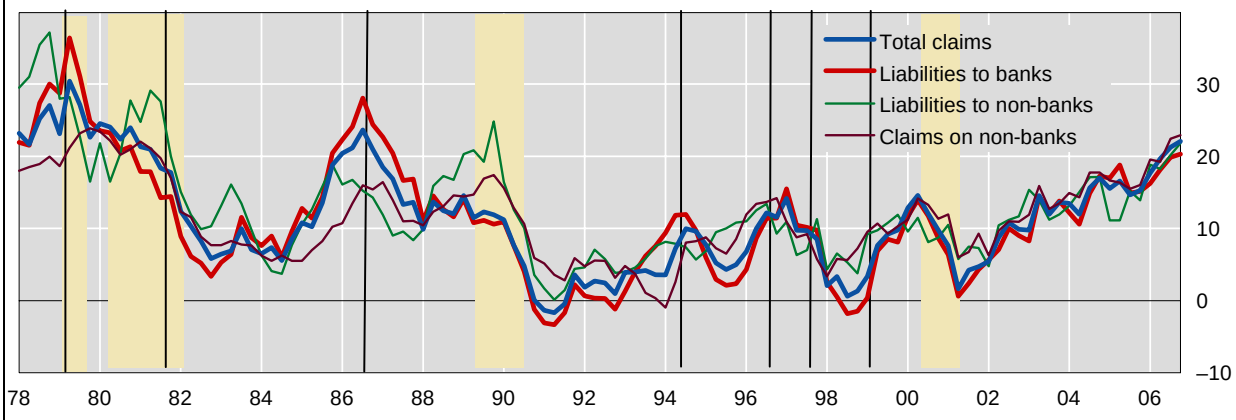
The primary measures used here are year-on-year growth rates of international positions on BIS reporting banks' balance sheets. Although simple, a long-term analysis of these series provides a convenient indicator of credit expansion in the international arena across the business cycle. Graph A plots the growth rate of total international claims and liabilities, broken down by sector.[①] The vertical lines represent well known economic shocks or the start of episodes of financial turmoil, and the shaded areas indicate periods of US recession using the NBER definition.

The data indicate a fairly clear relationship between these periods of global financial stress and major swings in the year-on-year growth in outstanding positions. Over the past 30 years, there were five major peaks in the growth rates of banks' total international claims. The peak followed by a deceleration in growth at the start of the period corresponds to the global slowdown following the second OPEC oil shock. As shown in the top panel of Graph B, banks recycled petrodollars into emerging economies, ahead of the Latin American debt crisis in the 1980s. Global lending peaked again in late 1987, around the time of the sharp US stock market sell-off in that year. As shown in the bottom panel of Graph B, which maps the contribution to overall growth by *nationality* of the reporting banking system, greater lending by Japanese banks contributed significantly to overall growth throughout the 1980s. The acceleration and deceleration of growth around 1987 for the most part reflected changing lending patterns of US and European banks. Growth peaked several times during the 1990s and after, roughly corresponding to the Mexican peso crisis and the bond market sell-off in 1994, the Asian financial crisis in 1997 and the bursting of the dotcom bubble in 2000 followed by recession in the United States. During these periods, lending to borrowers in the United States, United Kingdom and euro area were significant contributors to the overall growth in international banking activity (Graph B, top panel).

Historically, growth in *interbank* activity has corresponded more closely to these periods of financial stress, while the rates of growth in lending to and borrowing from non-banks have

Growth in international banking activity[1]

Year-on-year changes, in per cent



The vertical lines mark: 1979 second oil shock; 1982 Mexican default; 1987 stock market correction; 1994 Mexican peso devaluation; 1997 Asian financial crisis; 1998 Russian default and LTCM; 2000 Nasdaq peak. The shaded areas mark US recessions (NBER definition).

[1] Growth in BIS reporting banks' cross-border claims in all currencies and foreign currency claims on residents. Graph A

exhibited more variable patterns. This can be seen by comparing the growth rates across sectors in Graph A. In several cases, the growth in liabilities to non-banks slowed in the quarters preceding an event, even as borrowing from banks continued to grow.

In the most recent cycle, lending to non-banks has contributed to overall growth as well. Banks' total international claims have been growing at more than 20% a year for the past three quarters, a rate not seen since the mid-1980s just before the stock market crash of 1987. Moreover, growth has accelerated since 2002, roughly at the same time as broader (scaled) measures of activity in the global banking market show a marked increase.② Since 2002, total claims on non-banks have expanded by $8 trillion (to $13.4 trillion), with roughly one quarter of this expansion reflecting greater credit to residents of the United States, and another quarter to residents of the euro area.

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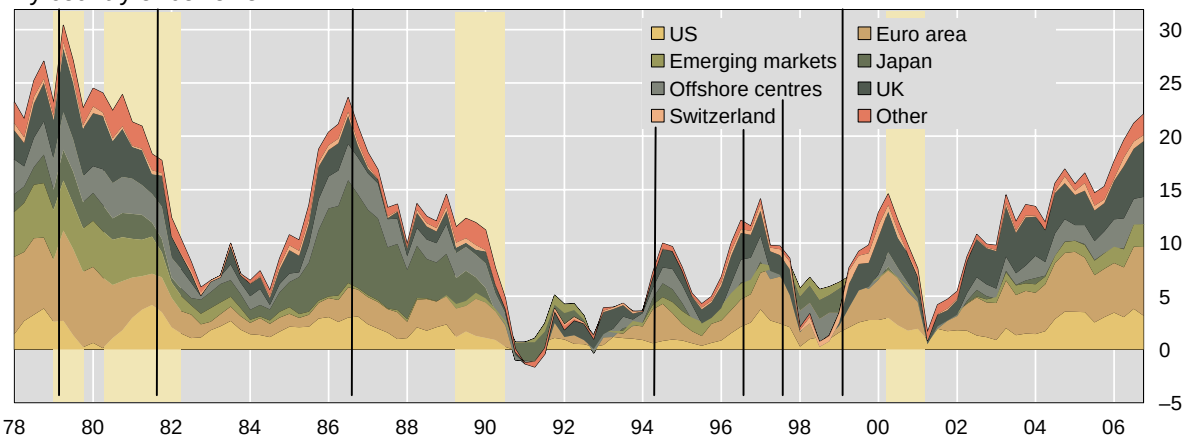
① Year-on-year changes in outstanding stocks are calculated by summing the quarterly exchange rate adjusted flows in quarters *t* to *t*-3, and dividing by the outstanding stock in quarter *t*-4. ② For example, Graphs 1 and 2 in McGuire and Tarashev's "Tracking international bank flows", *BIS Quarterly Review*, December 2006 indicate that the overall stock of international bank claims scaled by global GDP kinked upwards in 2000. Scaling total liabilities by M2 yields a similar picture.

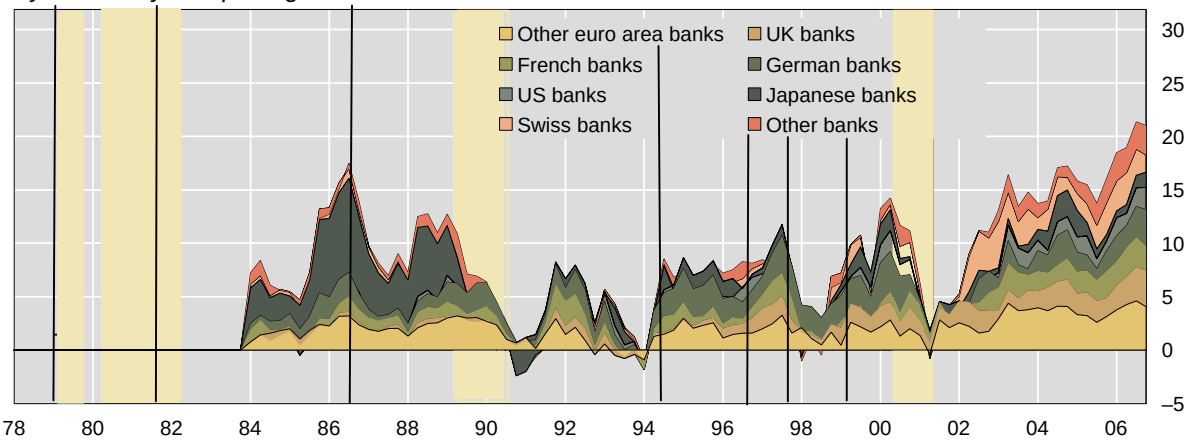
Contributions to growth in international bank claims

Year-on-year changes, in percentage points

By country of borrower[1]



By nationality of reporting bank[2]



The vertical lines mark: 1979 second oil shock; 1982 Mexican default; 1987 stock market correction; 1994 Mexican peso devaluation; 1997 Asian financial crisis; 1998 Russian default and LTCM; 2000 Nasdaq peak. The shaded areas mark US recessions (NBER definition).

[1] Based on the BIS locational banking statistics by *residence*. [2] Based on the BIS locational banking statistics by *nationality*, which start in 1983. The overall growth rate implied by these data differs from the top panel due to a smaller reporting population and because inter-office positions are excluded.

Graph B

US-headquartered banks' foreign claims on other banking systems have grown significantly since 2005 to reach $403 billion by the second quarter of 2007, of which UK banks accounted for $88 billion.

US banks reduce exposure to other banking systems

Tentative signs of a credit contraction in some segments of the interbank market emerged in the third quarter. US banks trimmed their exposures to almost all major banking systems, reducing foreign claims on banks by an estimated $42 billion (Graph 4, top left-hand panel). This was the largest decline in interbank claims reported by US banks since the inception of the statistics on a UR basis (first quarter of 2005), and occurred in spite of a positive valuation effect.[10] Swedish banks also reduced their foreign interbank exposures by $43 billion (–17%), of which half vis-à-vis German banks. The single largest bilateral reduction in interbank exposures ($49 billion, –14%) was reported by French banks vis-à-vis US banks (Graph 4, top right-hand panel).

The international debt securities market

Net issuance of bonds and notes remains sluggish

Borrowing in the international debt markets remained sluggish amid the turmoil in financial markets. It rebounded somewhat in the fourth quarter of 2007 from the previous one, but was still well below prevailing levels before the turmoil. Net issuance of bonds and notes increased to $487 billion from $399 billion. The year-on-year growth rate, which has averaged 20% since 2000, plunged to –45%, down even further from the –23% recorded in the previous quarter.

Euro-denominated borrowing increases

The increase from the third quarter came mostly from euro-denominated bonds and notes: net issuance increased to $207 billion from $90 billion. By contrast, net issuance of US dollar- and sterling-denominated bonds and notes was $203 billion and $30 billion, down from $221 billion and $48 billion, respectively. Net issuance of yen-denominated bonds and notes changed less markedly, from $18 billion to $14 billion. Gross issuance of yen-denominated bonds by non-Japanese issuers in the Japanese local market (samurai bonds) increased from $3 billion to $5 billion and posted a year-on-year growth rate of 27%, perhaps reflecting the relative stability of Japanese credit markets.

The increase in euro-denominated bonds and notes took place in several countries across the euro area (Graph 5, left-hand panel). For example, net issuance increased from $10 billion to $35 billion in Ireland, from $17 billion to $39 billion in Spain, and from $12 billion to $30 billion in France. For these countries, the increase in net issuance came mostly from financial institutions, whose borrowing in securities markets had largely dried up in the third quarter when the financial market turbulence commenced. In contrast, net issuance in Germany was still negative at –$8 billion, due mainly to sluggish borrowing by public financial institutions. The decline was less marked than the –$26 billion seen in the preceding quarter.

Most developed countries outside the euro area did not show a marked gain in borrowing from the third quarter. Net issuance in the United States and Japan was almost the same as in the third quarter, and that of the United

[10] The depreciation of the US dollar over the course of the quarter tends to overstate end-of-period stocks of other currencies when expressed in dollars.

Kingdom and Australia fell to some extent. A notable exception was Canada, where net issuance increased from $3 billion to $19 billion, almost fully recovering from the slump in the previous quarter. Most of the increase in Canadian issuance came from financial institutions.

Declines seen in all credit rating categories

By credit quality class (for which only gross figures are available), declines in issuance were seen in all rating categories. Gross issuance of AAA-rated bonds decreased from the previous quarter's $283 billion to $255 billion in the fourth quarter, resulting in a year-on-year growth rate of –31%. Gross issuance of other investment grade and non-investment grade bonds decreased from $279 billion and $5 billion to $264 billion and $2 billion, respectively, which corresponds to year-on-year growth rates of –34% and –92%.

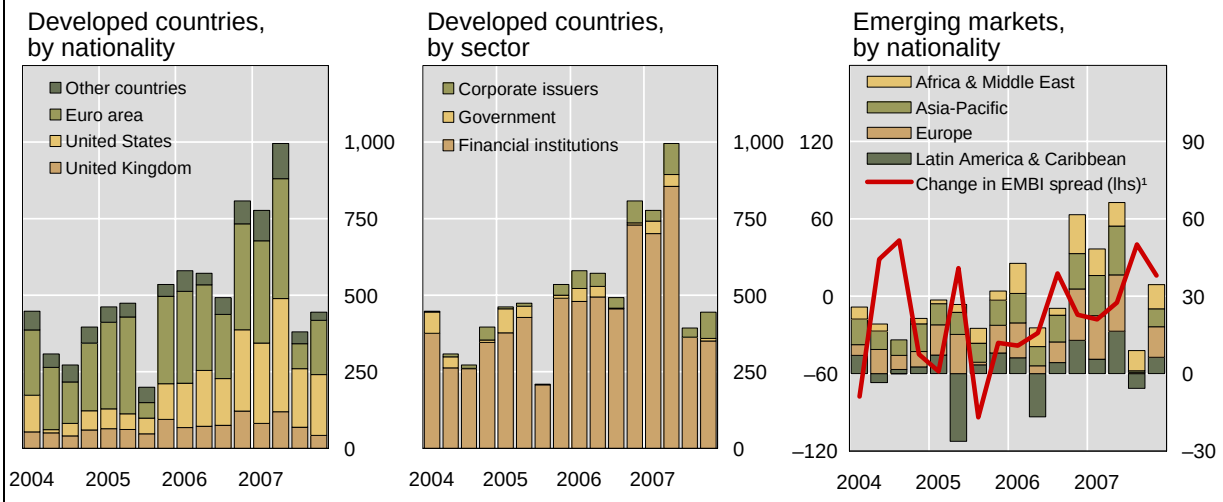
Distinct contrast between financial institutions and corporate issuers

By sector, there was a distinct contrast between the borrowing of financial institutions and that of corporate issuers during the period. Net issuance of bonds and notes by financial institutions in developed countries decreased further to $351 billion in the fourth quarter from $363 billion, which represented a year-on-year growth rate of –52% (Graph 5, centre panel). The largest contributor to this development was declining issuance by US private financial institutions. By contrast, net issuance by corporate issuers increased to $86 billion from the previous quarter's $30 billion, which corresponded to a positive year-on-year growth rate of 21%. The growth came chiefly from an increase in borrowing by US and European corporations.

Emerging economies showed gains from the third quarter. Net issuance of bonds and notes increased from $3 billion to $34 billion in the fourth quarter, albeit still below the $66 billion achieved in the second quarter (Graph 5, right-hand panel). The bounce was due to a recovery in offerings from Latin America (from –$6 billion to $6 billion), emerging Europe (from $1 billion to $12 billion) and Asia (from $1 billion to $7 billion). The rebound in emerging market net issuance coincided with some narrowing of emerging market bond spreads, which had widened significantly in the third quarter.

Net issuance of international bonds and notes

In billions of US dollars and basis points



¹ Quarterly change in spread of JPMorgan EMBI Global Composite index.

Sources: Dealogic; Euroclear; ICMA; Thomson Financial; BIS. Graph 5

Derivatives markets

A large decline in turnover ...

The fourth quarter of 2007 saw a substantial decline in activity on the international derivatives exchanges. This marked a reversal from the third quarter, in which the turmoil in financial markets had resulted in the highest turnover on record. The largest fall was in derivatives on short-term interest rates, whose turnover based on notional amounts decreased from the previous quarter's $535 trillion to $405 trillion in the fourth quarter. Declines were also evident for derivatives on long-term interest rates (from $59 trillion to $53 trillion) and stock indices (from $81 trillion to $75 trillion). Foreign exchange derivatives showed a more moderate descent from $6.2 trillion to $6.0 trillion. Total turnover in listed futures and options on these financial instruments fell from $681 trillion to $539 trillion in the fourth quarter, although the year-on-year growth rate still remained at a high level of 25%.

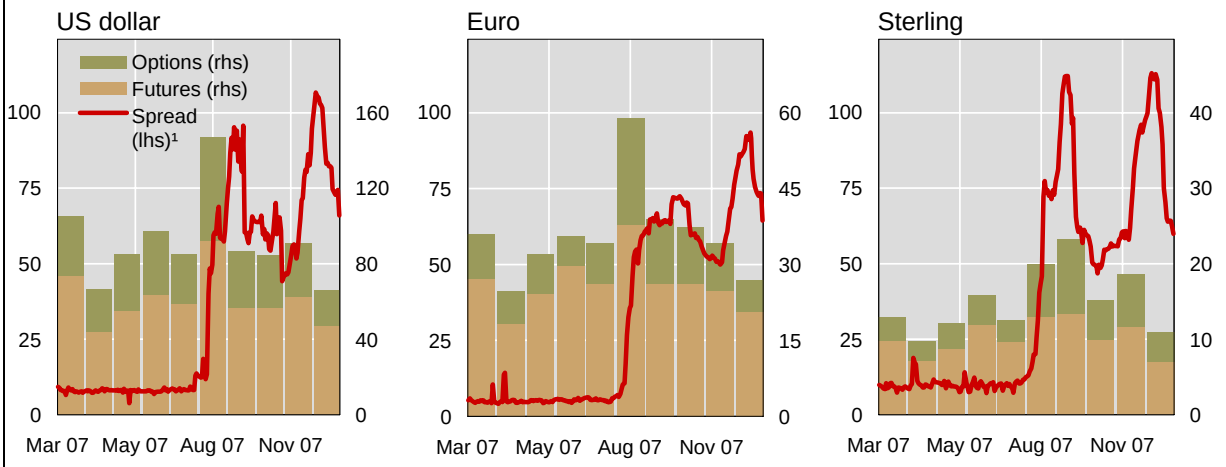
... particularly in money market contracts

The decline in derivatives on short-term interest rates followed a quarter in which heightened hedging needs by financial institutions had contributed to the active use of futures and options (Graph 6). Although money market turmoil continued into the fourth quarter, as evidenced by a widening of the spread between three-month interbank rates and overnight index swap rates, sharp falls were seen in currency segments heavily affected by the recent financial market turmoil. The largest decrease came in the US dollar segment (from $319 trillion to $241 trillion), followed by the euro (from $131 trillion to $98 trillion) and sterling (from $55 trillion to $44 trillion). Rapid declines were also recorded in short-term interest rate derivatives denominated in the Japanese yen (from $10 trillion to $7.4 trillion), Australian dollar (from $8.1 trillion to $6.5 trillion) and Swiss franc (from $2.9 trillion to $1.8 trillion).

While turnover in futures and options on three-month eurodollar rates dropped substantially from $266 trillion to $187 trillion in the fourth quarter,

Turnover in short-term interest rate contracts

Monthly data, in trillions of US dollars



[1] Three-month interbank Libor rates (for the United States, eurodollar; for the euro area, Euribor) minus corresponding overnight index swap rates (for the euro area, EONIA swap), in basis points.

Sources: Bloomberg; FOW TRADEdata; Futures Industry Association; BIS calculations. Graph 6

turnover in those on federal funds rates showed an increase from $34 trillion to $41 trillion. This suggests that hedging needs and speculative activity by financial institutions and other investors were skewed to some extent towards overnight rates instead of term rates, possibly reflecting heightened expectations of policy rate cuts in the United States. In addition, the impairment of liquidity that was reported in the term money markets may have been a factor dampening turnover in futures and options on the term rate segment.

Activity in equity derivatives on stock indices also declined, from the third quarter's $81 trillion to $75 trillion in the fourth quarter, although the year-on-year growth rate was still very high at 66%. By currency of denomination, South Korean won-denominated contracts decreased the most, from $21 trillion to $17 trillion, followed by contracts in the US dollar (from $30 trillion to $27 trillion) and the euro (from $18 trillion to $17 trillion). Conversely, the largest increase was in Indian rupee-denominated contracts (from $2.0 trillion to $2.5 trillion), followed by sterling (from $2.0 trillion to $2.3 trillion).

Trading in FX derivatives declines slightly

Trading in foreign exchange derivatives declined slightly from $6.2 trillion to $6.0 trillion in the fourth quarter. The main contributors were contracts in the yen (from $1.1 trillion to $890 billion), Swiss franc (from $464 billion to $353 billion) and sterling (from $740 billion to $652 billion). The large decline in yen and Swiss franc contracts is broadly in line with reports of less active position-taking on carry trades after the large-scale unwinding in August and September. By contrast, increases were reported for currencies such as the euro (from $2.0 trillion to $2.1 trillion), Australian dollar (from $251 billion to $286 billion), US dollar (from $562 billion to $596 billion) and Brazilian real (from $611 billion to $630 billion).

Commodity derivatives continue an uptrend

In contrast to financial derivatives, activity in commodity futures and options continued an uptrend in the fourth quarter. Global turnover in commodity derivatives measured in number of contracts (notional amounts are not available) increased from 456 million to 528 million, owing largely to the rapid expansion in agricultural commodities (from 257 million to 296 million), followed by energy products (from 140 million to 160 million) and precious metals (from 25 million to 34 million). A large contributor to this development was Chinese commodity exchanges, whose turnover increased from 203 million to 255 million in the fourth quarter, posting a year-on-year growth rate of 112%.

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Monetary operations and the financial turmoil[1]

A proper understanding of central bank operations in response to the recent financial turmoil and of their implications for the monetary policy stance and for market functioning calls for an understanding of operating frameworks. And yet, not only are these the least familiar aspect of monetary policy, they also differ considerably across countries. The frameworks can have a first-order influence on the size and type of liquidity injections employed and on the need for exceptional measures.

JEL classification: E43, E49, G21, G32.

The serious disruptions in the interbank markets of several mature economies associated with the broader financial turmoil since August 2007 have firmly put the spotlight on central bank operations designed to implement monetary policy. This aspect of policy, normally taken for granted, is often not well understood, as the operations depend heavily on the peculiar characteristics of the market for bank reserves and on country-specific institutional features. While some of these features are largely immaterial in normal times, they acquire particular significance at times of stress. Moreover, at these times the risk of misunderstanding the nature of the operations is highest, not least as cross-country differences in institutional features may be misconstrued as substantive differences in the nature of the central banks' response.

Against this backdrop, the objective of this special feature is threefold. First, it provides a conceptual roadmap that can help to understand better the challenges that central banks face in implementing monetary policy at times of stress. Second, it discusses how central bank responses have been influenced by the operating frameworks in place. Finally, it highlights some questions that are raised by these operations. The focus is on seven central banks: those of the United States, the euro area, Japan, the United Kingdom, Canada, Australia and Switzerland. These central banks provide a broad, representative range of institutional arrangements in place.

The article is structured as follows. In the first section we briefly summarise the key features of operating frameworks, paying particular

[1] We would like to thank Magdalena Erdem for excellent research assistance and Piti Disyatat, Már Gudmundsson, Mico Loretan, Frank Packer, Christian Upper, William White and staff at central banks for their comments. The views expressed are our own and not necessarily those of the BIS.

attention to their operation in normal times and to similarities and differences across countries. In the second we examine central bank responses during the recent turmoil. In the third we discuss the validity of the distinction between setting the monetary policy stance and liquidity management operations at times of stress and elaborate on some trade-offs faced in the design of the frameworks to cope with both normal and stressful conditions. The conclusion summarises the key messages.

Operating frameworks[2]

Elements of operating frameworks:

Monetary policy operating frameworks establish the means by which central banks implement the desired monetary policy stance. It is important to make a distinction between two elements of such frameworks. One is the *signalling* of the desired policy stance, nowadays done through the announcement of a key interest rate ("policy rate"). The other is the *liquidity management operations* (LMOs) that support that stance by seeking to ensure that a short-term *market* rate (a "reference rate")[3] is consistent with the policy rate.[4]

The closeness of the relationship between the policy rate and the reference rate is a measure of how successful the implementation of the stance is. This is so regardless of whether the policy rate takes the form of a rate actually set through a regular market operation of the central bank, such as the minimum bid rate for the ECB, or of simply an announced target for a market rate, as in most of the other central banks in the sample (Table 1).[5] Moreover, because the reference rate has to be controlled closely, it is generally an overnight rate.[6] The main exception to this is the Swiss National Bank, which defines the policy rate as a range for the three-month uncollateralised interbank rate and therefore the reference rate has that maturity. Even so, the target is again achieved by ensuring consistency between the three-month rate and the overnight rate through adjustment in the one-week rate on its weekly fixed rate repo operations.

signalling …

All LMOs share a common element: they are designed to regulate the amount of liquidity supplied through a mix of discretionary operations and

… and liquidity management operations;

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[2] For an elaboration on the conceptual framework and on the evolution and the cross-country dispersion of actual practices, see Borio (1997, 2001) and Blenck et al (2001). For a recent discussion of operating frameworks also in emerging market countries, see Ho (forthcoming). For a more technical discussion and a review of the literature, see Bindseil (2004).

[3] This reference rate is often also known as the "operating target".

[4] While in the past it was not uncommon for central banks to rely also on quantity signals, thus blurring the distinction between signalling and LMOs, since the mid-1990s this has generally no longer been the case, except perhaps in exceptional circumstances, such as in Japan when the policy rate was set at zero.

[5] The Bank of England's policy rate is the rate at which it remunerates banks' target balances held with the central bank. This rate coincides with that at which short-term repos are carried out.

[6] While the ECB does not officially have a reference rate or operating target, the EONIA rate appears to perform a similar function.

Key features of operating frameworks before the turmoil

	AU	CA	EA	JP	CH	GB	US
Policy rate	o/n target	o/n target	MBR1	o/n target	target range 3m	Bank Rate2	o/n target
Reference rate (maturity)	o/n	o/n[3]	s-t[4]	o/n	3m	o/n[5]	o/n
Reserve requirements/ target balances			✓	✓	✓	✓[6]	✓
Maintenance period	•	•	4–5w[7]	1m	1m	1m	2w
Remuneration	•	•	✓			✓[6]	
Size (domestic currency)	•	•					
Lending facility (maturity/pricing, bp)	o/n + 25	o/n + 25	o/n + 100	o/n	o/n + 200	o/n + 100[8]	o/n + 100
Deposit facility (maturity/pricing, bp)	o/n – 25	o/n – 25	o/n – 100			o/n – 100[8]	
Main market operation[9]	RT	SB[10]	RT	RT[11]	RT	RT	RT
Frequency	daily	daily	weekly	daily[7]	daily	weekly	daily[7]
Maturity	1d–3m[7]	1d	1w	1d–4m[7]	1w[7]	1w	1d–2w
Other operations[12]	✓	✓	✓	✓	✓	✓	
Frequency[13]	medium	medium	low	high	medium	low	•
Maturity	1d–3m	1d	1d[7] or 3m	1d–2m[7]	1d[7]	1d–12m[7, 14]	•

AU = Australia; CA = Canada; EA = euro area; JP = Japan; CH = Switzerland; GB = United Kingdom; US = United States. ✓ = yes; blank space = no; ● = not applicable; o/n = overnight; s-t = short-term; d = day; w = week, m = month; bp = basis points; RT = reverse transaction (eg repos); SB = settlement balances.

[1] Minimum bid rate on main refinancing operation. [2] Rate paid on target balances; this coincides with the rate at which fixed rate tenders are carried out. [3] Collateralised. [4] No formal reference rate but the overnight rate appears to perform a similar function. [5] Overnight rates to be in line with the official Bank Rate resulting in a flat yield curve out to the next policy decision date. [6] Reserve balances are remunerated at the Bank Rate as long as they stay within a reserve range, in normal times ±1%. [7] Typically. [8] ±25 bp on the last day of the maintenance period. [9] Regular operation used to set the policy rate or most frequent one. [10] Influencing settlement balances by shifting government deposits from a deposit with the central bank through an auction. [11] Loans against pooled collateral. [12] Excluding outright transactions. [13] Based on typical frequency: low = less than three times per month; medium = three to seven times per month; high = at least eight times per month. [14] Including a regular fine-tuning operation at the end of the maintenance period.

Sources: Markets Committee (2007); central banks. Table 1

standing facilities. The operations generally seek to balance supply and demand in the market for bank reserves in order to ensure that it clears at an overnight rate consistent with the policy rate. Beyond this common element, they can differ in several respects, reflecting differences in the characteristics of both the demand for, and supply of, bank reserves.

reserve requirements/target balances with averaging provisions;

The demand for bank reserves is strongly influenced by whether or not banks are required to hold some target level of reserve balances measured over a certain period ("maintenance period"). If they are, an *averaging provision* allows banks to offset surpluses with shortfalls relative to the target level of reserves. If they are not, the demand for reserves ("settlement balances") is determined by a combination of two factors: payment-related needs and residual frictions in the distribution of reserve balances in the system. The former reflects mainly the characteristics of payment systems; the latter includes factors such as the degree to which some institutions actively manage their positions. In both cases, the resulting demand tends to be quite small and *unresponsive* to market rates. Where averaging provisions are in

place, the demand for excess reserves,[7] which banks typically wish to keep to a minimum because of the zero or low remuneration, is equally unresponsive to market rates at the end of the maintenance period.[8] The implication of this unresponsiveness is that control over the overnight rate requires central banks to meet that demand rather precisely (see below).

Averaging provisions perform a "buffer function", allowing banks to absorb shocks in the supply of reserves without creating tensions on the overnight rate. For that to be the case, banks should be largely indifferent between holding reserves at different points over the maintenance period. Thus, systems are generally designed to stabilise the opportunity cost of holding reserves during this period. In normal conditions, this cost is approximately equal to the spread between the remuneration of target reserves, if any, and the overnight rate. Remunerating target reserves at the prevailing policy rate, therefore, is one way of achieving this objective; where they are not remunerated, avoiding expectations of changes in the policy rate over the maintenance period can perform a similar role. Shocks to the supply of reserves will also tend to influence the overnight rate less, the longer is the maintenance period and the larger are the target balances.

The characteristics of the arrangements that influence the demand for bank reserves differ considerably across systems (Table 1). In two cases, Australia and Canada, there are no required or target reserves and so no averaging provisions. Elsewhere, averaging provisions are generally determined as a ratio of the deposit base ("reserve requirements"). The exception is the United Kingdom, where target balances are decided by banks themselves prior to each maintenance period and are set as a range.[9] The range is normally plus or minus 1% but it can be changed by the central bank depending on market conditions. Given the size of the reserve requirement, the length of the maintenance period and the features of the remuneration, the buffer role is especially large in the euro area and smaller in the United States.

discretionary operations and standing facilities;

As regards the supply of bank reserves, a key distinction is that between *discretionary operations* and *standing facilities* (lending and deposit facilities). These days, central banks rely heavily on discretionary operations, with standing facilities typically acting only as "safety valves" for end-of-day idiosyncratic shocks to holdings of reserves at individual banks or possibly end-of-maintenance period mismatches in the supply of, and demand for, reserves. As the corresponding rates are set above (lending) and below (deposit) the policy rate, the extent to which such facilities are activated depends in part on the size of the penalty compared with this rate. In a majority of the countries considered there are both lending and deposit facilities (a "corridor"); in the

[7] Excess reserves are defined as reserves in excess of those needed to satisfy target levels.

[8] In the United Kingdom, the fact that the target level of reserves is set as a range allows additional flexibility in the use of the averaging provisions.

[9] For an elaboration on the UK system, which presents a number of specific features, see Tucker (2004) and Bank of England (2006). In the United States, banks may establish required operating balances, which are similar to target balances at the Bank of England.

United States, Japan and Switzerland no deposit facility is in place.[10] Penalties vary considerably, from as low as 25 basis points in Australia and Canada to as high as 200 basis points in Switzerland (Table 1).

maturity ...

The *maturity* of discretionary operations is largely determined by their objective. Given their safety-valve and stabilising role in relation to the overnight market segment, standing facilities have an overnight maturity in all the systems selected, at least in normal times. By contrast, given the overriding objective of achieving the desired path in the supply of bank reserves to balance the market, the maturity of discretionary operations is decided quite independently of the maturity of the reference rate. Considerations include: the desired frequency of operations (see below); matching the expected duration of the shock to the supply and demand imbalance;[11] and possibly a certain reluctance to operate at longer maturities, so as to avoid the risk of influencing prices for the corresponding instruments at those maturities. Reverse transactions, such as repos, are so heavily employed at the expense of outright transactions precisely because they allow considerable flexibility in terms of maturity while at the same time having no or very limited impact on the price of the underlying instrument. The central banks in the sample are no exception to this general pattern (Table 1). They rely largely on reverse transactions with maturities that generally do not exceed one month, although they may extend infrequently up to three months and sometimes beyond. Outright transactions in securities at longer maturities are less frequent.

... and frequency of discretionary operations;

The *frequency* of discretionary operations is largely a matter of choice. Central banks that prefer to avoid a frequent presence in the market rely more on the buffer function of averaging provisions, which offset any volatility in the supply of reserves arising from "autonomous factors" beyond the control of the central bank over the relevant horizon. These include in particular, to varying degrees, changes in the demand for cash balances,[12] Treasury balances with the central bank, and lagged effects of foreign exchange operations. In the absence of averaging provisions, daily intervention is typically required to meet the inelastic demand for settlement balances, unless the remuneration on those balances through a deposit facility is very generous. In the sample of countries considered, the ECB and the Bank of England operate infrequently: in addition to the keynote operation, they rarely resort to fine-tuning operations, except perhaps at the end of the maintenance period or in unusual conditions. By contrast, the other central banks considered operate at least at a daily frequency (Table 1).

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[10] Legislation passed in October 2006 allows the Federal Reserve to remunerate required reserves beginning in October 2011.

[11] Likewise, permanent increases in the demand for reserves are more likely to be met by outright purchases and longer-maturity reverse operations.

[12] This demand is intentionally accommodated. That is, changes in the public's demand for cash (currency), which is a liability of the central bank, must be matched by a commensurate change in central bank assets to leave banks' reserve balances, the other main central bank liability, unchanged.

Two additional dimensions in which operating frameworks may differ, and which acquire particular significance at times of stress, are the range of eligible counterparties and that of collateral (Table 2).

choice of counterparties ...

As regards *counterparties*, arrangements vary considerably across countries. In the euro area, for instance, the range of eligible counterparties is very broad and common across operations, potentially including all the institutions that hold reserves with the central bank, although fine-tuning operations in normal times may be restricted to institutions meeting more selective operational criteria. A similarly broad set of counterparties, with complete or nearly complete overlap across operations, can be found in Australia and Switzerland.[13] At the other end of the spectrum, in the United States and, to a lesser extent, Canada, the overlap is limited and the set of counterparties for discretionary operations is considerably smaller than that with access to standing facilities. For example, in the United States discretionary operations are done with primary dealers – 20 large securities dealers – while all institutions that have reservable deposits have access to the lending facility. The situation in the other countries is somewhere in between.

... and collateral

As regards the range of *collateral*, central banks differ not only in terms of the varieties accepted but also in terms of whether collateral requirements vary across operations. The Federal Reserve, for example, accepts the widest range of collateral among central banks for its standing facility (it accepts most securities and loans on banks' books, including assets denominated in the

Key features of operating frameworks: collateral and counterparties

	AU	CA	EA	JP	CH	GB	US
Collateral, MOs							
Government securities	✓	✓[1]	✓[1]	✓	✓[1]	✓	✓[2]
Private sector securities	✓[1]		✓[1]	✓[1, 3]	✓[1]		
FX[4]	✓				✓	✓[5]	
Collateral, LF							
Same as MOs	✓		✓	✓	✓	✓	
Broader		✓					✓
Counterparties, MOs							
Securities firms	✓	✓		✓[1]		✓[1, 6]	✓[7]
Banks[8]	✓	✓	✓[9]	✓[1]	✓	✓[1, 6, 10]	
Counterparties, LF							
Same as MOs	✓		✓		✓		
Broader		✓[11]		✓		✓	✓
Overlap	complete	limited	complete	large	complete	large	limited

MOs = (discretionary) market operations; LF = marginal lending facility. See Table 1 for the mnemonics.

[1] Selected. [2] And agencies. [3] As well as loan deeds. [4] Including FX swaps. [5] Euro. [6] Active intermediaries. [7] Primary dealers. [8] The precise coverage varies somewhat from country to country. [9] Institutions subject to reserve requirements. [10] Including building societies. [11] LVTS participants.

Sources: Markets Committee (2007); central banks. Table 2

[13] In Switzerland, all banks, regardless of domicile or the legislation to which they are subject, potentially have access to the central bank's facilities.

major foreign currencies) but the narrowest range for its repurchase agreements (securities issued or guaranteed by the US government or by an agency). The ECB, by contrast, accepts a uniform, and relatively broad, set of collateral for its lending facility and market operations, although notably only assets denominated in euros.

Some common misconceptions

Three implications of this analysis are worth highlighting. First, because of the unresponsiveness of settlement balances and excess reserves to market rates, central banks change interest rates through signalling mechanisms without *permanently* altering the stock of bank reserves in the system (eg adding to it when reducing rates). By implication, actions that do change the amount of reserves in the system in a manner inconsistent with the demand run the risk of moving the overnight rate substantially away from the policy target.[14] Second, it is misleading to compare the size of net liquidity injections across systems to get a sense of the degree of accommodation of liquidity demands. Net liquidity injections over any given period are fundamentally determined by the balance between the net supply (possibly negative) associated with autonomous factors, previous maturing liquidity operations and the demand for bank reserves ("liquidity deficit"). For example, other things equal, the larger the reserve requirement, the larger is the net liquidity injection required to balance the market.[15] Finally, a fortiori, because of differences in the maturity of the operations it is equally misleading to compare the cumulative sum of gross operations over time. And yet, during the financial turmoil it was not uncommon for observers to make precisely these types of comparison to infer the degree of generosity of central bank injections, despite the large differences across countries in the required operations.

Operations at times of stress

The disorderly repricing of risk …

Before turning to the central bank responses to the financial turmoil, it is useful to recall briefly its key characteristics, extensively analysed elsewhere.[16] The turmoil was triggered by a sharp and disorderly repricing of credit risk, with the US subprime mortgage market at its epicentre. Given the leverage built up in the system and the opaqueness of valuations of new structured products and of their distribution within the system, the repricing led to, and was exacerbated by, an evaporation of liquidity in many markets, including in the interbank market. As the strains spread, banks became very concerned with the liquidity and capital implications of potential large-scale involuntary reintermediation and distrusted their counterparties. The reintermediation was primarily

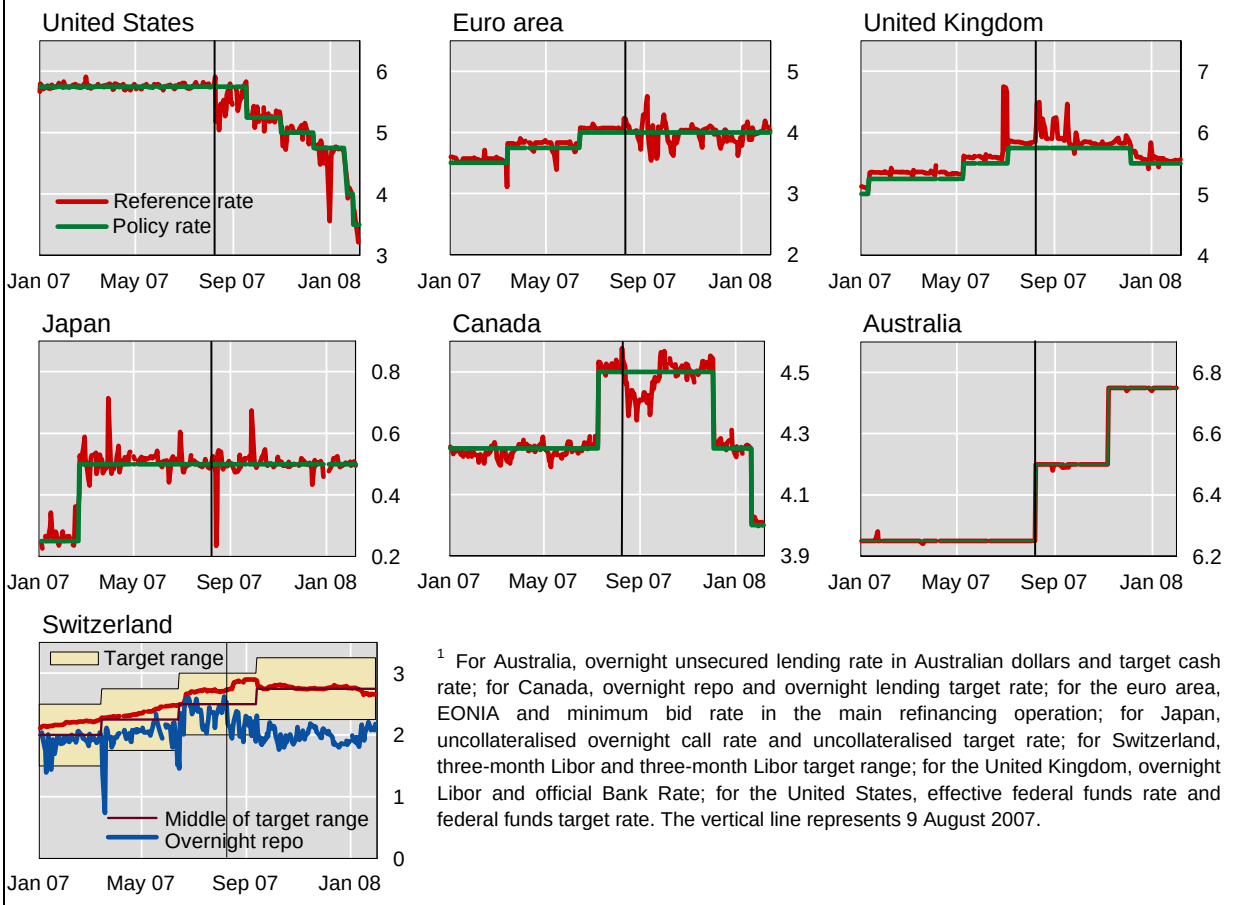
[14] In the United Kingdom, reserves can be varied within the permissible range for target balances without having such an effect.

[15] For instance, in the absence of a reserve requirement and in the limiting case in which, over a given period, the net impact of autonomous factors is zero and no previous operations mature, the net injection would also be approximately zero, as the demand for settlement balances hardly changes over time. This would be so *regardless* of the level of, or any induced change in, the policy rate.

[16] See the Overview section in this issue and that in the previous one.

Policy rates and reference rates[1]

In per cent



[1] For Australia, overnight unsecured lending rate in Australian dollars and target cash rate; for Canada, overnight repo and overnight lending target rate; for the euro area, EONIA and minimum bid rate in the main refinancing operation; for Japan, uncollateralised overnight call rate and uncollateralised target rate; for Switzerland, three-month Libor and three-month Libor target range; for the United Kingdom, overnight Libor and official Bank Rate; for the United States, effective federal funds rate and federal funds target rate. The vertical line represents 9 August 2007.

Source: Bloomberg.

Graph 1

associated with banks' backup credit lines for securitised vehicles and with the inability to dispose of assets intended to be sold off, in line with the originate-and-distribute model.

... spills over to money markets ...

In August, tensions were thus transmitted to the heart of the financial system – the interbank market, both in the United States and in a number of other mature markets (Graph 1).[17] These tensions took a variety of forms, including higher volatility in overnight and short-term interest rates, a sharp increase in interbank rates at longer tenors (such as the three-month rates), a drop in volumes, signs of rationing and greater dispersion in pricing. The increase in interbank rates reflected a mix of liquidity and counterparty credit risks, in proportions that have proved hard to disentangle. The problems intensified at year-end, owing to the usual seasonal pressures, as borrowers wanted to avoid the rollover risk and lenders wished to report as liquid a balance sheet as possible.

... raising three challenges for central banks

Against this backdrop, central banks faced a number of challenges. The first was to implement a given policy stance effectively in the face of the serious market disturbances; this involved keeping reference rates near targets

[17] See Michaud and Upper, Gyntelberg and Wooldridge, and Baba, Packer and Nagano in this issue.

or in the desired range through the control of the overnight rate or short-term market rates by means of supportive LMOs. The second challenge was to promote more "orderly" conditions in the term interbank market, a key price indicator of success being a narrowing in the sizeable "premium" over expected policy rates that had emerged in market rates at maturities longer than overnight. Finally, and outside the scope of this special feature, they had to decide whether and how to adjust the policy rate to respond to the potential macroeconomic implications of the turmoil.

Key distinction: implementing a policy stance …

The distinction between implementing a given policy stance and promoting orderly conditions in the term market segment, as reflected in the risk premium, is subtle but important. Implementing a given policy stance is largely a matter of responding to the changing characteristics of the *demand for bank reserves* at times of stress. This has primarily to do with the assets side of banks' balance sheets, ie their choice between reserves with the central bank and other liquid assets, such as government securities and widely accepted collateral. The liabilities side is relevant here to the extent that frictions in the interbank market – such as banks' reluctance to lend to each other – inhibit a smooth distribution of reserves. Promoting orderly conditions in the term segment is primarily a question of responding to the imbalance in the demand and supply in term markets, and hence to the changing *maturity composition* in the net demand for funding liquidity by banks, driven by perceived liquidity and counterparty risk concerns. This has to do largely with the liabilities side of the banks' balance sheets, in particular with the increase in the net demand for term funding relative to that for overnight funding, in relation to banks' total liquid assets. Central banks can address imbalances in term markets in two ways. First, they can seek to ensure stable and reliable overnight funding conditions, so as to encourage banks and other money market investors to supply more term funding. Second, they can provide more term funding themselves to the participants needing the financing.

… and addressing imbalances in the term market

The relationship between these two objectives – implementing a given policy stance and addressing imbalances in term markets – suggests that there is no clear-cut one-to-one mapping between actions addressed to one and the other. For example, ensuring that lending facilities are a reliable funding mechanism or that the central bank is more actively present in the overnight market to provide funding can promote both. It is fair to say that, by and large, central bank actions initially focused on the overnight market and, as time wore on and end-of-year seasonal tensions loomed, their strategy shifted towards more direct and ample provision of term funding.

No large cumulative net injections of reserve balances

It is equally important to dispel the apparently common belief that to implement policy effectively central banks, *on net*, had to inject large amounts of liquidity into the system (Table 3). In fact, given the specific nature of the market for bank reserves, the amount that banks hold on average remained pretty stable, broadly in line with historical patterns. For example, in the United States, there was only one maintenance period, in August, in which excess reserves were not reabsorbed, with the corresponding marked softness in the overnight rate indicating an excess supply and the central bank's preference for erring on the side of caution. The reason for this overall stability is that, as

Composition of reserve balances

	United States[1]		Euro area		Japan		Switzerland		United Kingdom	
	Total[2, 3]	Excess[4]	Total[2]	Excess[4]	Total[2]	Excess[4]	Total[2, 5]	Excess[4]	Total[2]	Excess[4, 6]
Jan–Jul 2007	15.1	10.4	182	0.5	5,106	7.2	10.2	15.0	16.4	0.00
Aug 2007	18.0	25.5[7]	192	0.4	4,966	5.0	10.1	14.1	16.6	0.00
Sep–Dec 2007	14.9	10.9	194	0.4	6,840[8]	5.6	10.1[9]	13.9[9]	21.5	–0.02

[1] Average of days in maintenance periods chosen to correspond closely to the periods indicated. [2] Includes the sum of required/target reserves and excess reserves; in billions of units of national currency. [3] Deposits of depository institutions at Federal Reserve Banks. [4] As a percentage of total reserves. [5] Includes banknotes and coins, which account for nearly half of the total. [6] Measured relative to the top (excess) and the bottom (shortfall) of the target range. [7] Excess reserves for the two-week maintenance period ending on 15 August 2007 were equal to 44% of total reserves. [8] The increase is largely explained by the addition of the Japan Post Bank in October. [9] Average of September and October.

Sources: Bloomberg; central banks; BIS calculations. Table 3

vehicles to park liquid funds, there are superior instruments in terms of risk/return characteristics to bank reserves, not least short-term government securities. As a result, excess reserve holdings tend to be minimised. In other words, *what central banks put in with one hand they largely took away with the other*, while at the same time responding to the changing properties of the demand for bank reserves.

While the steps taken to do this reflected the specifics of the situation and judgments about the most effective response, they were also influenced by the characteristics of the operating frameworks. In particular, in frameworks with no averaging provisions and with standing deposit facilities remunerated at close to the target rate, central banks accommodated a certain increase in precautionary holdings, which in any case remained contained in absolute terms (Australia and Canada).[18] In systems with reserve requirements, strategies differed somewhat, given the degree of leeway provided by averaging provisions. In particular, the ECB and the Swiss National Bank systematically front-loaded liquidity injections during the maintenance period, withdrawing liquidity towards the end of the period or when overnight rates fell below a certain level. In the face of heightened uncertainty and of frictions in the distribution of reserves, owing to tensions in interbank lending, this provided banks with a greater degree of comfort in meeting their needs. Elsewhere, not least where the size of the buffer was smaller, this strategy was not followed. In the United Kingdom, from September to December, banks decided to target higher reserve balances, in part to better exploit the flexibility in liquidity management provided by averaging provisions. In addition, alongside further liquidity injections, the Bank of England broadened substantially the band around reserve targets. As a result, it became unnecessary to withdraw any liquidity at the end of the maintenance period, since funds would be remunerated at the Bank Rate as long as they stayed within the band.

[18] Over the period January–July 2007, transaction balances (local currency amounts) averaged 50 million at the Bank of Canada and 816 million at the Reserve Bank of Australia; for August–December 2007 the respective figures were 260 million and 3 billion.

Steps taken during the financial turmoil

	AU	CA	EA	JP	CH	GB	US
Exceptional fine-tuning (frequency, conditions)	✓	✓	✓	✓	✓	✓	✓
Exceptional long-term open market operations	✓	✓	✓	✓	✓	✓	✓
Change in the standing lending facility							✓
Broadening of eligible collateral	✓	✓			✓[1]	✓	✓[2]
Change in banks' reserve requirements/target balances	•	•				✓	
Broadening of counterparties						✓[3]	✓[2]

See Table 1 for the mnemonics.

[1] Entered into effect on 1 October, but not linked with the turmoil. [2] The collateral and counterparty rules did not change, but the discretionary operations under the Term Auction Facility utilise the broader lists pertaining to discount window credit compared to those for ordinary open market operations. [3] Only for four auctions of term funding for which, however, there were no bids.

Source: Central banks. Table 4

Additional responses: adjustments to …

To varying degrees, the influence of the operating frameworks can also be traced in the steps taken to increase the frequency and gross size of the operations, to broaden the range of collateral and counterparties, and to increase term funding at the expense of short-term funding (Table 4).

… frequency and gross size of operations …

Increasing the frequency and gross size of discretionary operations was the first, common line of defence, largely in response to a more variable and uncertain demand for bank reserves and frictions in its smooth distribution. The actual frequency and amounts were closely related to the characteristics of the frameworks. For example, the ECB carried out overnight fine-tuning quick tenders for each business day from 9 to 14 August. The amount of credit provided through the operations began at €95 billion, adding about one third of the average outstanding amount of credit provided through the main refinancing operation over the previous month, but declined over the five days to €8 billion. On 10 August, the Federal Reserve conducted three auctions of overnight repurchase agreements totalling $38 billion, nearly double the average outstanding amount of credit provided via repurchase agreements over the previous two weeks. Its final auction occurred in the early afternoon, well after its normal operating time. Likewise, in the same month, and in some cases subsequently, the Reserve Bank of Australia, the Bank of Canada, the Bank of Japan and the Swiss National Bank also conducted market operations in response to the turmoil that were either outside their regular schedule or in larger than normal amounts. The Bank of England did not increase the frequency of its operations in August, in part because its monetary policy framework is designed to accommodate variations in the demand for reserves automatically. It did so, however, in September, not least as market rates continued to exceed the desired targets by more than normal.

… standing facilities and tender procedures …

Where felt appropriate, the increased size and frequency of operations were complemented by adjustments to other terms on the supply of funds. In particular, for the first fine-tuning operation, the ECB took the unusual step of meeting all demand at its policy rate of 4% rather than through the normal variable rate tender. This allowed it to inject an amount of liquidity matching counterparties' demand given the heightened uncertainty. In addition, on

17 August the Federal Reserve cut the interest rate on its standing loan facility (the discount rate) by 50 basis points and increased the allowable term on loans from overnight to 30 days. Admittedly, this change was primarily intended to temper upward pressure in term funding markets by signalling that the central bank stood ready to be a backstop source of liquidity (see below). Even so, it also tended to lessen upward spikes in the federal funds rate.

… range of collateral and counterparties …

In order to overcome the impediments to the smooth distribution of liquidity in the system, some central banks broadened the range of eligible collateral and, in fewer instances, also that of counterparties for discretionary operations. For example, both the Bank of Canada (in August) and the Federal Reserve (in December, see below) made it feasible to carry out some discretionary operations with the same, broader range of collateral as that available under their lending facilities.[19] Like the Federal Reserve, the Bank of England enlarged the eligible collateral for its term operations, while the Reserve Bank of Australia included additional securities issued by banks and securities backed by mortgages in the eligible set for both its market operations and its lending facility. The only two central banks that did not make any adjustments were the ECB and the Bank of Japan, which accept relatively broad ranges of collateral.[20] As regards counterparties, the Federal Reserve opened up its discretionary term operations to the larger set of institutions that had access to its standing facilities.[21]

… and reliance on term funding …

To a varying degree, all the central banks increased the availability of term funding supplied to the market through discretionary operations (Graph 2). Some of them started doing this well ahead of the year-end. Notable examples include the ECB, through some exceptional tenders of three-month funds beginning in August and renewed thereafter as the amounts matured, and the Swiss National Bank, which carried out its first ever tender of three-month funds in September. Starting in December, the Bank of England began to offer similar funding at the prevailing market rate in larger than normal amounts against extended collateral. The Bank of Japan started providing funds covering year-end in early October, earlier than in previous years.

… including through coordinated measures

Term operations intensified in December, as attention focused on the heightened tensions surrounding the end of the calendar and accounting year, but this time as part of a broader and coordinated international effort. In addition to showing a common resolve, the coordinated measures announced on 12 December also targeted the specific shortage of dollar funding faced by some non-US institutions, largely as a result of time zone differences and central bank counterparty restrictions. Thus, alongside the special Term (one-

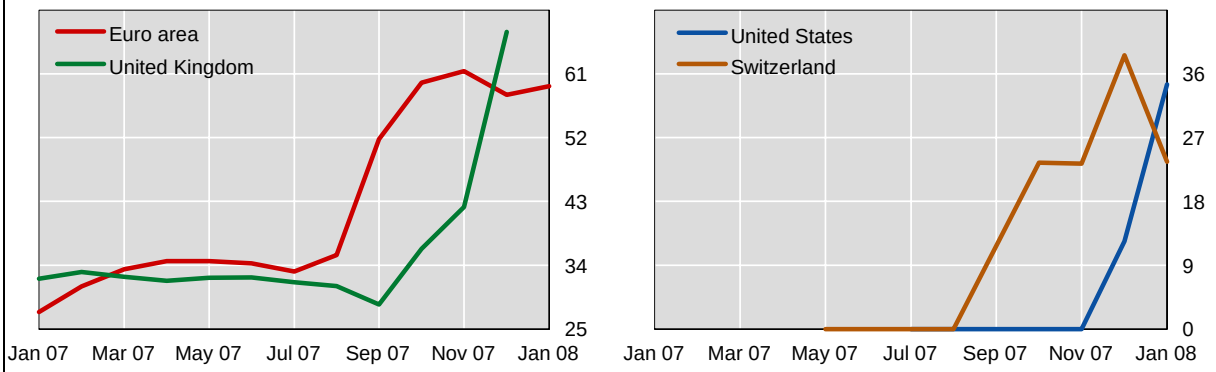
[19] The precise means, however, differed. The Bank of Canada temporarily broadened the range of collateral in its normal discretionary operations; the Federal Reserve introduced a special facility to auction loans under the same legal framework as that of discount window lending.

[20] In addition, however, the steps taken by the Swiss National Bank had already been planned before the turmoil and were unrelated to it.

[21] The Bank of England took a similar action for four auctions of long-term funds; however, owing to a somewhat elevated minimum bid rate relative to prevailing market rates, no bids were received.

Share of longer-term reverse operations at selected central banks[1]

In per cent



[1] Long-term reverse operations (one-month or greater); as a percentage of total outstanding reverse operations.

Sources: Central banks; BIS calculations. Graph 2

month) Auction Facility against the broader set of collateral and counterparties announced by the Federal Reserve,[22] US dollar swap lines were put in place with the ECB ($20 billion) and the Swiss National Bank ($4 billion).[23] These were activated for the nearly simultaneous one-month auctions carried out by the three central banks in December. Additional term funding auctions in their own currencies were also announced by the Bank of England and the Bank of Canada.[24] Joint term operations in dollar funding and, in some cases, unilateral ones in local currency continued for some time after the turn of the year.

How successful were central banks' actions to address the consequences of the turmoil? Judging from the relationship between the policy rate and the reference rate, after some difficulties in a number of jurisdictions in August and September, central banks regained control over the implementation of the announced policy stance (Graph 1). Judging from the term premium at longer tenors in the money market, operations were successful in easing tensions around year-end, although the premium remained somewhat elevated up to late January (Michaud and Upper, this issue).

Selected questions

Central bank operations at times of stress raise several interesting questions. Here, we consider briefly two of them.

[22] The facility was also partly intended to address the "stigma" associated with borrowing from the lending facility.

[23] The swap lines also helped establish a mechanism to address the pressures on the federal funds rate early in the US business day as European institutions sought dollar funding, an intraday pattern in the demand for reserves which complicated the Federal Reserve's liquidity management operations.

[24] While the Bank of Japan and Sweden's Riksbank did not announce any new measures, they welcomed those taken by the other central banks.

Distinction between setting the policy stance and implementing it via LMOs

The first is whether the distinction between setting the monetary policy stance, on the one hand, and implementing it through LMOs, on the other, is as clear-cut at times of stress as in normal times. If "stance" is defined as the current and possibly future intended path of the policy rate, the answer is affirmative. In particular, it is important to avoid the wrong inference that such LMOs, *by themselves*, carry any information about the policy rate path.

At the same time, of course, this does not mean that LMOs are irrelevant for the actual strength of the monetary stimulus for a given stance. In particular, to the extent that LMOs go beyond ensuring consistency between the policy rate and the reference rate and succeed in affecting the term risk premium, and that this premium is important in the transmission mechanism, then this stimulus is affected to some extent.

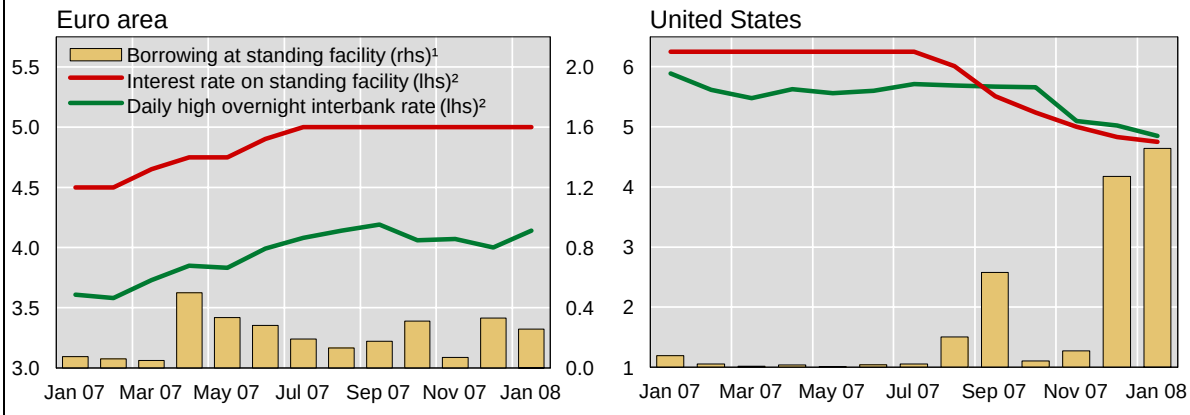
Nor does this mean that the choice of reference rate within an operating framework is irrelevant for the policy stance and its communication. The difference between an overnight rate and a three-month rate is especially relevant here. In order to keep its announced policy stance unchanged, the Swiss National Bank had to guide down the overnight rate to offset the increase in the risk premium in the three-month rate (Graph 1). By contrast, for other central banks, keeping policy unchanged required them *not* to respond to the increased premium. Clearly, the implied stimulus to the economy was different in the two cases.

Designing frameworks for normal and stress periods

The second question is how far operating frameworks should be explicitly designed with stress periods in mind. The answer is not so obvious because there can be trade-offs between desirable features in normal times and in times of stress. Exceptional adjustments at times of stress can imply costs. One may be the risk of sending the signal that the situation may be worse than it actually is. Another may be the risk of encouraging moral hazard, by giving the impression that rules may be softened to lessen the consequences of market

Use of standing facilities

Monthly averages



[1] For the euro area, marginal lending facility; for the United States, primary credit; in billions of units of national currency. [2] In per cent.

Sources: Central banks; BIS calculations. Graph 3

participants' mistakes. However, there are also costs of weighing considerations relevant at times of stress too heavily.

The potential trade-offs can best be illustrated by considering the issue of the limited willingness to resort to the lending facility during a period of financial turmoil. The recent experience has highlighted that financial institutions may perceive a "stigma" associated with such borrowing, for fear that it might be seen as a sign of weakness. For historical reasons, this stigma has been strongest in the United States, partly because a similar facility had been used to provide emergency liquidity assistance in the past. But during the current turmoil, signs of a stigma have also become visible elsewhere, such as in the United Kingdom. An (admittedly rough) indicator of this phenomenon is the spread between the daily high uncollateralised overnight interbank rate and the rate on the lending facility (Graph 3). One way of addressing this problem would be to have more frequent borrowing in normal times (eg by reducing the penalty rate). But this could have the undesirable side effect of tending to inhibit the development of an independent and active interbank market. Different views concerning this trade-off would point to a different architecture of the operating framework. To varying degrees, similar trade-offs also apply to issues such as the breadth of eligible collateral and the choice of counterparties.

Conclusion

Central bank responses to the recent financial turmoil exhibit considerable similarities. On net, liquidity was only temporarily, if at all, injected in larger amounts than usual in line with the fundamental characteristics of the demand for reserve balances. Beyond this, the average maturity of liquidity injections was lengthened in an attempt to meet the increased demand for term funding by banks. At the same time, the size, frequency and other modalities of the liquidity injections, while exhibiting many similarities, have been considerably influenced by the operating frameworks in place. Combined with the varying intensity of strains across currency areas, the frameworks have affected the need to make adjustments to existing practices in order to meet the changing conditions. If these differences are not taken into account, there is a serious risk of misunderstanding the character and implications of the operations.

The turmoil has highlighted a number of questions that would tend to go unnoticed in normal times. For example, we have argued that the distinction between setting the monetary policy stance and implementing it through liquidity management operations remains valid at times of stress. We have also argued that a trade-off can arise between the desirable characteristics of operating systems in normal times and times of stress, depending on views concerning what those desirable characteristics are and on country-specific circumstances. No doubt, these and other questions, such as the desirability and ability to influence the interbank risk premium, or the potential moral hazard implications of operations at times of stress, are likely to remain the focus of serious reflection in the period ahead.

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What drives interbank rates? Evidence from the Libor panel[1]

The risk premium contained in the interest rates on three-month interbank deposits at large, internationally active banks increased sharply in August 2007 and risk premia have remained at an elevated level since. This feature aims to identify the drivers of this increase, in particular the role of credit and liquidity factors. While there is evidence of a role played by credit risk, at least at lower frequencies, the absence of a close relationship between the risk of default and risk premia in the money market, as well as the reaction of the interbank markets to central bank liquidity provisions, point to the importance of liquidity factors for banks' day-to-day quoting behaviour.

JEL classification: G21, G32.

The functioning of interbank money markets was severely impaired during the second half of 2007. Uncertainty about losses associated with US subprime mortgage-related structured products led large banks to revise upwards their liquidity needs while making them also more reluctant to lend to each other, in particular at longer maturities. Central banks quickly reacted to the dislocations by temporarily increasing the supply of liquidity (see Borio and Nelson in this issue), but conditions in money markets, in particular for maturities beyond one day, worsened again towards the end of the year, triggering further central bank actions. Conditions in those markets improved after the turn of the year, although tensions remained as of mid-February 2008.

This feature analyses the risk premium reflecting credit and liquidity factors contained in the interest rates paid on interbank deposits by large, internationally active banks. The aggregate premium rose sharply in August, and, after some easing in the following months, again towards the end of the year. Disentangling credit from liquidity factors in this risk premium is difficult, as we are not able to observe banks' funding liquidity needs. Our analysis suggests that although concerns about bank credit risk increased at roughly the same time as the risk premium, our measure of credit risk has little explanatory

[1] We would like to thank Naohiko Baba, Paul Birckel, Claudio Borio, Dietrich Domanski, Már Gudmundsson, Jacob Gyntelberg, Peter Hördahl, Patrick McGuire, William Nelson, Frank Packer, Jean-François Rigaudy, Philip Wooldridge and Feng Zhu for useful comments and discussions as well as Jhuvesh Sobrun for excellent research assistance. The views expressed are those of the authors and do not necessarily reflect those of the BIS.

power for the day-to-day fluctuations in the premium. Similarly, the cross-sectional dispersion of the premia was largely independent of the perceived risk of default of banks. This could indicate that at short horizons risk premia are mainly driven by factors related to the funding liquidity, ie the ability to convert assets into cash, of individual banks.

The article is structured in three parts. A first section discusses the possible determinants of the risk premium contained in money market rates and draws tentative conclusions from aggregate data. This is supplemented in a second section by evidence based on the rates quoted by the individual banks contained in the Libor panel. The third section reviews the reaction of interbank rates to bank announcements and central bank actions during the second half of 2007. A final section concludes.

Evidence from aggregate data

Expectations hypothesis of interest rates

Arbitrage arguments suggest that the rates paid on term bank deposits should be closely related to expected overnight rates over the same period of time, since term deposits and revolving overnight deposits are close substitutes. However, this relationship, known as the "expectations hypothesis" of interest rates, need not hold perfectly due to the presence of counterparty credit risk, liquidity factors or a term premium related to the uncertainty about the future path of short-term interest rates. All these factors can drive a wedge between the rates paid on the two types of deposits, which may also fluctuate over time.

Interbank rates proxied by Libor fixing

Time series on the rates paid by individual banks on their interbank borrowing are notoriously hard to obtain. This is because the interbank market is organised on a bilateral basis, where only the two parties involved in each trade know the precise terms of the transaction. In the absence of comprehensive data on individual transactions, we proxy money market interest rates by the daily Libor fixings published by the British Bankers' Association (BBA) for a wide range of currencies and maturities. The Libor fixing is meant to capture the rates paid on unsecured interbank deposits at large, internationally active banks. Every day, the BBA surveys a panel of banks, asking them to provide the rates at which they could borrow "reasonable amounts" in a particular currency and maturity at 11:00 GMT. The fact that Libor is based on non-binding quotes, as opposed to actual transactions, may open up the possibility of strategic misrepresentation. The BBA tries to reduce the incentives for such behaviour (and to remove quotes that are untypical for other reasons) by eliminating the highest and lowest quartiles of the distribution and averaging the remaining quotes.[2]

Overnight-indexed swaps as measures of interest rate expectations

Estimating risk premia in money market rates also requires a measure for expected overnight rates. In the analysis that follows, we use the rates on overnight-indexed swaps (OISs) as a proxy for expected future overnight

[2] See Gyntelberg and Wooldridge in this issue for more details on the fixing mechanism and its implications.

rates.[3] We believe that these rates provide a reasonably accurate measure for investors' expectations for two reasons. First, the counterparty risk associated with these contracts is relatively small as they do not involve the exchange of principal; moreover, the residual risk is further mitigated by collateral and netting arrangements. Second, and perhaps more importantly, the liquidity premia contained in OIS rates should be very small as these contracts do not involve any initial cash flows. Under normal market conditions, OIS rates tend to be slightly below the corresponding Libor.

Sharp increase in risk premium …

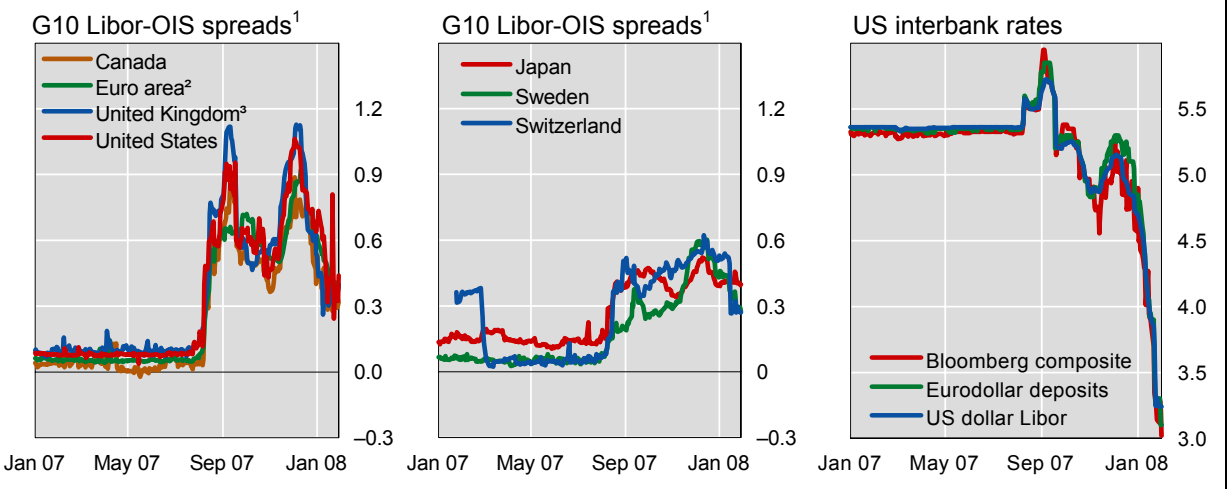
In August 2007, risk premia in short-term money market rates, as represented by the spreads between Libor and OIS rates, increased significantly in most major currencies (Graph 1, left-hand and centre panels). Among the G10 markets, spreads were larger in the Canadian dollar, euro, sterling and US dollar markets. Other non-G10 money markets were much less affected, if at all.

… for deposits at international banks …

Even at the aggregate level, there is evidence that large, internationally active banks behaved differently during the turmoil than smaller banks whose operations are more focused on the domestic market. In several currencies, the gap between the rates quoted by international banks and domestic money market rates widened noticeably. The impact of large banks' treasury management was perceptible across time zones. In particular, European banks were reported to be bidding rather aggressively in the US dollar market to match their dollar liquidity needs (see Baba, Packer and Nagano in this issue), resulting in specific patterns in the US dollar money market during the morning session. Intraday tensions were also observed in the Australian money market,

Three-month interbank interest rates and spreads

In per cent



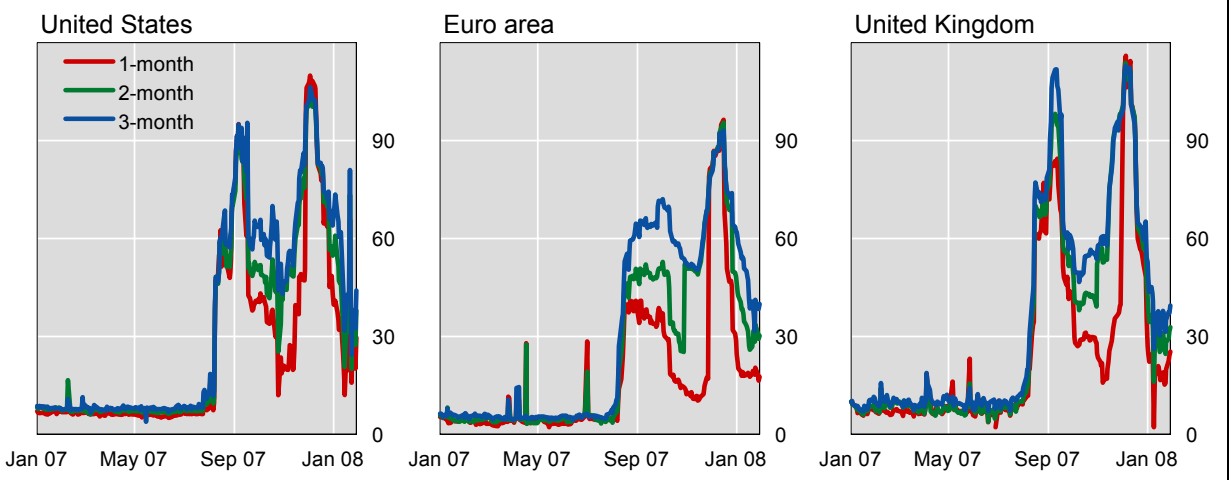
[1] Libor rates minus OIS rates. [2] EONIA swap. [3] SONIA swap.

Sources: Bloomberg; BIS calculations. Graph 1

[3] OISs are interest rate swaps in which the floating leg is linked to a published index of daily overnight rates. The two parties agree to exchange at maturity, on an agreed notional amount, the difference between interest accrued at the agreed fixed rate and interest accrued through the geometric average of the floating index rate.

Libor rate minus OIS swap rate[1]

In basis points



[1] Libor rates minus corresponding OIS rates (for the euro area, EONIA swap; for the United Kingdom, SONIA swap).

Sources: Bloomberg; BIS calculations. Graph 2

which is the first to open. The analysis below focuses on large, internationally active banks in the dollar, euro and sterling markets, which were particularly affected by the turmoil.

The developments highlighted in the previous paragraphs were not merely the result of the fixing process used to compute Libor as other measures of three-month interbank interest rates evolved similarly over the same period. This was, for instance, the case with the three-month eurodollar deposit rate and the Bloomberg three-month composite deposit index, which are closer than Libor to prices and rates actually traded (Graph 1, right-hand panel).

… particularly at longer maturities

The increase in Libor-OIS spreads was particularly large and persistent at the three-month maturity. In September and December, this spread reached levels close to those briefly observed at the end of 1999 in the United States and the euro area due to Y2K concerns. Shorter-maturity spreads initially moved in tandem with three-month spreads in the dollar and sterling markets, but declined well below the latter in late September (Graph 2). The difference between the Libor-OIS spreads across different maturities was even larger in the case of the euro. Two-month spreads in all three currencies shot up at the end of October as their maturity began to extend beyond the end of the year. A month later, an even more pronounced jump was recorded for similar reasons in the one-month maturity, with one-month spreads even exceeding those for longer maturities for a brief period. The differences across maturities and the sudden jumps point to the importance of bank liquidity needs, in particular around the turn of the year, as a driver of Libor-OIS spreads during this period; concerns about counterparty risk would have implied less volatile rates and less variation across maturities.

Decomposing the risk premium

Components of the risk premium

The risk premium contained in money market rates can be decomposed into several factors reflecting the characteristics of the borrowing bank as well as

market-wide conditions. Among the bank-specific variables, it is useful to distinguish between the compensation for the risk of default (*credit*) and a premium related to the demand for funds, which depends on the funding liquidity of the borrowing bank (*bliq).* Market-wide conditions include the uncertainty about the path of expected overnight rates, which is reflected in a term premium (*tprem*), the ease of trading (market liquidity *mliq*), and factors related to the fixing process and the microstructure of the market (*micro*):

$$riskpremium = tprem + credit + bliq + mliq + micro$$

Measures for credit risk …

Disentangling the different components of the risk premium is tricky since there are no financial instruments whose payoffs are directly related to any of the individual factors. In what follows, we proxy banks' risk of default by two different measures: the spread between unsecured and secured interbank rates, and the premium paid on credit default swaps (CDSs) referencing the debt of the borrowing banks. Neither measure is fully satisfactory. Unsecured-secured spreads are affected by a series of liquidity premia, reflecting conditions in the unsecured market, in the secured (repo) market and in the market for the underlying collateral, and there is no reason to believe that these premia offset each other. In particular, if Libor is used as a measure for the unsecured rate, the spread would contain *bliq*, *mliq* and *micro* by construction. Also, safe haven flows during a financial turbulence may drive down rates in the repo market. CDS premia are much less affected by liquidity conditions than the unsecured-secured spread due to our use of benchmark CDSs with a maturity of five years. The main drawback of this measure is, of course, the sizeable maturity mismatch. A final point worth noting is that both unsecured-secured spreads and CDS premia refer to a combination of the risk of default *and* the compensation demanded by investors for bearing this risk, rather than only to the risk of default.[4]

… and market liquidity …

Data on market liquidity conditions in the money market are not easily available. For the euro money market, we compute indicators for market liquidity from prices and quantities observed on the electronic trading platform e-MID.[5] There are very few transactions in the three-month segment on e-MID, so we use liquidity in the overnight market as a proxy for liquidity in term deposits.[6] Since market liquidity in the overnight market appears to have been much less affected by the turmoil than market liquidity in the market for term deposits, the e-MID data are likely to understate the deterioration in liquidity

[4] There are several measures for credit risk which do not contain a risk premium, but these are generally not available at high frequencies. See Duffie and Singleton (2003) for an overview of credit risk models.

[5] According to market sources, e-MID had a share of approximately 20% of the unsecured euro money market, although this may have fallen during the turbulence. This decline in market share may affect the reliability of volume-based liquidity indicators but should have less of an impact on price-based measures as long as some market participants are able to arbitrage between the electronic and non-electronic markets.

[6] Less than 1% of all transactions on e-MID have a maturity of three months, while almost 80% are overnight loans.

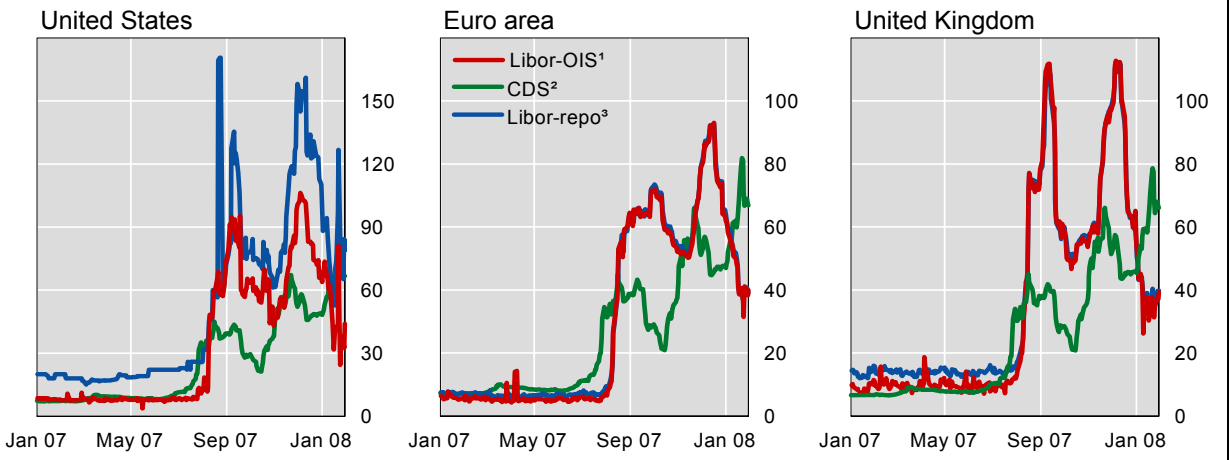
conditions in the term market during the second half of 2007. That said, they may still provide useful information on *when* market liquidity was impaired, even if they understate the extent of the problems. The various dimensions of market liquidity are captured by the number of trades, volume, bid-ask spreads,[7] and the price impact of a trade.[8] In order to ensure exogeneity, all measures are computed for the time from market opening until 10:50 GMT, ie 10 minutes before the Libor fixing.

… but not on banks' funding liquidity positions

Measurement problems are greatest when it comes to assessing bank-specific funding liquidity and microstructure effects. Relevant information for assessing the funding liquidity of Libor banks would include liquidity ratios and the size of potential commitments. Unfortunately, these variables are not available on a systematic basis at a relevant frequency.[9] We therefore treat *bliq* (and *micro*) as an unobserved variable whose effects will appear as a residual once the impact of all other variables has been taken into account.[10] If funding liquidity deteriorated around the same time as our measures for credit risk, then treating *bliq* as an unobserved variable may result in us attributing too much of the variation in risk premia to credit factors. Indeed, there are at

Three-month money market and credit spreads

In basis points



[1] Three-month Libor rates minus corresponding OIS rates (for the euro area, EONIA swap; for the United Kingdom, SONIA swap). [2] Average of the five-year on-the-run CDS spreads for the panel banks reporting Libor quotes in the domestic currency's panel. [3] Three-month Libor rates minus general collateral repo rates (for the United States, ICAP government general collateral repo; for the euro area, EBF eurepo; for the United Kingdom, BBA repo) in the same currency and maturity.

Sources: Bloomberg; BIS calculations. Graph 3

[7] Effective spreads are computed from transaction data using the Roll (1984) approach.

[8] A daily series for the price impact of a transaction is obtained by regressing price changes over a five-minute interval on signed volumes during that interval. The coefficient on signed volumes corresponds to the price impact.

[9] Ashcraft and Bleakley (2006) use shocks to daily reserve balances of US banks in order to control for funding liquidity. Similar data do not exist on an international basis.

[10] A similar approach has been taken by Bank of England (2007), who calculate a credit premium from CDS premia and refer to the residual as the non-credit premium.

least two reasons why our measures for credit risk might be related to banks' funding liquidity. First, banks may hoard liquidity in times of high systematic risk. Second, they may default for liquidity as well as for solvency reasons.

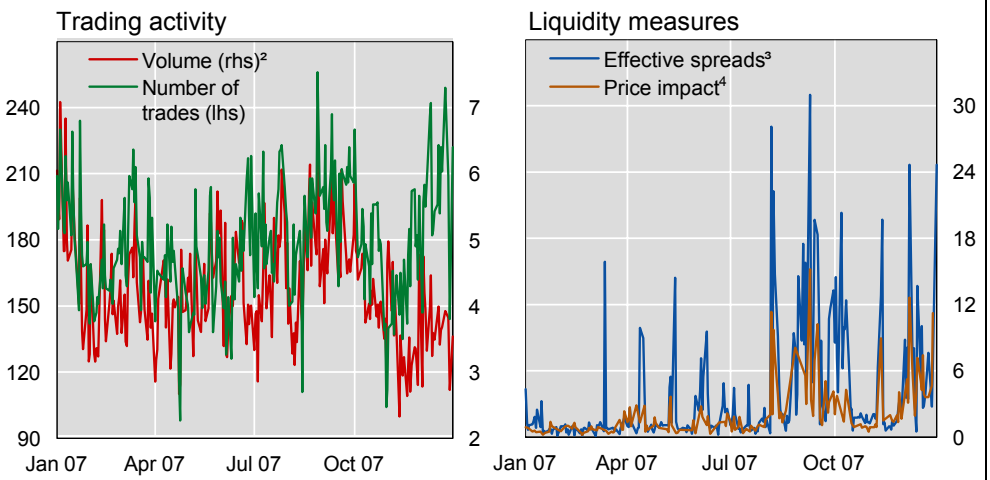
Libor-OIS spreads co-move with measures for credit risk

A comparison of the aggregate series suggests that both indicators for credit risk track Libor-OIS spreads reasonably well during the second half of 2007. In the second half of 2007, unsecured-secured spreads were almost identical to Libor-OIS spreads in the euro and sterling market (Graph 3), or even above them in the dollar market, perhaps reflecting the fact that both indicators are driven by the same liquidity premia. This is in sharp contrast to the situation in late 1999, when concerns about liquidity around the turn of the millennium drove up the spread between Libor and policy rates[11] but hardly moved credit risk indicators. This suggests that, compared with that episode, credit concerns might have played a significantly larger role in the current episode.

However, the relationship between CDS premia and Libor-OIS spreads is much less close than that between Libor-OIS spreads and the unsecured-secured spread. If anything, CDS premia lead Libor-OIS spreads in all three currencies during the second half of 2007. For example, CDS premia on the Libor banks began to rise in late July, almost two weeks before Libor-OIS spreads went up. A similar leading relationship is apparent for the temporary decline in Libor-OIS spreads in October and the rise towards the end of the year. The relationship between Libor-OIS spreads and CDS premia breaks down in January 2008, when the risk premium in the money market declined whereas CDS premia shot up.

There are at least two potential explanations for the relatively loose relationship between Libor-OIS spreads and CDS premia. First, it could be due

Liquidity in the euro overnight market[1]



[1] Computed from opening to 11:50 CET from transaction data. [2] In billions of euros. [3] Roll (1984) measure, in basis points. [4] Slope coefficient from regressions of five-minute price changes on signed order flows; in per cent.

Sources: e-MID; BIS calculations. Graph 4

[11] OISs either did not exist or were not actively traded at the time.

to the different maturities of the two indicators. While it is impossible to dismiss this hypothesis, it cannot explain the fact that CDS premia lead Libor-OIS spreads. Second, and probably more realistically, it points to the importance of liquidity factors (*bliq* and *mliq*). For example, the relatively wide gap between euro Libor-OIS spreads and CDS premia in August and September is consistent with the evolution of the market liquidity in the euro overnight market (Graph 4), where both effective bid-ask spreads and the measure for the price impact of a trade executed on the e-MID platform increased sharply during the same period. Similarly, the differences across maturities of Libor-OIS spreads driven by concerns about banks' funding liquidity around the turn of the year (see above) are also consistent with this hypothesis.

Evidence from panel data

Marked differences across banks

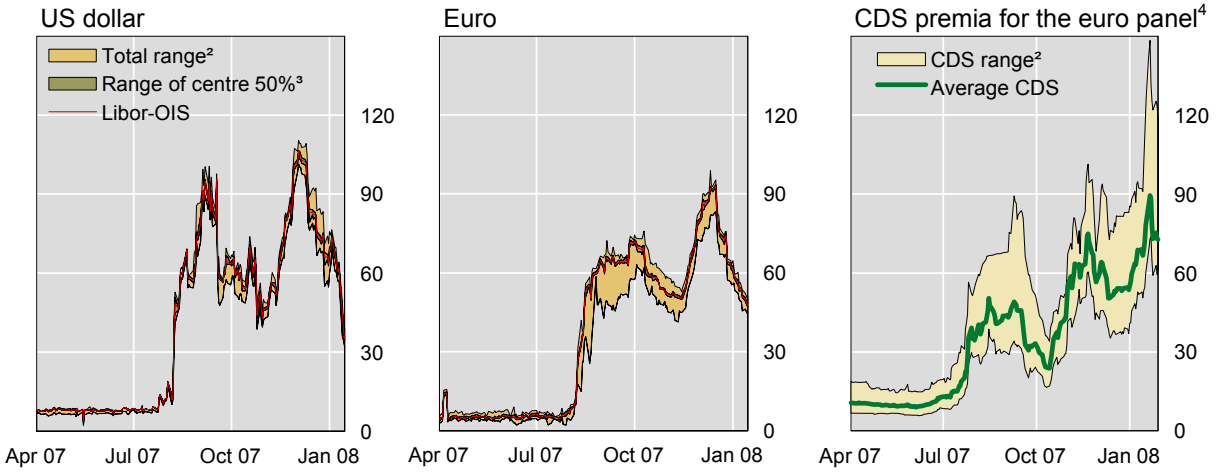
While Libor-OIS spreads increased for all banks in the second half of 2007, the extent of the increase clearly varied across markets and institutions. In the euro money market (Graph 5, centre panel), the dispersion in quoted rates was more pronounced than in the dollar (left-hand panel) or sterling (not shown). However, even in the euro area the dispersion was, at least initially, driven by a small number of banks quoting relatively low rates in their responses to the Libor panel. The interquartile range, from which Libor is calculated, was extremely narrow in all three currencies, rarely exceeding 2 basis points even at the height of the turmoil. This contrasts with anecdotal evidence gathered from conversation with market participants, who argued that the rates quoted and paid by banks on their interbank borrowing tended to vary more than usual (and by more than what appears in the Libor panel) during the turbulence.

Little evidence for credit factors affecting quoting behaviour …

The fairly low degree of dispersion of Libor quotes compared with the dispersion of their CDS premia (right-hand panel) suggests that banks' quoting

Libor panel banks: three-month Libor-OIS spreads[1] and CDS premia

In basis points



[1] Three-month interbank Libor rates minus corresponding OIS rates (for the euro area, EONIA swap). [2] Range for all 16 panel banks. [3] Centre quartiles of the distribution. [4] Five-year on-the-run CDS mid-spreads.

Sources: Bloomberg; BIS calculations. Graph 5

behaviour in the interbank market reflected only to a small extent, if at all, any risk of default. This first impression is confirmed by econometric evidence. Regressing daily cross sections of three-month Libor-OIS spreads on the cross section of CDS premia[12] yields a coefficient that is both economically and statistically insignificant in all three currencies. This indicates that banks with higher CDS premia do not appear to have quoted significantly higher rates on a given day than banks with lower credit risk.

… except perhaps in the long run

Similar econometric evidence suggests that while credit factors may have influenced the longer-term movements in Libor-OIS spreads, they do not appear to have had much of an effect on their day-to-day variations. Specifically, a panel estimation of Libor-OIS spreads on CDS premia points towards the existence of a long-term equilibrium (cointegrating) relationship between the two variables in all three currencies, even as day-to-day changes in CDS premia have little explanatory power for those in Libor-OIS spreads. Experimenting with a large number of specifications at daily and weekly frequencies shows that it takes a long time for changes in CDS premia to feed into Libor-OIS spreads.[13]

While useful, the above econometric evidence should be interpreted with considerable caution. For one, it is vulnerable to the omitted variable bias noted above. In addition, even the evidence of a long-term relationship between credit and Libor-OIS spreads could be picking up the effect of structural breaks in the sample, at the time the turmoil erupted.

Evidence from event analysis

Price reactions to bank losses and central bank emergency liquidity ...

Additional information on the respective roles of credit and liquidity factors as determinants of Libor-OIS spreads can be obtained from reviewing the impact on spreads of news related to credit quality and liquidity conditions. For example, announcements of large writedowns, losses or the support to off-balance sheet vehicles by individual banks have been interpreted by many observers as providing information on the credit quality also of other banks. Similarly, extraordinary liquidity provision by central banks has led to large changes in the funding liquidity of banks, at least temporarily. Neither type of event is easily included in regression analysis, since both tend to occur on an irregular basis and their impact is not readily quantifiable except by looking at market reactions in various segments.

This section is based on the responses of Libor-OIS spreads in the three currencies, CDS premia and equity prices of the panel banks to 20 events, one half bank announcements, the other half central bank actions.[14] If

[12] Secured-unsecured spreads are not available for individual banks.

[13] As a consequence, a large number of lags is needed to capture the dynamics of adjustment, with the corresponding risk of overfitting the data. Moving to a lower frequency does not solve the problem, since the number of lags becomes very large relative to the estimation period even when weekly data are used.

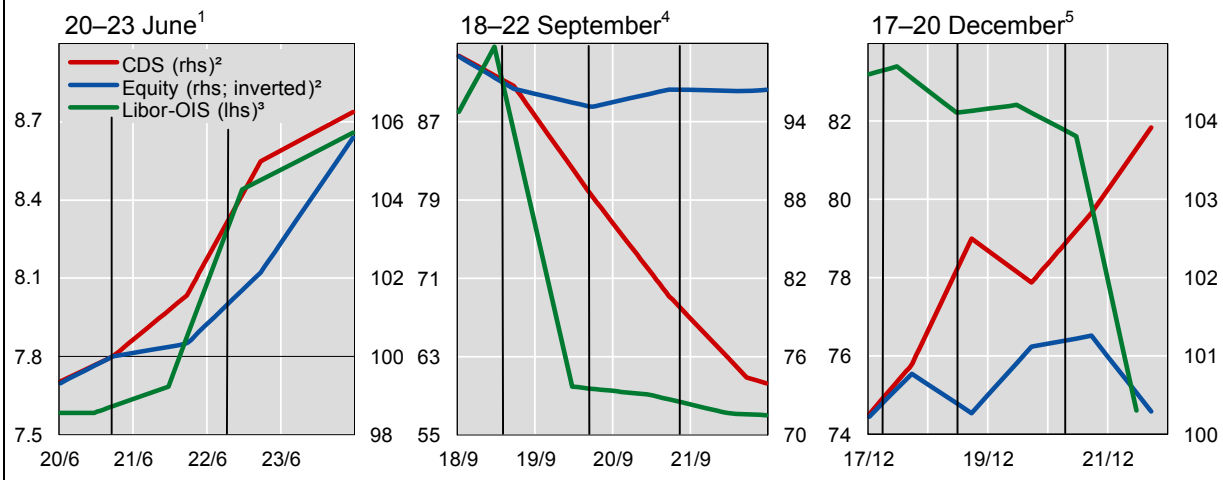
[14] Central bank extraordinary liquidity management operations were aimed at helping banks manage their liquidity needs. It is worth noting that the total outstanding amount of reserve

unanticipated, both types of events can be expected to affect Libor-OIS spreads. While bank announcements of unanticipated writedowns or similar events might be expected to drive up both Libor-OIS spreads and CDS premia, the effect of central bank actions is less clear-cut: the provision of additional liquidity should drive down Libor-OIS spreads but not necessarily CDS premia. Provisions of central bank liquidity should reduce CDS premia only if market participants fear that banks may default due to liquidity problems; otherwise their expected impact on measures of credit risk is not obvious.

… vary over time

The effects of the events on market prices were surprisingly diverse across events and over time (see examples for the US dollar panel in Graph 6). Only six out of the 10 bank announcements resulted in higher Libor-OIS spreads, and five in higher CDS premia. For example, the announcement by Bear Stearns that it had pledged up to $3.2 billion in loans to bail out one of its hedge funds on 22 June led to an increase in both Libor-OIS spreads and CDS premia. Similarly, Citigroup's disclosure of large subprime-related exposures and the retirement of its CEO on 4 November also caused Libor-OIS spreads and CDS premia to rise and equity prices to fall. By contrast, the announcement on 20 September by Bear Stearns of a $700 million writedown on mortgage and leveraged loan commitments was associated with a decline in

Impact of selected events in 2007 on the US dollar panel



[1] The vertical line at 17:25 CET on 20 June indicates Merrill Lynch seizing and selling $800 million of bonds held as collateral for loans to money-losing hedge funds; the vertical line at 07:00 CET on 22 June indicates Bear Stearns pledging up to $3.2 billion in loans to bail out one of its hedge funds which was collapsing because of bad bets on subprime mortgages. [2] Average across the Libor panel banks; based on five-year on-the-run indices for CDSs and equity prices in US dollars for equity; rebased to 100 at 17:00 CET on 20 June in the left-hand panel, at 17:00 CET on 17 September in the centre panel and at 17:00 CET on 4 November 2007 in the right-hand panel. [3] Average across the Libor panel banks of three-month interbank Libor rates minus three-month OIS rates; in basis points. [4] The vertical line at 14:50 CET on 18 September indicates Lehman Brothers cutting commitments and mortgage-related exposure by a net $700 million; the vertical line at 17:16 CET on 19 September indicates Morgan Stanley's announcement of its third quarter results and marking-down of assets by $940 million; the vertical line at 21:08 CET on 20 September indicates Bear Stearns taking $700 million in writedowns on mortgages and leveraged loan commitments. [5] The vertical line at 6:26 CET on 17 December indicates the Fed's term auction facility (TAF) of $20 billion in one-month funds; the vertical line at 12:16 CET on 18 December indicates the ECB's auction of €350 billion in a two-week reverse operation; the vertical line at 7:05 CET on 20 December indicates the Fed's TAF of $20 billion in one-month funds.

Sources: Bloomberg; BIS calculations. Graph 6

transactions at large central banks has remained stable overall since August 2007. In other words, liquidity provision by central banks did not replace interbank borrowing, except perhaps for short periods of time.

CDS premia and Libor-OIS spreads and had no apparent impact on share prices. CDS premia declined in three other cases concentrated between the end of September and beginning of December, possibly reflecting some relief on the part of market participants after the announcement of third quarter results by several US investment banks and additional official support to Northern Rock.

As expected, the 10 central bank extraordinary liquidity management operations appear to have had a clear-cut impact on Libor-OIS spreads but not on CDS premia. Libor-OIS spreads declined in seven out of the 10 cases, with the largest effects being felt in the central banks' own currency. CDS premia fell in only five cases. One of the central bank measures consisted in three consecutive auctions of overnight repurchase agreements by the Federal Reserve on 10 August. It led to declines in both US dollar and euro Libor-OIS spreads, as well as to lower CDS premia and higher share prices for the banks in the two (largely overlapping) panels.[15]

Overall, the reaction of asset prices to the 20 events gives support to the notion that both credit and liquidity risk played a role in explaining the high level of the three-month risk premium in the second half of 2007, although the evidence is stronger in the case of the liquidity factors. However, this may in part be due to a general shortcoming in the methodology used, since we cannot be sure that the bank announcements were always considered as bad news by market participants. For example, investors may interpret the announcement of losses as banks actually recognising and addressing problems that had been virulent for some time.[16]

Concluding thoughts

This feature offers some evidence on the importance of credit and liquidity factors for the rates paid in the interbank market during the recent financial turmoil. However, the results are still preliminary and subject to a longer than usual list of caveats for a variety of reasons. First, the turbulence was still unfolding at the time of writing, despite significant improvements in money market conditions. New data will invariably offer new insights, which may cause us to revise some of the conclusions drawn at this early stage. Second, a central variable of interest, namely bank-specific funding liquidity, cannot be observed and is therefore treated as a residual. Since funding liquidity may be related to our measures of credit risk, this may result in too much of the

[15] While it is not part of the list of events, it is also worth noting that the decision by the Federal Open Market Committee to lower its target for the federal funds rate by 50 basis points to 4.75% on 18 September resulted in lower Libor-OIS spreads and CDS premia and higher equity prices across all three currencies and various maturities.

[16] Interestingly, Libor-OIS spreads, CDS premia and equity prices did not appear to move more synchronously within the event windows than they did outside them. Reactions across asset classes following bank announcements and central bank operations were consistent in only five and four out of the 10 cases, respectively. This, as well as the mixed responses of CDS premia, may reflect other factors, such as investors' overall risk appetite at a given point in time, lags in market reactions or different investor classes across market segments.

variation in the risk premium being attributed to credit factors. Third, there may be a problem with using quotes rather than actual transaction data.

With all these caveats in mind, our results support the view that both credit and liquidity factors were behind the increase in risk premia in the interbank money market. The role of credit factors is more easily traceable at lower frequencies. Evidence from aggregate data, panel regressions and event studies show that, at higher frequencies, bank-specific funding liquidity needs have played a more important role. Finally, in the cross section, we do not find systematic evidence that banks with higher perceived credit risk quoted higher Libor rates than their peers on a given day.

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Interbank rate fixings during the recent turmoil[1]

The turmoil in global interbank markets in the second half of 2007 raises questions about the robustness of interbank rate fixings. A comparison of alternative fixings for similar interest rates confirms that they diverged to an unusual extent. Nevertheless, the design of fixing mechanisms worked as intended to moderate the influence of strategic behaviour and changing perceptions of credit quality.

JEL classification: F30, G12, G15.

The evaporation of liquidity in the term segment of major interbank markets in the second half of 2007 raises questions about the reliability of rate fixings purported to represent conditions in these markets. Financing for terms of more than a few days was reportedly not readily available at some commonly referenced interest rates, such as the London interbank offered rate (Libor). A comparison of alternative fixings for similar interest rates confirms that, during the recent turbulence, Libor diverged from other reference rates to an unusual extent. A deterioration in market liquidity, an increase in interest rate volatility and differences in the composition of the contributor panels were the main causes of the divergence. Nevertheless, the design of the fixing mechanism moderated the influence of extreme quotes from contributor banks, as intended.

Below, we first discuss the role of money market benchmarks in financial markets. The following section compares the design of different interbank fixings and considers the incentives banks face to contribute accurate quotes. We then examine the influences on fixings during the market turmoil in the second half of 2007. The final section concludes.

The role of money market benchmarks

Money market rates are referenced in many financial contracts

Short-term interest rates are referenced in a wide variety of financial contracts. Well established benchmarks are therefore critical to the efficient functioning of markets in these instruments. However, the importance of benchmarks for

[1] The authors are grateful to Claudio Borio, Pierre Cardon, Már Gudmundsson, Mico Loretan, Robert McCauley, Frank Packer, Jean-François Rigaudy, Oliver Schmidt and Christian Upper for comments and to Emir Emiray for research assistance. The views expressed in this paper are those of the authors and do not necessarily reflect those of the BIS.

short-term interest rates goes well beyond their use in contracts. They anchor the short end of the yield curve, thereby conveying information about expected future policy rates and other macroeconomic fundamentals.

The use of money market rates to price other financial instruments dates back to at least the 1970s. The pickup as well as the variability in inflation at the time made long-term fixed rate securities unattractive to investors. In response, floating rate bonds were introduced with coupon payments linked to money market rates plus a credit spread. The syndicated loan market, which began to grow around the same time, adopted a similar pricing mechanism (Gadanecz (2004)).

The terms of many financial derivatives also make explicit reference to money market rates. Futures contracts on money market rates were the first to emerge. Their over-the-counter equivalent, forward rate agreements, were developed in the early 1980s, along with interest rate swaps (Stigum and Crescenzi (2007)). Numerous other derivatives linked to money market rates followed, including swaptions, cross-currency swaps and asset swaps.

Even for instruments not contractually linked to them, money market rates have an important impact on market functioning. For example, forward foreign exchange contracts are priced off of money market rates. The discount rates used in a wide variety of cash flow models, such as those used to estimate the fair value of bonds or equities, are typically based on money market rates.

There are a range of money market rates that could serve as references, including Treasury bill, interbank, repo and commercial paper rates. Typically only one will be elevated to the status of benchmark, and that will tend to be the rate with the most stable relationship to the prices of other securities. A key requirement of a benchmark is that it be liquid. Movements in benchmark yields should not be driven by order imbalances but rather should exclusively reflect new information about fundamentals (Wooldridge (2001)). Benchmark yields need not be risk-free rates. Indeed, interest rates with a small credit risk premium might be more effective hedging and positioning vehicles because they are closer approximations of the rates faced by financial institutions. However, the risk premia in benchmark yields need to be predictable if the yields are to be a stable reference for pricing.

Benchmark status is gained through competition

Benchmark status is gained through competition; it is not conferred. Therefore, it can also be lost. Persistent pricing anomalies limit the usefulness of a benchmark as a hedging or positioning vehicle. This may result in a switch to an alternative reference rate. Each participant who switches subtracts liquidity from the established benchmark and adds liquidity to its competitor. In the self-reinforcing process whereby liquid markets become more liquid, this makes it more attractive for others to do likewise.

Such a process of benchmark tipping occurred in the US dollar money market in the mid-1980s (McCauley (2001)). US Treasury bills were once the pre-eminent short-term reference rate. When derivatives based on offshore interbank rates were introduced, financial institutions found that their prices more closely approximated their own borrowing costs. Periodic large changes in the supply of Treasury bills and associated breakdowns in normal pricing relationships strengthened the incentive for market participants to re-examine

their risk management practices. By the late 1980s, three-month Libor was well established as the benchmark rate in the US dollar money market.

The design of interbank rate fixings

Libor is the best known fixing arrangement

An interbank rate is the rate of interest paid on a loan from one bank to another. Typically the market rate is estimated through a "fixing" arrangement, wherein an average rate is calculated from quotes contributed by a panel of banks. The best known fixing arrangement is that for Libor. Compiled by the British Bankers' Association (BBA), Libor refers to the interest rate at which banks in London offer to lend funds to each other just prior to 11:00 local time.[2] The BBA collects quotes from a panel of banks. Quotes are ranked in order, the top and bottom quartiles are disregarded, and the middle two quartiles are averaged to compute Libor. At present, Libor is fixed for 15 different maturities, from overnight to 12 months, in 10 international currencies.[3]

Similar fixing arrangements exist in markets around the world (Table 1). Although these copy many features of Libor, there are some important differences: the liquidity of the market, the composition of the contributor panel, the type of rate quoted and the design of incentives to contribute accurate quotes. These differences influence the representativeness of the fixing and can result in systematic discrepancies between rate fixings in the same currency.

Market liquidity

Liquidity is arguably the most important determinant of whether rate fixings accurately represent conditions in money markets. In countries where other segments are more liquid than the interbank market, interbank fixings have struggled to emerge as money market benchmarks. That said, the advantages of referencing an interest rate based on banks' borrowing costs are such that in most cases the alternative is a close substitute for an interbank loan.

One simple indicator of market participants' perceptions of the most liquid segment in money markets is the reference rate in interest rate swaps (IRSs). Whereas IRSs for US dollars and most other major currencies reference interbank fixings, those for a number of Asia-Pacific currencies reference other rates (Table 1). In Australian dollar IRSs, the floating rate leg is linked to banks' expectations of where bank bills will trade. In most Philippine peso, Singapore dollar and Thai baht IRSs, the floating rate leg is linked to the interest rate implied by foreign exchange swaps. Chinese renminbi IRSs typically reference the onshore seven-day repo rate.

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[2] The current instructions from the BBA state: "An individual BBA Libor Contributor Panel Bank will contribute the rate at which it could borrow funds, were it to do so by asking for and then accepting inter-bank offers in reasonable market size just prior to 1100".

[3] The Australian dollar, the Canadian dollar, the Danish krone, the euro, the Japanese yen, the New Zealand dollar, the pound sterling, the Swedish krona, the Swiss franc and the US dollar.

Features of selected money market fixings

Currency	Fixing	Onshore/ offshore rate?	Panel composition		Average	Type of quote	Bench-mark tenor[3]	IRS reference rate?[4]
			Size[1]	Foreign banks[2]				
AUD	Libor	Offshore	8	6	Trimmed	Non-binding	3-month	No
	Bank bills	Onshore	14	8	Trimmed	Non-binding	3-month	Yes
CAD	Libor	Offshore	12	9	Trimmed	Non-binding	3-month	Yes
	Bank bills	Onshore	9	3	Trimmed	Non-binding	3-month	No
CNY	Chibor	Onshore	. . .	. . .	. . .	Transacted	7-day	No
	Shibor	Onshore	16	3	Untrimmed	Non-binding	7-day	No
	Repo	Onshore	. . .	. . .	Untrimmed	Non-binding	7-day	Yes
DKK	Libor	Offshore	8	8	Trimmed	Non-binding	3-month	No
	Cibor	Onshore	12	5	Trimmed	Non-binding	6-month	Yes
EUR	Libor	Offshore	16	11	Trimmed	Non-binding	3-month	No
	Euribor	Onshore	45	–	Trimmed	Non-binding	6-month	Yes
HKD	Hibor	Onshore	20	14	Trimmed	Non-binding	3-month	Yes
IDR	Jibor	Onshore	18	7	Untrimmed	Non-binding	3-month	No
INR	Mibor	Onshore	33	7	Trimmed	Non-binding	Overnight	Yes
JPY	Libor	Offshore	16	12	Trimmed	Non-binding	6-month	Yes
	Tibor	Onshore	16	1	Trimmed	Non-binding	3-month	No
KRW	Koribor	Onshore	14	4	Trimmed	Non-binding	3-month	No
	CD rate	Onshore	10	. . .	Trimmed	Transacted	3-month	No
MYR	Klibor	Onshore	11	6	Untrimmed	Non-binding	3-month	Yes
NZD	Libor	Offshore	8	8	Trimmed	Non-binding	3-month	No
	Bank bills	Onshore	7	7	Trimmed	Non-binding	3-month	Yes
PHP	PHIREF	Offshore	. . .	. . .	Untrimmed	Transacted	3-month	Yes
	Phibor	Onshore	17	8	Untrimmed	Non-binding	3-month	No
SGD	Sibor	Onshore	13	10	Trimmed	Non-binding	6-month	No
	SOR	Onshore	. . .	. . .	Trimmed	Non-binding	6-month	Yes
THB	THBFIX	Offshore	13	14	Trimmed	Non-binding	6-month	Yes
	Bibor	Onshore	16	7	Trimmed	Non-binding	3-month	No
USD	Libor	Offshore	16	13	Trimmed	Non-binding	3-month	Yes
	Sibor	Offshore	15	12	Trimmed	Non-binding	3-month	No
	H.15	Offshore	Broker prices		. . .	Binding	3-month	No

Libor = London interbank offered rate (IBOR); AUD bank bills = bank bill swap reference rate; CAD bank bills = bankers' acceptance rate; Chibor = China IBOR; Shibor = Shanghai IBOR; Cibor = Copenhagen IBOR; Euribor = euro IBOR; Hibor = Hong Kong IBOR; Jibor = Jakarta IBOR; Mibor = Mumbai IBOR; Tibor = Tokyo IBOR; Koribor = Korea IBOR; KRW CD rate = 90-day CD rate published by the Korean Securities Dealers Association; Klibor = Kuala Lumpur IBOR; NZD bank bills = 90-day bank bill reference rate; PHIREF = PHP interest rate derived from USD/PHP foreign exchange swaps; Phibor = Philippine IBOR; Sibor = Singapore IBOR; SOR = swap offer rate implied by USD/SGD foreign exchange swaps; THBFIX = THB interest rate implied by USD/THB foreign exchange swaps; Bibor = Bangkok IBOR; H.15 = offered rate for offshore certificates of deposit published by the US Federal Reserve.

[1] Total number of contributor banks. [2] Number of contributor banks headquartered outside the currency's home country. [3] Most widely referenced maturity. [4] Floating rate leg typically referenced in interest rate swap contracts.

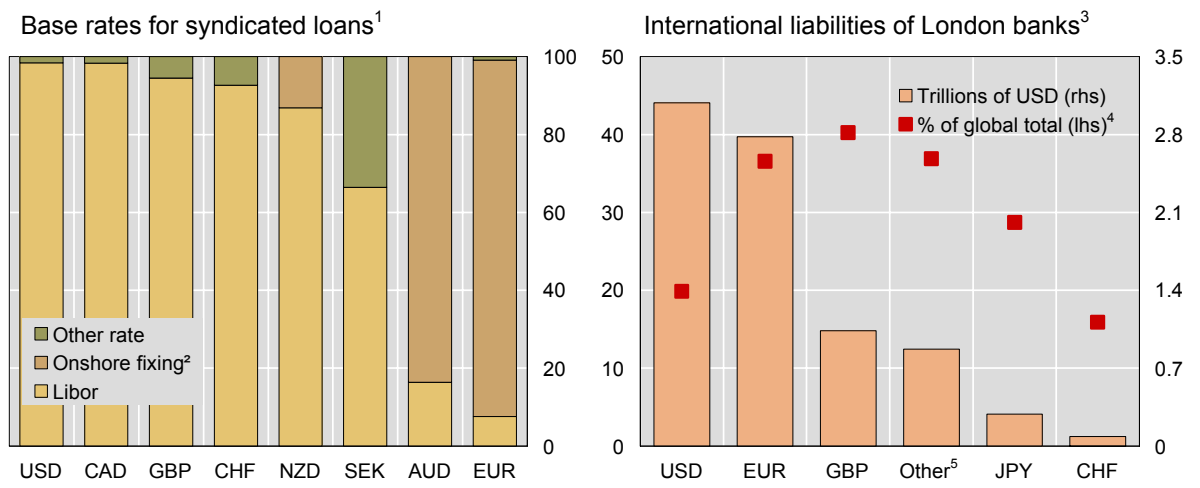
Sources: BBA; Bloomberg; Reuters. Table 1

In those markets where interbank rate fixings serve as a benchmark, offshore rates are frequently preferred to onshore ones. Most fixings, other than those in London and Singapore, refer to domestic, onshore interest rates. In contrast, Libor is an offshore rate for all currencies except sterling. Even though there are comparable onshore fixings, Libor is widely referenced in the Canadian dollar, New Zealand dollar, Swedish krona, Swiss franc and US dollar markets. For example, it is the base rate for a large share of syndicated loans denominated in these currencies (Graph 1, left-hand panel).

One reason for preferring offshore rate fixings as benchmarks is that they are less likely to be distorted by regulations. Capital controls can lead to a wedge between on- and offshore rates by preventing banks from taking advantage of arbitrage opportunities. Even in fully integrated markets, reserve requirements, deposit insurance premiums and other regulations affecting banks' domestic operations tend to reduce onshore rates relative to offshore ones because offshore banks can offer higher rates on wholesale deposits not subject to such regulations (Kreicher (1982)).

Another reason is that offshore markets are often as liquid, and in some cases more so, than onshore markets. This is especially true of London, where a large share of international banking activity is transacted (Graph 1, right-hand panel). Singapore too has liquid international interbank and foreign exchange markets, upon which rate fixings in US dollars and a few other currencies are based. The diversity of market participants is often greater in offshore markets, which helps to boost activity. In particular, barriers to entry and exit are typically lower in offshore markets, making them less vulnerable than onshore markets to the actions of a few large institutions. Indeed, the Swiss National Bank targets Libor instead of an onshore rate because the former is less affected by short-term imbalances in activity (Gehrig (1999)).

Use of Libor as a reference rate



[1] Percentage of international syndicated credit facilities signed in 2007 that are based on the specified rate; excludes loans where no base rate is specified by Dealogic Loanware. [2] For AUD and NZD, bank bills rate; for EUR, Euribor. [3] Liabilities to non-residents in all currencies plus residents in foreign currencies, of banks domiciled in the United Kingdom, at end-June 2007; includes inter-office positions. [4] As a percentage of the international liabilities of all banks in the BIS reporting area; for EUR, the global total excludes euro area banks' cross-border liabilities to euro area residents. [5] Liabilities denominated in currencies other than the five specified.

Sources: Dealogic Loanware; BIS; authors' calculations. Graph 1

Composition of the contributor panel

Rate fixings based on a large sample of banks are likely to be more representative of market conditions than those derived from a small sample. There is a trade-off, however, because banks are not equally active. A few banks might account for a disproportionately large volume of transactions, and so a panel of many small banks might be less representative of overall activity than a panel of a few large banks.[4]

The majority of fixing panels have 12 to 16 contributor banks (Table 1). Libor has as few as eight for currencies other than the US dollar, euro and yen, for which it has 16. Contributing banks are selected based on their reputation, credit quality and activity in London, and the composition of the panel is reviewed at least once a year. The euro interbank offered rate (Euribor) is based on quotes from as many as 45 banks, from every country in the euro area.

Differences between fixings may reflect the panel composition ...

In addition to the number of banks, contributor panels differ in the kinds of banks included. Foreign banks – in particular large, internationally active ones – dominate the Libor panels but are in the minority on most others. For example, 15 of the 16 banks on the Tokyo panel and 13 of the 16 banks on the Shanghai panel are domestic banks, headquartered in the country. The credit quality and business models of these banks are often different from those of foreign banks.

Even with 12 to 16 banks, the average can be unduly influenced by unusually high or low quotes. Therefore, fixings are typically based on a trimmed average. Most fixings follow Libor and exclude the top and bottom 25% of contributed quotes. Euribor excludes the top and bottom 15%. The Mumbai interbank offered rate (Mibor) identifies outliers using a statistical bootstrapping method. A few fixings, including those in Jakarta and Kuala Lumpur, include all submitted quotes and, consequently, are likely to be more affected by extreme quotes.

Types of quotes

... the type of quote ...

Fixings obtained from transactions or transactable quotes by definition capture market conditions, at least in part of the market. Indices based on interbank transactions are available in several markets, but usually only for overnight interest rates. Examples include the federal funds effective rate in the US dollar market and the European overnight index average (EONIA) in the euro market. The compilation of these indices is either done or assisted by the central bank because it has privileged information on transactions in what is otherwise a private, bilateral market.

Indices based on binding quotes or transactions can also be constructed from brokers' systems and electronic trading platforms. One example is the eurodollar interest rate published in the US Federal Reserve's H.15 statistical release. This series is based on the best offered rate on offshore US dollar

[4] Banks are asked to contribute quotes for a "standard" transaction size, which is likely to be different for large and small institutions.

certificates of deposit brokered by ICAP at around 09:30 in New York. A weakness of such rates is that the broker or platform may not have a large presence in the market, so the sample of transactions might not be representative.

Incentives to contribute accurate quotes

Most fixings, however, are based on non-binding quotes; contributing banks are not obliged to transact at the interest rates they submit. Therefore, the reliability of such fixings as measures of market conditions depends on the willingness of contributing banks to reveal their true, transactable quotes. In particular, it depends on the incentives given to market participants to reveal private information truthfully. Processes which achieve this objective are said to be "incentive compatible" (Hurwicz (1972), Royal Swedish Academy of Sciences (2007)).

One way in which fixings seek to be incentive compatible is by publishing individual banks' contributed interest rates. Transparency exposes the banks to reputational risk because their customers will penalise them for transacting at rates significantly different from their submitted rates.

However, transparency raises questions about the information signalled by contributing banks through their quotes. There may be circumstances in which contributing banks deliberately choose to disclose biased quotes. If there is uncertainty about the liquidity position of a contributing bank, the bank will be wary of revealing any information that might add to this uncertainty for fear of increasing its borrowing costs (Spence (1973)). Therefore, for the purposes of the fixing, the bank has an incentive to quote a lower interest rate publicly than it might be prepared to pay in a private transaction.

The widespread use of fixings as reference rates also gives contributing banks an incentive to misquote. The costs of manipulating a given rate might be outweighed by the potential profit from positions based on those rates (Ewerhart et al (2007)). For example, market participants with large positions in derivative contracts referencing a rate fixing might seek to move the fixing higher or lower by contributing biased quotes. Alternatively, they might indirectly influence the accuracy of the fixing by choosing not to join the contributor panel.

... and strategic behaviour by banks

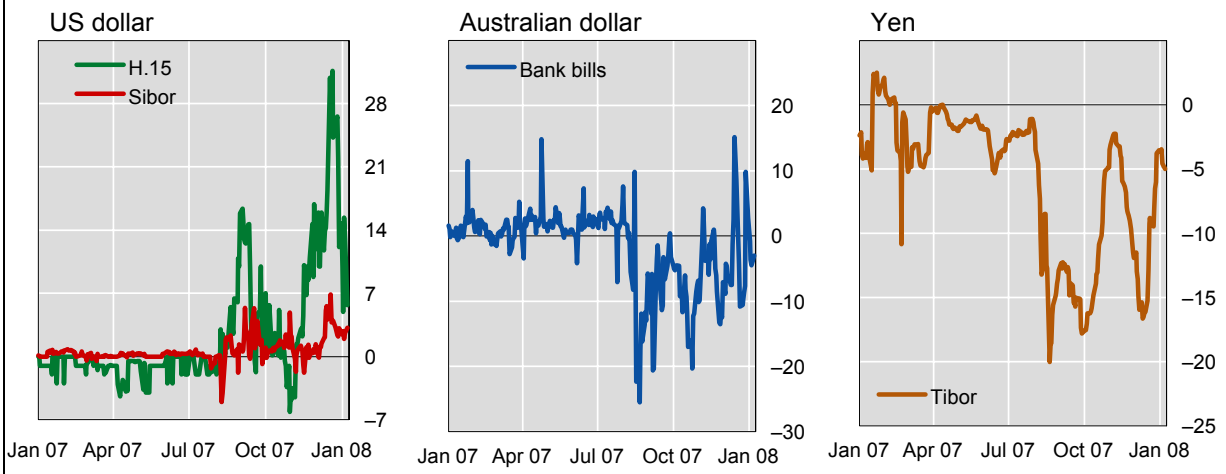
The scope for such strategic behaviour to influence the fixing can to some extent be limited by trimming, in which biased or extreme quotes are disregarded. However, even trimmed means can be manipulated if contributor banks collude or if a sufficient number change their behaviour.

Fixings during the recent turmoil

The turbulence in global interbank markets in the second half of 2007 saw the normally low and stable spread between similar rate fixings widen markedly (Graph 2). Below, we consider the impact of the factors discussed in the previous section on the spread between similar fixings and, by extension, on the representativeness of different rate fixings.

Spreads over Libor

In basis points



Sources: Bloomberg; authors' calculations.

Graph 2

Change in spreads over Libor

We focus on currencies for which more than one fixing is available. For the Australian dollar, Canadian dollar, Danish krone, euro and yen, one fixing refers to an offshore rate (Libor) and the other to an onshore rate. For the US dollar, all refer to offshore rates but each is fixed at a different time during the day: first in Singapore (Sibor), then in London (Libor) and finally in New York (H.15). Spreads and correlations between various fixings and Libor are shown in Table 2. Two periods are distinguished: a normal period, from 1 January to 8 August 2007, and a stress period, from 9 August 2007 to 30 January 2008.

Spreads between fixings in the same currency widened ...

The US dollar market stands out for being the one market where Libor rose by substantially less than similar fixings during the stress period. The average spread between Sibor and Libor widened from about zero in the normal period to 2 basis points in the stress period, and the spread between

Spreads and correlations between interbank fixings

Currency	Fixing rate[1]	Average spread over Libor[2]			Correlation[3]	
		1 Jan–8 Aug 07	9 Aug 07–30 Jan 08	Change	1 Jan–8 Aug 07	9 Aug 07–30 Jan 08
AUD	Bank bills	1.7*	–6.4*	–8.1*	0.24	0.44
CAD	Bank bills	7.4*	–8.4*	–15.8*	0.15	0.61
DKK	Cibor	–0.3*	0.1*	0.4*	0.53	0.89
EUR	Euribor	0.1*	–0.0*	–0.1	0.75	0.99
JPY	Tibor	–2.1*	–10.0*	–7.9*	0.11	0.14
USD	Sibor	0.2*	1.8*	1.6*	0.21	0.98
USD	H.15	–1.0*	6.7*	7.7*	0.09	0.89

[1] Three-month interest rates. [2] In basis points; * indicates that the mean is significantly different from zero at the 1% level based on a t-test. [3] Mean of the August–January period minus mean of the January–August period. [3] Correlation of daily yield changes corrected for the increase in volatility following Loretan and English (2000).

Sources: Bloomberg; authors' calculations.

Table 2

H.15 and Libor widened from –1 to 7 basis points.

In the Australian dollar and Canadian dollar markets, the average spread of onshore rates over Libor turned from positive during the normal period to negative during the stress period. The change in the spread between the two periods was as much as –16 basis points in the case of Canadian dollar rates. In the yen market too, the average spread between the onshore rate and Libor fell sharply between the two periods, by 8 basis points.

In the euro market, there was no change in the Euribor–Libor spread between the normal and stress periods. A similar pattern was seen in the market for the Danish krone, which is pegged to the euro.

Panel composition

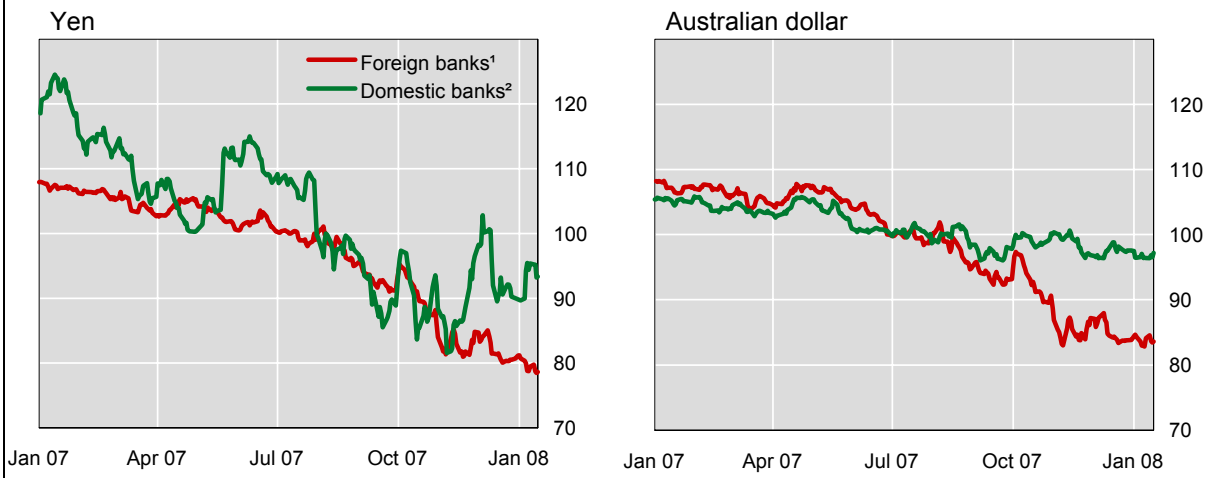
... because domestic banks were less exposed to structured credit than foreign banks ...

The widening of spreads between similar fixings was driven in part by differences in panel composition. The large, international banks which dominate Libor panels had larger exposures to subprime mortgages and structured investment vehicles than many of the domestic banks which dominate onshore panels. Consequently, the perceived credit quality and funding needs of Libor contributor banks deteriorated by more than those of domestic banks, putting greater upward pressure on Libor than on onshore rate fixings.

During periods of calm, panel composition is usually not an important source of volatility in rate fixings because most contributor banks have a high credit standing. The credit rating of banks in almost all Libor panels averages AA. So too does the rating of banks in Australia's bank bills swap reference rate panel and the Cibor panel. Among the fixings considered in Table 2, Tibor has the lowest-rated panel, averaging A+. However, credit ratings tend to lag changes in credit quality; therefore, during periods of uncertainty differences in panel composition become more important.

Contributor banks' equity prices

Relative to domestic equity market indices; 9 August 2007 = 100



[1] Banks headquartered outside the currency's home country and included in the Libor panel. [2] Banks headquartered inside the currency's home country and included in the Libor panel.

Sources: Bloomberg; authors' calculations. Graph 3

One indication that credit and funding concerns played a part in the recent divergence of rate fixings comes from equity prices for foreign versus domestic banks. As shown in Graph 3, Australian and Japanese banks did better relative to their respective equity markets than foreign banks did relative to their equity markets. In particular, in November 2007 Japanese banks in the Tibor panel outperformed the Tokyo equity market, whereas foreign banks in the yen Libor panel underperformed their home equity markets. The equity prices of Australian banks in the onshore fixing panel matched the Sydney market, whereas foreign banks in the Australian dollar Libor panel underperformed.

For Australian dollar and yen fixings, correlations between changes in rates are also consistent with panel composition being an important explanation for the widening of spreads between similar fixings. The correlation between Tibor and yen Libor remained very low during the normal and stress periods, indicating that factors unique to each fixing had a significant influence on daily yield changes (Table 2). For Australian dollars, the correlation between the onshore fixing rate and Libor rose during the stress period, but only to 0.4.

In the Canadian dollar, euro and US dollar markets, panel composition was not as important an explanation for the divergence in rate fixings. Many of the banks in these panels were perceived to have significant exposure to structured credit products. Nevertheless, in the Canadian dollar market, the deterioration in Canadian banks' credit quality was not fully reflected in the onshore rate because the fixing is based on bankers' acceptances. The payment of bankers' acceptances is jointly guaranteed by the accepting bank and the ultimate borrower, thereby diversifying investors' credit risk exposure.

Liquidity and volatility

Another factor which contributed to the widening of the spreads between similar rate fixings was a deterioration in market liquidity. In less liquid markets, imbalances in order flow are more common and prices are consequently more prone to jumps. Changes in interest rate volatility and correlations between the normal and stress periods are consistent with a deterioration in liquidity, especially in the US dollar and euro markets.

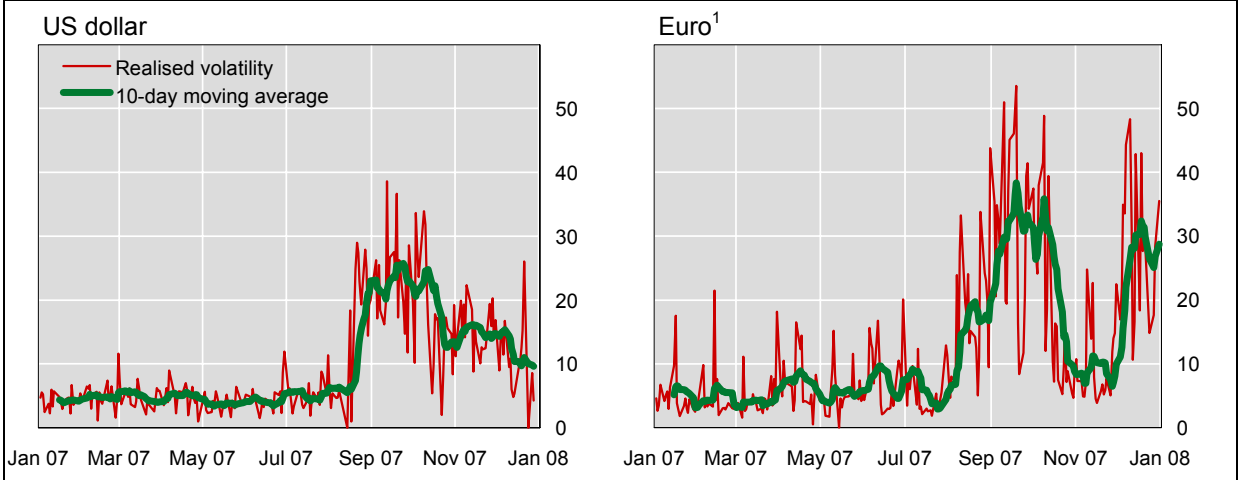
... and volatility increased

The volatility of money market rates increased many times over during the recent period of turmoil. Graph 4 plots the realised volatility of overnight interbank rates for the US dollar and the euro. Greater uncertainty about future economic conditions and banks' creditworthiness was responsible for part of the increase. Volatility tends to be highest around macroeconomic announcements (Andersen et al (2005)). Considering that most news is announced during onshore trading hours, greater uncertainty probably had a larger impact on fixings that took place during those hours. This might explain part of the increase in the spread of the H.15 rate over US dollar Libor.

That said, our estimate of volatility is based on overnight rates, so arguably only a small part of the increase was driven by greater uncertainty about the future. A deterioration in liquidity was most likely responsible for the larger part of the increase. Consistent with this interpretation, correlations between daily changes in different US dollar, euro and Danish krone rate fixings rose to almost 1 during the stress period (Table 2). This indicates that

Volatility of overnight interest rates[1]

In basis points



[1] Based on interest rates for overnight interbank loans sampled intraday at 30-minute intervals; estimation procedure follows Andersen et al (2003).

Sources: e-Mid; authors' calculations. Graph 4

the changes were driven by factors common to the different fixings. Whereas the composition of the contributor panel, and therefore counterparty credit risk, differs across fixings in the same currency, liquidity premia are likely to be similar. Indeed, Michaud and Upper (in this issue) find that at daily frequencies liquidity considerations were a more important driver of US dollar, euro and sterling Libor than credit risk.

An open question is whether central banks' operations in money markets accentuated differences between rate fixings by bolstering liquidity in onshore markets. During the stress period, central banks adjusted their operating procedures to facilitate the distribution of liquidity (Borio and Nelson in this issue). If banks in offshore markets do not have access to central banks' distribution channels, then central banks' operations might have caused spreads between on- and offshore rates to widen, at least temporarily. In the euro and Danish krone markets, there is no evidence of segmentation: on- and offshore rates were almost the same on average during the stress period. For other currencies, asynchronous polling times make it difficult to test this proposition.

Strategic behaviour and trimming

Finally, we consider whether strategic behaviour contributed to the widening of spreads between similar rate fixings. As previously discussed, during periods of turmoil banks are likely to behave in a more strategic manner. They might seek to signal information about their credit quality or liquidity needs through their quotes, or they might quote in a way that benefits their positions in instruments which reference the fixing. However, if there were any attempts to manipulate fixings during the recent turbulence, trimming procedures appear to have minimised their impact.

Trimming procedures were clearly much more important during the turmoil period. In the normal period, the difference between the maximum and minimum contributor banks' rates ranged between 1 and 2 basis points in the US dollar Libor panel and 2 and 3 basis points in the euro Libor panel (Graph 5). The maximum–minimum range was wider in the yen Libor panel because of larger differences in contributor banks' credit quality. However, during the stress period, the range between the maximum and minimum contributor banks' rates in all panels widened markedly. If this was because a few banks engaged in manipulative behaviour, then the trimming procedure ensured that their rates were not used to calculate the rate fixing.

Trimming is more important during periods of turmoil

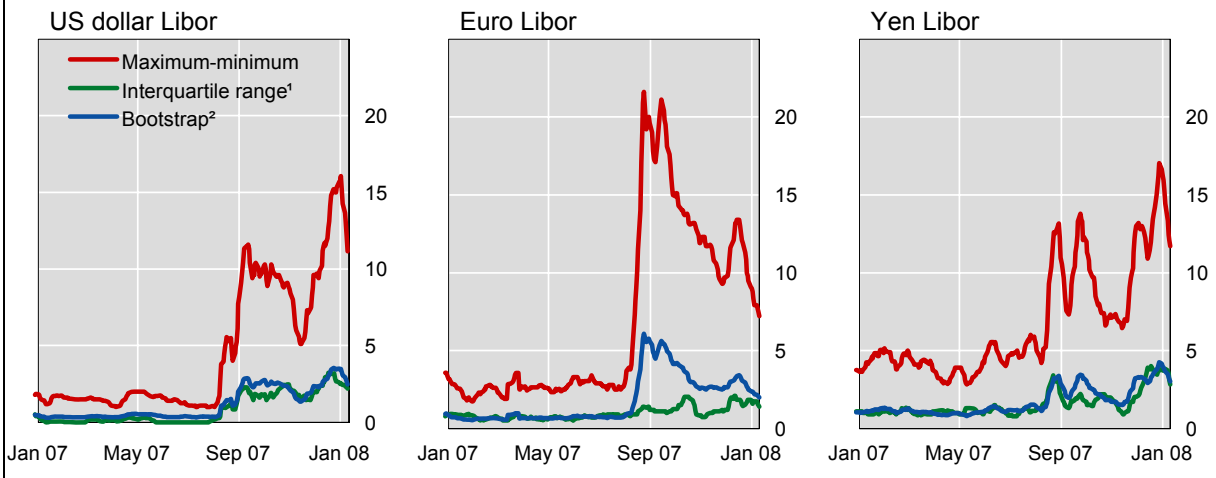
If a majority of banks engaged in strategic behaviour, then trimming alone would not have mitigated the impact on the fixing. That said, there is little evidence that this was the case. In the US dollar market, the widening of Sibor and H.15 spreads over Libor is consistent with signalling by Libor contributor banks. However, many of the banks on the US dollar Libor panel are also on the euro Libor panel, and there are no signs that signalling distorted the latter fixing. Likewise, available data do not support the hypothesis that contributor banks manipulated their quotes to profit from positions based on fixings. Eurodollar futures contracts traded on the Chicago Mercantile Exchange indicate that commercial traders – a category which includes banks and other market participants that might seek to hedge their business activities in the futures market – had a larger than normal net open short position in the third quarter of 2007. To the extent that futures positions are representative of their overall exposure, banks would have gained by submitting low quotes to move Libor below the true market rate. In fact, Libor moved in the opposite direction: it rose in early August.

Little evidence of manipulation

Supplementing this anecdotal evidence, alternative methods of estimating Libor also give no indication that fixings were manipulated. If rates were polled

Dispersion in contributor banks' rates

Libor panel; 10-day average range, in basis points



[1] Third minus first quartile. [2] Confidence interval of 95% for the mean of sampled rates; based on 5,000 daily panel samples from actual rates contributed by panel banks.

Sources: Bloomberg; BIS calculations. Graph 5

from an unrepresentative sample of banks, then even a trimmed mean would be biased. Furthermore, trimming procedures might not produce the best estimate of the mean because information in the highest and lowest quotes is disregarded. To test the robustness of trimming procedures, we re-estimated the mean of the US dollar, euro and yen Libor panels using a bootstrap technique. This technique minimises the influence of non-random observations and outliers on the mean without disregarding any quotes (Efron and Tibshirani (1994)). The bootstrapped mean is not significantly different from Libor for any of the panels considered.

Moreover, the 95% confidence interval around the bootstrapped mean loosely corresponds to the interquartile range in the Libor panel (Graph 5). In other words, the bootstrap technique indicates that 19 days out of 20, the design of the Libor fixing produces an estimate that is close to the true interbank rate. This is the case even during the stress period. Only for euro Libor is the bootstrapped confidence interval noticeably wider than the interquartile range during the stress period, reflecting the wider dispersion of polled rates.

Conclusions

A comparison of different fixings in the same currency reveals that interbank rates diverged to an unusual extent in the second half of 2007. This divergence was not caused by shortcomings in the design of the fixing mechanism. Rather, it reflected the dislocation in the underlying interbank markets. Changes in the credit quality of contributor banks and a deterioration in liquidity affected fixings to varying degrees. Credit quality appears to have had an especially large impact on offshore fixings, dominated by foreign banks. Liquidity was a significant factor in US dollar and euro fixings.

Design of fixings worked as intended to minimise the influence of outliers

A number of lessons regarding the design and use of fixings can be drawn from these developments. First, the representativeness of rate fixings depends critically on the mechanisms used to minimise the influence of outliers. Banks' quotes are determined by strategic behaviour as well as credit quality and funding needs. Transparency and trimming are important ways to lower, albeit not eliminate, the vulnerability of fixings to sampling noise and manipulation. Transparency strengthens banks' incentive to contribute accurate quotes, while trimming procedures limit the scope for individual banks to distort the fixing.

Second, the confidence interval around rate fixings – even trimmed fixings – is wider during periods of uncertainty. In other words, fixings are likely to be less representative when market conditions are volatile. During calm periods there is usually very little dispersion in polled rates. By contrast, during volatile periods there can be significant dispersion because of greater uncertainty about credit quality and greater incentives to engage in strategic behaviour.

Finally, rate fixings measure conditions in a given market segment. Differences in market participants, liquidity and regulations can lead to deviations between fixings and conditions in closely related markets. If these deviations persist, they might undermine the role of a particular fixing as a

pricing reference, which could ultimately lead market participants to switch to a new benchmark.

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The spillover of money market turbulence to FX swap and cross-currency swap markets[1]

We analyse the spillover of the turmoil in money markets in the second half of 2007 to FX swap and long-term cross-currency basis swap markets. We find that the use of swap markets to overcome US dollar funding shortages by non-US financial institutions resulted in marked deviations from covered interest parity conditions and the impairment of liquidity in these markets.

JEL classification: G12, G14, G15.

Foreign exchange (FX) and related derivatives markets are some of the most liquid markets in the world. The growth of interest rate and FX/currency swaps is often cited as a factor promoting the further integration of global financial markets.

This article documents the spillover of the turmoil in money markets in the second half of 2007, particularly in the US dollar, euro and sterling, to FX swap and cross-currency basis swap markets. Our analysis of swap market deviations from covered interest parity and the impairment of liquidity in the swap markets is consistent with anecdotal market observations that dollar funding shortages of non-US financial institutions were largely responsible.

In the next section, we review the money market turbulence in four currencies: US dollar, euro, pound sterling and Japanese yen. In the second section, we assess the effects on short-term FX swap markets in terms of deviations from no-arbitrage conditions between cash and swap-implied interest rates, as well as measures of changing liquidity. The third section discusses the related developments in cross-currency basis swap markets, which are more commonly used than FX swap markets at longer maturities. The final section concludes.

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Turbulence in money markets

Widening spreads of interbank rates over OIS rates

Spreads of interbank interest rates over overnight index swap (OIS) rates and treasury bill rates widened substantially in early August 2007 and then persisted at higher levels (Graph 1). As discussed in Michaud and Upper (in this issue), this probably reflected a combination of factors, including increased demand for term funding liquidity and rising credit risk premia. Market concerns were particularly acute prior to the turn of the year. While the Libor-OIS spread declined markedly in early 2008, as of mid-February it was still greater than at the beginning of 2007.

Movement in dollar market is larger and earlier …

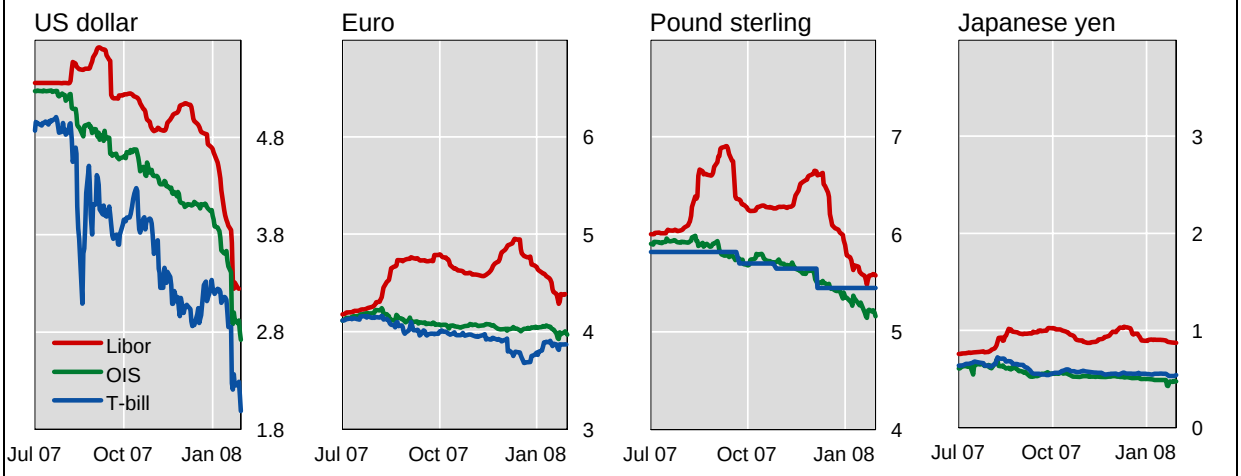
Comparing money market indicators across the dollar, euro, sterling and yen, it appears that while the direction of movements has followed the same general pattern, the magnitude and timing of the moves have often differed significantly across currencies. The Libor-OIS spread has been largest in the dollar and sterling markets, in the range of 25–110 basis points, followed by the euro, where the spread has fluctuated roughly within a 20–90 basis point range since the turmoil began. By contrast, the yen Libor-OIS spread has remained within a much smaller range of 20–50 basis points. As for the timing of the surge in the Libor-OIS spreads, the most significant jump came earlier for the dollar than for sterling and the euro.

… possibly reflecting dollar funding shortages

An important aspect of the turbulence was a shortage of dollar funding for many financial institutions: frequently reported were efforts by European financial institutions to secure dollar funds to support US conduits for which they had committed backup liquidity facilities.[2] At the same time, the usual suppliers of dollar funds to the interbank market were looking to conserve their liquidity, due to their own growing needs and increased concerns over counterparty credit risk. Facing these unfavourable demand/supply conditions

Three-month interest rates

In per cent



Source: Bloomberg.

Graph 1

[2] See eg "Central bank action calms investor nerves" (Financial Times, 13 August 2007) or "Fed-ECB currency swap politically tricky" (Reuters, 13 August 2007). See also the discussion of US dollar funding in the international interbank markets in the Highlights (this issue).

in the interbank market, many non-US financial institutions moved to actively convert euro into dollar liquidity through FX swaps (ECB (2007)). Exactly how this can occur, and the potential impact on the pricing of swaps, is discussed in the next section.

Spillover to FX swap markets

An FX swap is a bilateral contract where different currencies are exchanged by combining FX spot and forward contracts (see Box). As assets in one currency serve as collateral for securing obligations in the other, FX swaps are effectively collateralised transactions, although the collateral does not necessarily cover the entire counterparty risk.[3]

Using FX swaps to raise foreign currencies

FX swaps are a means of raising foreign currencies

Financial institutions can use FX swaps to raise foreign currencies from other funding currencies. More specifically, financial institutions with a need for foreign currency funds face a choice between borrowing directly in the uncollateralised cash market for the foreign currency, or borrowing in another (typically the domestic) currency's uncollateralised cash market, and then converting the proceeds into a foreign currency obligation through an FX swap. In this article, we call the total funding cost of the second alternative the "FX swap-implied rate".

For instance, when a financial institution raises dollars via an FX swap using the euro as the funding currency, it exchanges euros for dollars at the FX spot rate, while contracting to exchange in the reverse direction at maturity at the FX forward rate. Thus, the FX swap-implied dollar rate from the euro can be defined as

$$F/S\left(1+r_{EUR}\right) \tag{1}$$

where S and F represent the FX spot and forward rates between the euro and dollar and r_{EUR} is the uncollateralised euro funding rate. F/S corresponds to the euro/dollar forward discount rate and is used for the FX swap price quotation.[4] In the same manner, we can calculate the FX swap-implied dollar rates from other funding currencies including sterling and the yen. (Financial institutions with global networks often compare cash rates for a target currency and different FX swap-implied rates based on an *array* of funding currencies.)

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[3] For instance, if the counterparty were to default at some future time during the contract period, the party would need to reconstruct the position at the current market price, which entails replacement cost. Duffie and Huang (1996) show that FX and cross-currency swaps are typically subject to significantly more exposure to counterparty risk than are interest rate swaps, due to the exchange of notional amounts.

[4] More precisely, the price of FX swaps is quoted as $F–S$. The swap price data we use in this article are NY composite rates taken from Bloomberg, where the composite bid rate is equal to the highest bid rate of all 34 currently contributing financial institutions and the composite ask rate is the lowest ask rate offered by these same financial institutions. We take the average of the bid and ask as of 17:00 New York time. Since the Libor fixing is done slightly after 11:00 London time (06:00 NY time), the time difference between FX forward discount rates and Libor might cause more volatility in the FX swap-implied dollar rates than otherwise.

The use of the FX swap market to raise dollars should depend on relative costs. When the FX swap-implied dollar rate for a given currency is less than the cost of uncollateralised dollar funds, institutions would tend to borrow on an uncollateralised basis in that currency and use the FX swap market to raise dollars. Likewise, a higher FX swap-implied dollar rate would discourage the use of FX swaps in financing. The equality of dollar and FX swap-implied rates defines a condition of indifference. In terms of the euro/dollar pair, this condition can be written as

$$1 + r_{USD} = F/S\,(1 + r_{EUR}) \qquad (2)$$

The covered interest parity (CIP) condition

which is actually equivalent to the covered interest parity (CIP) condition.

Covered interest parity

CIP postulates that interest rate differentials among currencies should be perfectly reflected in the FX forward discount rates. Arbitrage arguments are often invoked in support of CIP. For instance, if the dollar cash market rate is lower than the FX swap-implied dollar rate from the euro in equation (2), financial institutions should increase dollar funding from the cash market instead of the FX swap market until the dollar cash rate rises to the same level. Were CIP to hold, then the FX swap-implied dollar rate as defined above should be equal to the dollar cash rate, dollar Libor in our case.[5]

A number of studies have attempted to assess the degree to which the short-term CIP hypothesis is supported by the data. Most of them show that the deviations from the short-term CIP have diminished significantly among G10 currencies. However, one notable study by Taylor (1989) finds that, despite increasing efficiency in FX markets, deviations from CIP tend to rise during periods of uncertainty and turbulence,[6] and persist for some time before they are arbitraged away.

Deviations from CIP tend to arise during periods of turbulence

For CIP to hold strictly depends on minimal transaction costs, as well as the lack of political risk, credit/counterparty risk, liquidity risk and measurement error.[7] Needless to say, none of these assumptions are fail-safe, and some may have been particularly problematic during the period of financial stress under review.

Reasons CIP might not hold include …

While transaction costs and political risk are largely negligible in today's G10 currency markets, credit/counterparty risk may have increased

… counterparty risk …

[5] The use of an uncollateralised rate such as Libor in combination with FX swap prices to calculate implied rates is broadly consistent with market practice. To be sure, not every institution necessarily uses Libor in calculating the FX swap-implied dollar rate. Some use estimates of their own internal (uncollateralised) funding costs, but these naturally are not available to us. As long as the base currency is funded in uncollateralised markets, the FX swap-implied dollar rate should also include a risk premium and maintain comparability to uncollateralised dollar market rates such as dollar Libor.

[6] For instance, significant deviations were observed on such occasions as the flotation of sterling in 1972 and inception of the European Monetary System in 1979 (Taylor (1989)).

[7] Another risk of possible importance to FX swaps is settlement risk (Herstatt risk), given that two legs of an FX transaction are often settled in two different time zones at different times. However, given that this risk is likely to be highly correlated with and difficult to distinguish from credit/counterparty and liquidity risks, we do not discuss it further.

significantly in the second half of 2007 (Michaud and Upper (in this issue)). To the extent that credit/counterparty risk was concentrated on one end of the FX swap market, a deviation from CIP could have occurred. For instance, if European financial institutions on the dollar borrowing side of the FX swap market were perceived as exceptionally risky by US financial institutions on the dollar lending side, then risk premia could have been added to FX swap price.[8] This would have increased the FX swap-implied dollar rate above dollar Libor.

... liquidity risk ...

Liquidity risk too may have played a role, particularly if market liquidity was impaired due to outsized or one-sided order flow, with effects compounded by perceptions of increased counterparty risk. In the above-mentioned case of dollar funding shortages of European financial institutions, their order flow for dollars in the FX swap market was reported to have surged, due to constraints on borrowing in the uncollateralised dollar interbank market. At the same time, suppliers of dollar funds to the FX swap market, typically US financial institutions, may have become more reluctant to extend their swap lines, particularly when concerns about counterparty risk had increased. The resulting dislocations could have led FX swap-implied dollar rates to exceed dollar Libor.

... and measurement error

Finally, measurement error could have been heightened as well. During the recent turmoil, dollar Libor may have underestimated the dollar funding costs that European financial institutions actually faced. As argued in Gyntelberg and Wooldridge (in this issue), the non-binding nature of Libor, where institutions contributing to the Libor survey are not obliged to transact at the rates they report, may lead to biased quotes on the part of institutions wary of revealing information that might increase their borrowing costs in times of stress. This factor alone could have created a spread between the FX swap-implied dollar rate and dollar Libor.

FX swap-implied US dollar rates

Graph 2 plots the FX swap-implied dollar rates calculated from Libor of the euro, sterling and yen, respectively, against dollar Libor. The term of all the rates is three-month.

In the first half of 2007, we see that the FX swap-implied dollar rates from the euro and sterling moved together quite closely with dollar Libor. For the yen, the spread was negative in the first quarter of 2007, then slightly positive, but never ranged beyond 5–10 basis points. These results suggest that CIP broadly held for these currency pairs in the period preceding the turbulence.

Spreads between FX swap-implied dollar rates and dollar Libor rose from 9 August ...

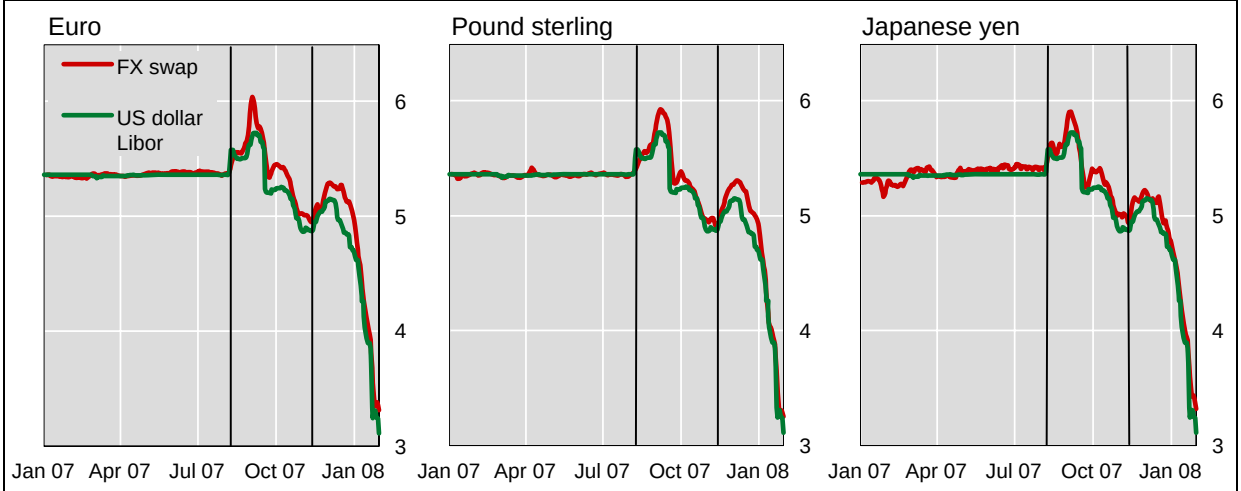
For all three potential funding currencies, the spreads between the FX swap-implied dollar rates and dollar Libor rose considerably from 9 August, moving up from July levels by close to 35 basis points in the euro, 25 basis points in sterling, and 15 basis points in the yen.[9] The homogeneity and the

[8] As discussed in footnote 3, FX swaps are not entirely free from counterparty risk.

[9] The relative quiescence of the yen/dollar swap represents a stark contrast to the late 1990s, when a so-called "Japan premium" – due to perceived differences in counterparty risk between Japanese and other financial institutions – was observed in global cash markets.

Three-month FX swap-implied US dollar rates[1]

In per cent; five-day moving averages



[1] The two vertical lines indicate 9 August and 14 November 2007; for the pound sterling, correction is made for the difference in calculation basis (360 or 365 days).

Sources: Bloomberg; BIS calculations. Graph 2

direction of the spread movement across currency pairs are supportive of the view that the source of volatility in FX swap markets was dollar funding shortages. Also supportive is the fact that the differences of FX swap-implied euro rates (from sterling and the yen) and euro Libor rates were quite small and stable over the same period. While the dollar spreads declined considerably in late September and October, from the middle of November there was resurgence towards earlier peaks in the case of the euro and sterling. After the beginning of 2008, the spreads tightened again.

… consistent with one-sided order flow

The above deviations are consistent with anecdotal evidence that, during the recent money market turmoil, European financial institutions that needed US dollars, but faced heightened concerns over their own counterparty/credit risk in dollar cash markets, turned to the FX swap market to raise dollars using both the euro and sterling as funding currencies. Movements in the FX swap price away from CIP conditions may have reflected a shift towards one-sided order flow in the FX swap market, with liquidity further impaired by the fact that institutions under increasing scrutiny for counterparty risk were concentrated on the dollar borrowing side of the market as well. Another, complementary explanation is that reported Libor was less representative of actual interbank rates during the times of particular stress, and the gap may have become greater for dollar Libor than Libor for other currencies.[10] In any case, the FX

Hanajiri (1999) argues that the FX swap-implied dollar rate from the yen diverged substantially from the baseline dollar rate in the late 1990s due to the Japan premium.

[10] A differential effect for dollar Libor is unlikely to stem from panel composition effects, since 14 out of 16 panel banks are the same across the dollar, euro and sterling panels. Rather, to the extent measurement error was a factor, it was probably due to the cost of funds being misstated by dollar Libor (more than by the posted interbank rates of other currencies) for the same set of banks.

swap-implied dollar rates appeared more sensitive to the increased demand for dollar funding than reported dollar Libor rates.[11]

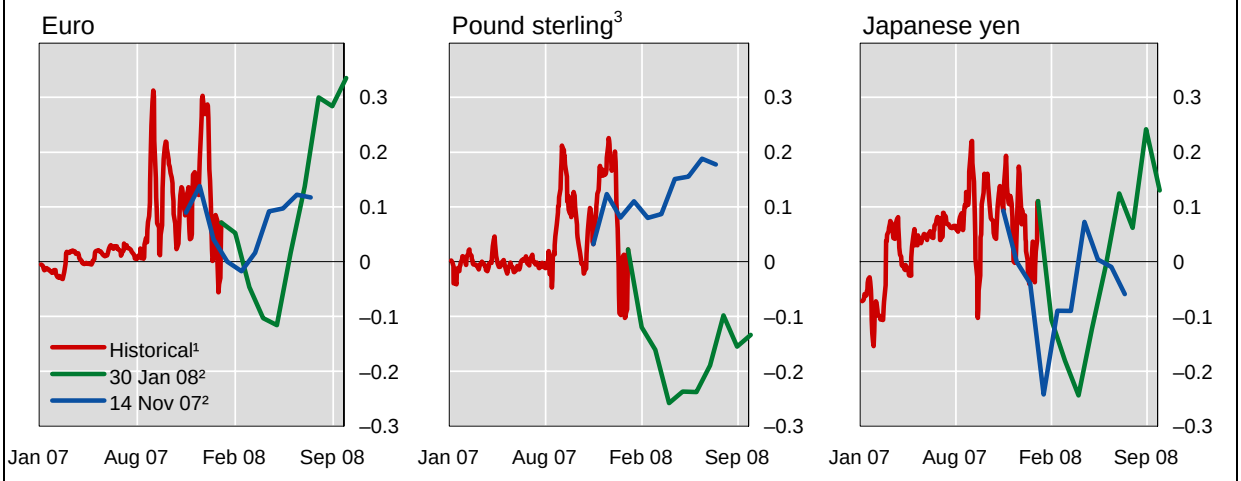
Though the degree of divergence from CIP was smaller than in the case of the euro and sterling, even the FX swap-implied dollar rates from the yen showed some such deviations, suggesting that FX swaps in yen were also used in increased volumes to secure dollar funding. This might seem surprising at first sight since Japanese financial institutions did not seem to face as much difficulty in securing dollar funding as did their euro area and UK counterparts. However, in early September and towards year-end, there were anecdotal reports of certain European financial institutions with access to the yen money market swapping considerable amounts of yen into dollars to meet their dollar funding needs.[12] In contrast to the other FX swap markets, the spread between the FX swap-implied dollar rate from yen and dollar Libor became miniscule starting in November and December, suggesting that the reliance on the yen swap market to fund demand for dollar liquidity had greatly receded by then.

Some European banks swap yen into dollars to meet funding needs

Owing partly to concerted measures by the central banking community to ease liquidity concerns in the money markets, as described in Borio and Nelson (in this issue), implied forward spreads between the FX swap-implied dollar rates and dollar Libor shifted downwards significantly as the new year began (Graph 3). However, as of end-January, they still seemed to signal

Spreads between FX swap-implied rates and Libor

In per cent



[1] Three-month spreads between FX swap-implied US dollar rates and US dollar Libor; five-day moving averages. [2] Implied three-month forward spreads between FX swap-implied US dollar rates and US dollar Libor; calculated from the term structure of the spreads on the indicated dates. [3] Correction is made for the difference in calculation basis (360 or 365 days).

Sources: Bloomberg; BIS calculations. Graph 3

[11] Ideally, observing intraday movements of FX swap-implied dollar rates would give us a deeper insight into the US dollar funding needs of specific borrowers. However, intraday cash rates consistent with the intraday FX forward discount rates were not available.

[12] Market participants also suggest that Japanese banks, anticipating the increased demand of European financial institutions in the yen/dollar FX swap market, made efforts to secure necessary dollar funding using FX swaps ahead of the fiscal half-year-end (September) and calendar year-end.

expectations of a resurgent demand in the swap market for dollar liquidity later in 2008, particularly via the euro/dollar and yen/dollar pairs. These developments were broadly in line with the view of many market participants that tight liquidity conditions in the FX swap market might return over the course of 2008.

Impaired liquidity

Impaired liquidity in FX swaps involving dollars …

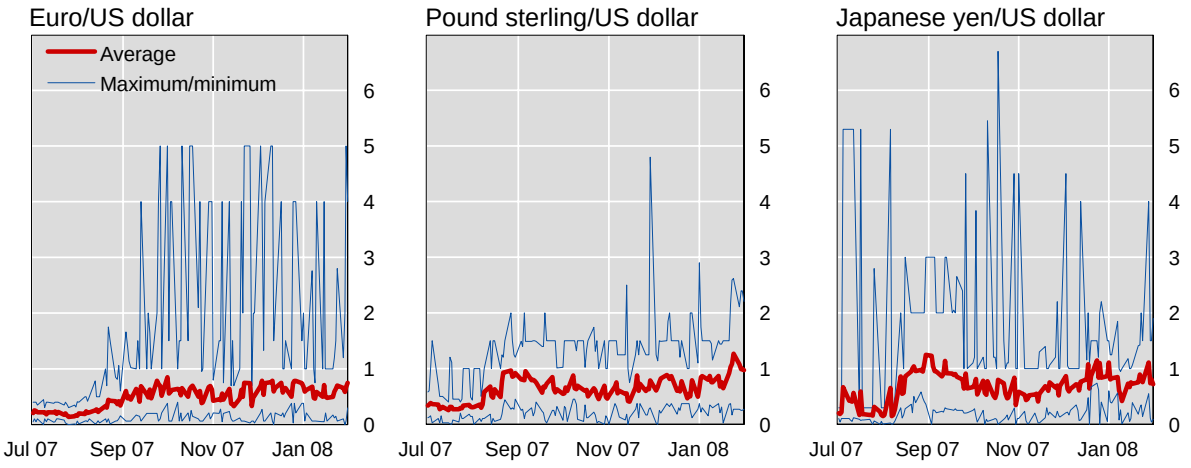
As discussed above, impaired market liquidity – more likely under conditions of increased counterparty risk – can lead to deviations from CIP. In fact, in addition to cases of liquidity crunches across fixed income and other markets, such as the LTCM episode in 1998, there have also been episodes of greatly reduced liquidity in the FX market (Lyons (2001)). And as we have just documented, during the recent period of financial stress, coinciding with the strong demand for dollar funds by European financial institutions, the prices of FX swaps involving dollars appear to have been disproportionately affected.

To be sure, measurement error provides another possible explanation for the deviations from CIP we have documented over the period. But if the deviations from CIP were purely a function of measurement error, observed liquidity in the FX swap markets per se should not have been affected. Thus, a direct examination of liquidity conditions in the FX swap market is called for.

In the absence of actual transaction data, one method of gauging liquidity is to examine quoted bid-ask spreads. Graph 4 presents the average and the range of quoted bid-ask spreads on the FX forward discount rates (the standard price metric for FX swaps) for the euro/dollar, sterling/dollar and yen/dollar pairs.[13] We find that average bid-ask spreads widened in the FX

Bid-ask spreads for three-month FX forward discount rates

In pips[1]



[1] A pip is the smallest price change that a given FX rate can make. For most major currency pairs, including the ones in this graph, one pip corresponds to the change of the fourth decimal point. Pip values can differ depending on the currency pairs, following the difference between the base currency and the terms currency.

Sources: Bloomberg; BIS calculations. Graph 4

[13] Here we use hourly closing bid-ask spreads from Bloomberg, meaning the last quoted indication for each hourly band.

swap markets, starting just around the time that significant spreads emerged between FX swap-implied rates and dollar Libor as shown in Graph 3.[14] The average bid-ask spread moved up from mid-August onwards by nearly 50% for both the euro/dollar and sterling/dollar pairs. The average yen/dollar bid-ask spread has also moved up from the lows of July and early August. In all of the charted currencies, the shift up of bid-ask spreads still persisted as of the beginning of 2008.

… as evidenced by widening bid-ask spreads

The range of bid-ask spreads has widened sharply as well, as evidenced by the blue lines in Graph 4, which plot the minimum and maximum spreads for forward discount rates during each business day. The upward shift in the range is particularly large for the euro/dollar swap, with bid-ask spreads of up to 5 pips seen on repeated occasions after September 2007. The range moved up more gradually for the sterling/dollar in August, but then was maintained through the beginning of 2008.

Spillover to the cross-currency basis swap market

Cross-currency basis swaps

Turbulence spills over to cross-currency basis swaps …

The longer-term cross-currency basis swap market was also affected by the turmoil in money markets. When market participants wish to commit to an exchange of foreign currency obligations over a term of one year or more – say, for the purpose of hedging foreign currency assets or liabilities – they often resort to the cross-currency basis swap market (see Box).[15] In such a swap contract, parties effectively borrow from each other in different currencies, exchanging principals at both the start and maturity of the swap, as well as regular interest rate payments, where the underlying index is Libor or some other interbank standard. Since the amount of future principal payment is fixed at the start of the contract, cross-currency basis swaps are largely free from FX risk in its traditional sense, as are FX swaps.[16] Though the structure is different from FX swaps, cross-currency basis swaps in many respects serve the same economic function as FX swaps.

… which have greater liquidity at longer maturities

The cross-currency basis swap market, because it has greater liquidity than straight FX swaps over all maturities of one year or more, is the main source of data for tests of long-term CIP.[17] Popper (1993) and Fletcher and

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[14] This is consistent with FRBNY (2007), which states that trading liquidity in the FX swap market was severely impaired particularly from mid-August to mid-September.

[15] There are numerous types of cross-currency swap contracts, among which the most widely used in recent years is the cross-currency basis swap.

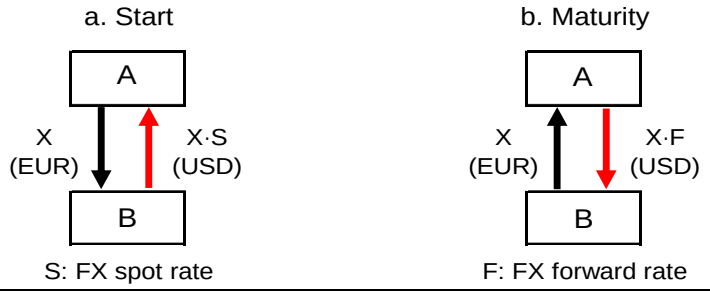
[16] In the case of cross-currency basis swaps, the interest payments are subject to FX risk. Furthermore, cross-currency basis swaps involve the same degree of counterparty risk as FX swaps, which is described in footnote 3 above.

[17] Amatatsu and Baba (2007) compare price discovery between cross-currency basis swap and long-term FX swap contracts of the same maturity in which the US dollar and Japanese yen are exchanged. They find that the cross-currency basis swap market plays a more dominant

The basic mechanics of FX swaps and cross-currency basis swaps

An FX swap agreement is a contract in which one party borrows one currency from, and simultaneously lends another to, the second party. Each party uses the repayment obligation to its counterparty as collateral and the amount of repayment is fixed at the FX forward rate as of the start of the contract. Thus, FX swaps can be viewed as FX risk-free collateralised borrowing/lending. The chart below illustrates the fund flows involved in a euro/US dollar swap as an example. At the start of the contract, A borrows X·S USD from, and lends X EUR to, B, where S is the FX spot rate. When the contract expires, A returns X·F USD to B, and B returns X EUR to A, where F is the FX forward rate as of the start.

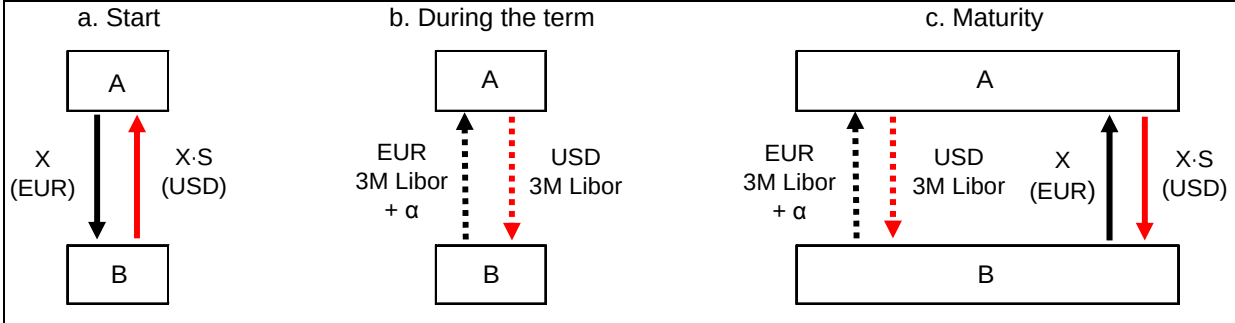
FX swaps have been employed to raise foreign currencies, both for financial institutions and their customers, including exporters and importers, as well as institutional investors who wish to hedge their positions. They are also frequently used for speculative trading, typically by combining two offsetting positions with different original maturities. FX swaps are most liquid at terms shorter than one year, but transactions with longer maturities have been increasing in recent years. For comprehensive data on recent developments in turnover and outstanding in FX swaps and cross-currency swaps, see BIS (2007).



S: FX spot rate F: FX forward rate

A cross-currency basis swap agreement is a contract in which one party borrows one currency from another party and simultaneously lends the same value, at current spot rates, of a second currency to that party. The parties involved in basis swaps tend to be financial institutions, either acting on their own or as agents for non-financial corporations. The chart below illustrates the flow of funds involved in a euro/US dollar swap. At the start of the contract, A borrows X·S USD from, and lends X EUR to, B. During the contract term, A receives EUR 3M Libor+ α from, and pays USD 3M Libor to, B every three months, where α is the price of the basis swap, agreed upon by the counterparties at the start of the contract. When the contract expires, A returns X·S USD to B, and B returns X EUR to A, where S is the same FX spot rate as of the start of the contract. Though the structure of cross-currency basis swaps differs from FX swaps, the former basically serve the same economic purpose as the latter, except for the exchange of floating rates during the contract term.

Cross-currency basis swaps have been employed to fund foreign currency investments, both by financial institutions and their customers, including multinational corporations engaged in foreign direct investment. They have also been used as a tool for converting currencies of liabilities, particularly by issuers of bonds denominated in foreign currencies. Mirroring the tenor of the transactions they are meant to fund, most cross-currency basis swaps are long-term, generally ranging between one and 30 years in maturity.



S: FX spot rate

Taylor (1994, 1996), using cross-currency swap prices in the late 1980s and early 1990s, found that non-negligible deviations existed from the CIP condition at various times, but that such deviations diminished over time.

The conventional quoting procedure for cross-currency basis swaps is as follows. A yen/dollar 10-year basis swap, for instance, might be quoted as yen Libor minus 5 basis points versus dollar Libor flat. This means that the lender/borrower of dollar/yen funds is obligated to pay yen Libor minus 5 basis points every three months in exchange for receiving dollar Libor flat. In this fashion, the prices for swaps involving the dollar (–5 basis points in the above case) turn negative if there is strong demand for dollars and consequently a willingness to receive less in interest rate payments on the funds lent in other currencies.

Basis swap prices and liquidity

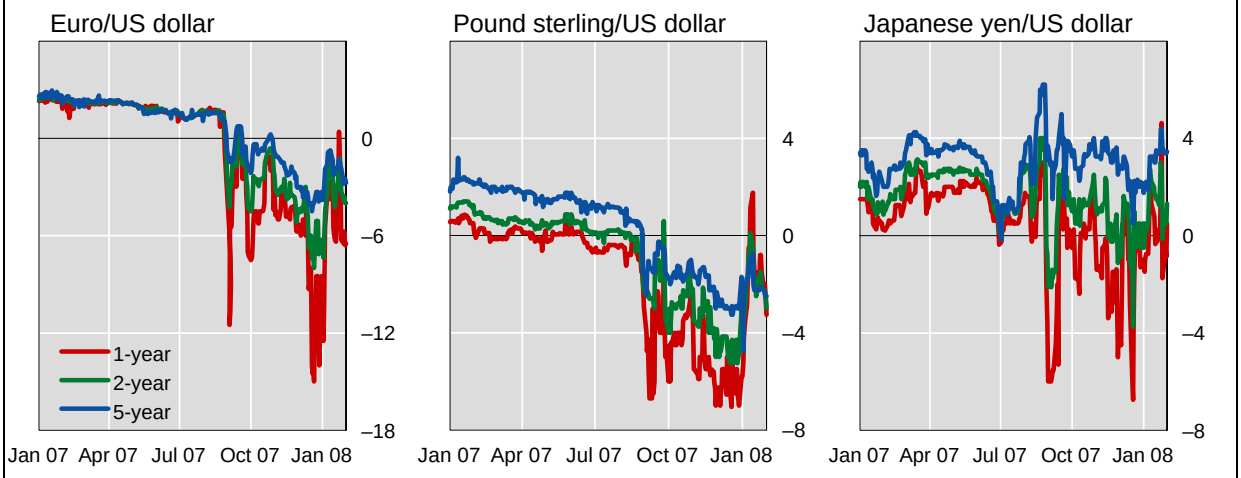
Basis swap prices traded in negative territory ...

The movements of basis swap prices over the one-, two- and five-year tenor for the euro/dollar, sterling/dollar and yen/dollar pairs are shown in Graph 5.[18] In the case of the euro/dollar, it is clear that, starting from the end of August, the basis swap of all tenors began to trade in significantly negative territory, falling by more than 10 basis points in only a few days for the one-year basis swap.

Movements in the basis swap market appear to have been affected by the deviations from (short-term) CIP documented earlier. Table 1 shows the result of tests of Granger causality between the deviation of FX swap prices from CIP

Cross-currency basis swaps

In basis points



Source: Bloomberg.

Graph 5

role in price discovery, in that cross-currency basis swaps contribute more to the volatility of the efficient price common to both swaps.

[18] The basis swap prices are also NY composite prices as of 17:00 New York time taken from Bloomberg.

Granger causality test between FX swap and cross-currency basis swap

Funding currency	Period	Causality	
		FX swap to basis swap	Basis swap to FX swap
Euro	2 Jan – 8 Aug 07	12.17**	6.87
	9 Aug 07 – 31 Jan 08	14.43**	0.15
Pound sterling	2 Jan – 8 Aug 07	2.13	0.22
	9 Aug 07 – 31 Jan 08	19.58**	1.95
Japanese yen	2 Jan – 8 Aug 07	0.15	3.58
	9 Aug 07 – 31 Jan 08	23.15**	0.00

The maturities of the FX swap and cross-currency basis swap are three months and one year, respectively. Figures denote the chi-squared statistics from VAR Granger causality/Block exogeneity Wald tests. * and ** indicate significance at the 5% and 1% level, respectively. Lag length is chosen by the Schwarz information criterion.

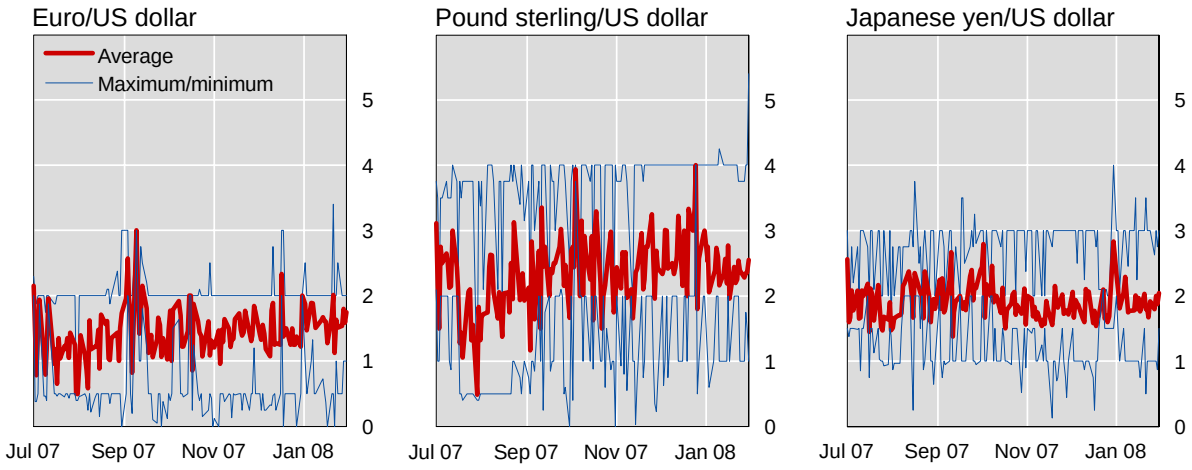
Table 1

and basis swap prices for each funding currency.[19] Using data for the period preceding the turbulence in early August 2007, a significant lead-lag relationship is found from the FX swap to the basis swap only for the euro. During the turmoil, however, all the currencies show that cross-currency basis swaps lagged significantly behind the movement of FX swaps. This suggests that FX swaps were the avenue for spreading turbulence from money markets to long-term cross-currency basis swap markets. One of the reasons for this suggested by market practitioners is that some European financial institutions turned from short-term dollar funding through FX swaps to longer-term funding through currency basis swaps, once they realised that the financial turmoil would last longer than initially expected.

... as turbulence spread through the FX swap market

Bid-ask spreads for one-year cross-currency basis swaps

In basis points



Sources: Bloomberg; BIS calculations.

Graph 6

[19] As mentioned earlier, the time zone difference between FX forward discount rates (17:00 New York time) and Libor fixing (slightly after 11:00 London time) might generate a bias in estimation results. But the changing pattern of causality during the period of financial turmoil is less likely to be affected by this factor, because we use the data consistently during the whole period.

Graph 6 shows the bid-ask spreads for one-year basis swaps.[20] Average bid-ask spreads as well as their range rose to some extent from mid-August for the euro/dollar and sterling/dollar swap, but declined soon thereafter for the euro/dollar. The degree of impairment of liquidity in the cross-currency basis swap market thus appears to have been less significant than that documented for FX swaps.

Comparison with the Japan premium episode

In order to provide one perspective on the magnitude of the price movements in cross-currency basis swaps, it is useful to compare the recent episode with the Japan premium episode in the late 1990s. At that time, due to a substantial deterioration of their creditworthiness, Japanese banks found it difficult to raise foreign currencies in global cash markets.

The euro/dollar basis swap price dropped sharply ...

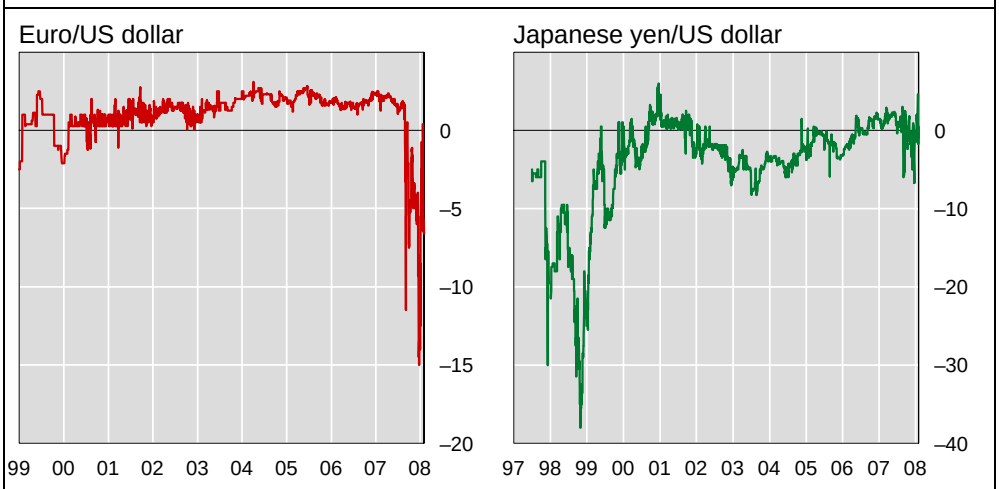
Graph 7 plots the prices of one-year basis swaps for the euro/dollar and yen/dollar pairs since the late 1990s. We find that, except for the period immediately preceding early 2000, the basis swap price for the euro/dollar pair stayed in a narrow range of 0–2.5 basis points until 2007. From the end of August 2007, however, the euro/dollar price moved into negative territory to an unprecedented degree, reaching around –15 basis points in late November.

... though not as much as that for the yen/dollar in the late 1990s

By contrast, the basis swap price for the yen/dollar pair showed a dramatic decline from late 1997 to early 1999, going below –30 basis points. During this period, Japanese banks were known to have turned to the cross-currency basis swap market to secure long-term dollar funding using their ample yen deposits for their funding currency. The comparison between the two episodes tells us that, while the recent distortion of basis swap prices for the euro/dollar pair is particularly large by its own historical standards, it remains significantly less than the price movements seen for the yen/dollar pair in the late 1990s.

One-year cross-currency basis swaps

In basis points



Source: Bloomberg.

Graph 7

[20] As is the case with the bid-ask spreads for FX forward discount rates, we use hourly closing bid-ask spreads, taken from Bloomberg.

Conclusion

We have documented that the turmoil in the money market from the second half of 2007 spilled over not only to FX swap markets, but also to the cross-currency basis swap market. The evidence is consistent with the view that the FX swap market was increasingly used by financial institutions to overcome dollar funding shortages, which resulted in marked deviations from covered interest parity conditions and an impairment of liquidity in the FX swap market from early August. Much less well known is the fact that by early September the turbulence had spread further to the longer-term cross-currency basis swap market. An unprecedented movement in the euro/dollar basis swap price reflected a surge in demand for dollar term funding relative to that of the euro. However, the degree of the distortion did not reach that seen for the yen/dollar pair in the late 1990s.

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Credit fundamentals, ratings and value-at-risk: CDOs versus corporate exposures[1]

This article compares the linkages between credit fundamentals, ratings and value-at-risk measures for CDO tranches with those for corporate bond exposures. A sensitivity analysis incorporating market information and rating migrations data reveals that the behaviour of CDO tranche ratings can differ markedly from that of corporate ratings. In addition, tranching is found to have an important impact on the probability of large losses. This highlights how investors who narrowly focus on ratings and draw direct parallels with corporate exposures can seriously misjudge the value-at-risk of CDOs.

JEL classification: G24, G32.

Owing to weakening house prices and declining underwriting standards in 2006 and 2007, mortgage markets in the United States have seen a significant deterioration. Large numbers of rating downgrades on securitised mortgage products, in turn, have revived questions about the nature of structured finance ratings, their sensitivity to changes in credit fundamentals, the degree to which rating transitions for products such as collateralised debt obligations (CDOs) should be expected to differ from those for corporate bonds, and the extent to which ratings can serve as universal measures of credit risk.[2]

In an attempt to address these questions, this article analyses the risk profile of CDOs, mainly through comparison with that of corporate exposures. The analysis is based on a hypothetical CDO that reflects key features of the market for structured products backed by mortgage collateral. A number of stylised but realistic scenarios, motivated by market reports and observed rating migrations, are applied to a set of baseline ratings for different CDO tranches. The results shed some new light on the recent downgrade activity experienced by these products and the extent to which these downgrades could have been anticipated by market participants. In addition, the results extend the existing literature by lending new quantitative support to earlier

[1] The views expressed in this article are those of the authors and should not be taken to reflect the views of the BIS; any errors and omissions remain those of the authors. The authors would like to thank Marjorie Santos for her help with graphs and tables.

[2] See Kiff and Mills (2007) for details on the US mortgage market, and Fender and Mitchell (2005) for an overview of the key issues related to structured finance ratings.

findings on the characteristics of tranche ratings (eg CGFS (2005)) and by adding comparisons across like-rated exposures in different asset classes to existing analyses of CDO risk (eg Gibson (2004)).

This article is organised as follows. The first section briefly introduces CDOs and how they are rated, using so-called structured finance CDOs as an example. This is followed by a second section focusing on the impact of credit fundamentals on CDO ratings. A key finding of this exercise, namely that expected losses and, hence, ratings of CDO tranches can be substantially more sensitive to changes in credit fundamentals than ratings of like-rated corporate bonds, is taken further in the third section. That section argues that dimensions of credit risk not captured by ratings can drive substantial differences between credit value-at-risk (VaR) measures of like-rated instruments. These differences surface both in VaR levels and in their sensitivity to changes in credit fundamentals. The last section concludes.

Overview: CDOs and how they are rated

Market structure and recent developments

CDOs are structured finance products in which a distinct legal entity, a so-called special purpose vehicle, issues claims against an underlying pool of assets (CGFS (2005)). These claims, in turn, are prioritised by creating classes of securities with different levels of seniority, including senior and mezzanine tranches and an equity (first loss) piece. Senior tranches are insulated from default risk up to the point where credit losses deplete the more junior ones.

CDOs are structured finance products ...

While CDO collateral pools can consist of various forms of debt (such as loans, bonds or synthetic exposures), recent vintages have increasingly been based on other structured products (such as tranches of mortgage-backed securities or of other CDOs). Issuance data for these so-called *structured finance* CDOs suggest that they accounted for some 49% of the $560 billion worth of CDOs issued during 2006. This was up from 45% in 2005 and 40% in 2004. In 2007, despite the turmoil in credit markets during the second half of the year, the share remained at around 46%, with some $182 billion issued up to year-end (Graph 1, left-hand panel).

Whereas early structured finance CDOs had relatively diversified pools, more recent vintages have increasingly been based on mortgage collateral. As a result, by 2006, mezzanine structured finance CDOs (ie those backed primarily by BBB-rated mezzanine tranches of other securitisations) had almost 90% of their assets invested in home equity loan and residential mortgage-backed securities (RMBSs; Graph 1, right-hand panel). According to Moody's (2007b), 45% of these pools were on average devoted to subprime exposures, with variation around that level ranging from close to zero to as high as 88%.

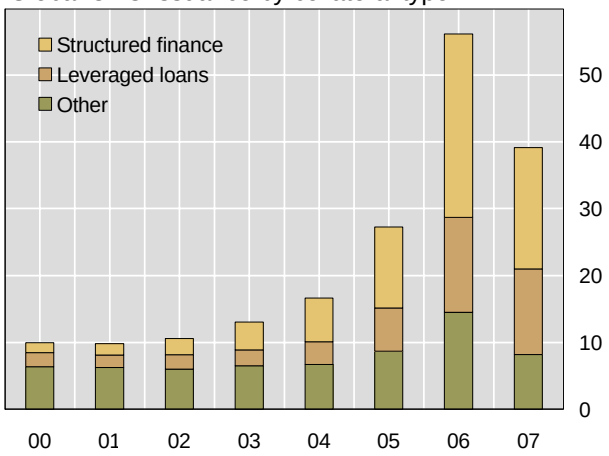
... increasingly based on tranches of mortgage-backed securities

In 2007, given the high exposures of these pools to US mortgage collateral, deterioration in credit quality became increasingly evident at the end of the securitisation chain. As rising mortgage delinquencies triggered large numbers of negative rating actions on RMBSs referencing subprime collateral, these downgrades subsequently fed into CDOs as well. Specifically, between

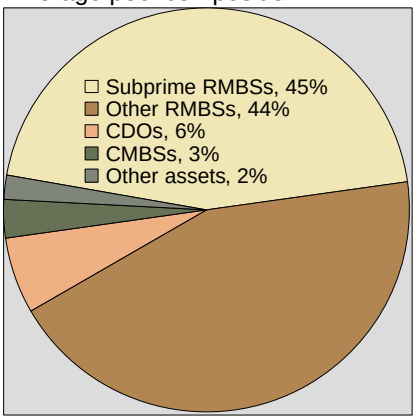
CDOs suffered large-scale rating downgrades in 2007 ...

CDO market structure

Global CDO issuance by collateral type[1]



Average pool composition[2]



[1] In billions of US dollars; combines funded deals as well as the funded portions of synthetic deals. [2] Mezzanine structured finance CDOs issued in 2006.

Sources: Citigroup; Lehman Brothers; Moody's; authors' calculations. Graph 1

January and December 2007, Moody's alone downgraded almost 1,400 CDO tranches from 462 transactions originally valued at about $76 billion. These included numerous cases of rapid rating transitions by six notches or more and affected tranches with original ratings as high as Aaa.[3]

There are several channels through which this happened.[4] One of these, which is the focus of the remainder of this article, works through the effect of credit quality deterioration on the protection provided through the tranching process. That is, as credit quality deterioration leads to collateral downgrades, it becomes increasingly likely that, given an otherwise unchanged CDO structure, at least some of the tranches are also downgraded.

CDO rating methodology

... reflecting higher expected loss estimates

Ratings of CDOs, just as those of more traditional debt instruments, are indicators of default risk based on expected loss (EL) or probabilities of default (PDs).[5] In assigning these ratings, the rating agencies rely on an iterative, two-stage process that combines estimated loss distributions (the result of *credit risk modelling*) with expert judgment based on deal-specific contractual information (the result of *cash flow analysis*). This process delivers estimates of tranche EL (or PD), which are translated into alphanumeric ratings via

[3] See Moody's (2008). The observed average downgrade of about 7.5 notches for the 2006 and 2007 vintages compares to an average downgrade of about 3.8 notches for earlier (1997 to 2006) vintages of US CDO tranches (Moody's (2007a)).

[4] Collateral downgrades below investment grade, in particular, can trigger structural provisions within CDOs that, in turn, may cause quasi-automatic downgrades of the affected CDO tranches. One example are "event-of-default" tests linked to the ratings composition of the CDO collateral pool. Of the 700 or so CDOs that saw collateral downgrades in 2007, at least 50 are reported to have experienced such events.

[5] Moody's ratings are based on EL whereas those of Standard & Poor's and Fitch Ratings are based on PDs. See Fender and Kiff (2005) for more detail on CDO rating methodology.

historical "mappings" benchmarked to the performance of *corporate bonds*. By implication, like-rated instruments are deemed by the rating agencies to have broadly similar ELs (or PDs).[6]

At the credit risk modelling stage, the major rating agencies rely heavily on Monte Carlo simulations, especially when assigning ratings to CDOs backed by synthetic or structured finance instruments (eg Fitch Ratings (2006), S&P (2005)). In operationalising these simulations, it is standard practice to approximate the complex structure of losses on a CDO pool by assuming that these losses are the *direct* consequence of *hypothetical* asset values falling below a prespecified threshold. Such an assumption allows recourse to so-called *structural* credit risk models (designed for corporate bonds), which require estimates of instrument-specific EL and pairwise asset return correlations as inputs (eg Moody's (2005)). Rating agencies obtain such estimates from observed ratings dynamics and feed them into the models in order to simulate the risk properties of the entire CDO collateral pool through repeated draws of random credit losses.

This delivers an estimate of the probability distribution of pool losses, the exposure to which is then parcelled out across tranches, taking the results of agencies' cash flow analysis into account. Specifically, the *attachment point* (ie the minimum loss on the underlying pool that affects the tranche) and the *detachment point* (ie the minimum pool loss that wipes out the entire tranche) are chosen so that the resulting EL of the tranche matches the level required for a desired rating. On this basis, a typical CDO comprises tranches with different levels of seniority, rated as high as Aaa/AAA at the senior end. Taken together, these tranches will amount to some 95% of the pool, with the remainder issued or retained by the CDO originator as (typically unrated) equity (Fender and Mitchell (2005)).

The modelling approach of the rating agencies has at least two important limitations if CDOs are not backed by corporate bonds (or loans) – that is, if the pool underlying a CDO comprises tranches of mortgage-backed securities. First, this approach will introduce approximation errors as long as default-related losses on *individual* structured finance exposures in the CDO pool are not captured appropriately by structural models designed to account for corporate defaults.[7] Second, by approximating the default behaviour of the *overall* collateral pool via pairwise correlations of hypothetical asset returns, rating agencies may not fully account for the default clustering within and across the different instruments in this pool. That said, the impact of such approximation errors on credit ratings is difficult to assess – not least because the rating agencies themselves attempt to correct for these errors by making

[6] The remainder of this article will focus only on the first part of the rating process (pool credit risk modelling), and will assume that ratings are assigned on the basis of EL (not PD).

[7] Mortgage-backed securities do not default in the sense of a singular corporate default event. Instead, reflecting delinquencies and prepayments on the underlying collateral, such securities will experience cash flow shortfalls and writedowns over the lifetime of the underlying collateral.

adjustments at the cash flow analysis stage or via the specific calibration of their credit risk models.[8]

The impact of credit fundamentals on CDO ratings

When exposed to changes in credit fundamentals ...

This section employs sensitivity analysis to gauge the impact of changes in credit fundamentals on tranche ratings, based on a hypothetical CDO structure. The exercise is implemented by "shocking" two key credit risk fundamentals, PDs and asset return correlations, using various scenarios inspired by recent market developments. The analysis then proceeds to illustrate how rating migrations of CDO tranches can differ from those of corporate exposures.

Setting up a hypothetical CDO pool

For tractability, the following analysis abstracts from the heterogeneity and complexity of actual CDO deals and focuses on a hypothetical pool that incorporates realistic, albeit stylised, credit risk features. The hypothetical CDO pool is composed of 100 equally sized individual assets with the same "Baa3" rating on the Moody's scale (ie "BBB–" on the Fitch/S&P scale). Furthermore, each underlying asset is assumed to have the same degree of exposure to a single common factor or, equivalently, all pairwise asset return correlations are fixed at 15%.[9] Finally, loss-given-default (LGD) is assumed to be independent of default events and to follow a symmetric triangular distribution in the range of [0.1, 1]. The resulting mean value of 55% corresponds to the assumption employed by Moody's in deriving PDs from their "idealised" expected loss data. These same data are used here to infer PD estimates from the assumed ratings of a CDO's underlying assets, and to map EL estimates into indicative ratings for various CDO tranches.

Under these assumptions, baseline tranche ratings for the hypothetical CDO pool can be derived through Monte Carlo simulations of its loss distribution, calculating the expected loss for each tranche and assigning ratings accordingly. The results of such an exercise are reported in Table 1. Two sets of tranche specifications are included, one corresponding to a typical tranche structure (as used, for example, in the CDS index market) and the other comprising two alternative tranches that are tailored to have the same EL corresponding to a Baa3 rating.

The chosen approach to assigning CDO ratings warrants some remarks. First, it follows market practice by essentially treating the assets in the CDO's

[8] Another way to mitigate approximation errors is the use of so-called "look-through" approaches that attempt to capture overlapping credit risks among underlying tranches in CDOs backed mainly by tranches of other CDOs.

[9] The heterogeneous asset pools contained in actual CDOs would typically necessitate a more complex correlation structure in which default clustering depends on asset sector and asset type composition. The correlation assumption adopted here was chosen for simplicity, but is in line with estimates reported in related studies. For instance, Lopez (2004) documents an average asset return correlation of 12.5% for a large number of US firms. A similar average asset return correlation arises for typical structured finance CDOs, as depicted in Graph 1, under standard correlation assumptions (eg Moody's (2005)).

Tranche ratings: hypothetical CDO pool

Baseline scenario

Attachment (%)	Detachment (%)	Tranche EL (%)	Rating
0.0	3.0	7.5748	B3
3.0	7.0	0.0916	Baa2
7.0	10.0	0.0028	A1
10.0	15.0	0.0002	Aa1
15.0	30.0	0.0000	Aaa
30.0	100.0	0.0000	Aaa
Tailor-made tranches			
2.6	5.0	0.231	Baa3
0.9	25.0	0.231	Baa3

In the hypothetical CDO pool, there are 100 homogeneous assets with the same Baa3 rating and the same pairwise asset return correlation of 15%. LGD is assumed to follow a symmetric triangular distribution between 10 and 100%. The ratings are assigned on the basis of Moody's idealised EL data. Tranche attachment and detachment points are defined as percentages of pool value; tranche EL is as a percentage of tranche notional.

Source: Authors' calculations. Table 1

underlying pool as corporate bonds. This "shortcut" approach, as mentioned above, simplifies the analysis of pool credit risk at the cost of introducing a source of approximation error.[10] Second, the analysis focuses on credit losses that are realised over a single one-year period and abstracts from cash flow analysis. As a result, factors such as default timing assumptions, amortisation/prepayment effects, cash flow redistributions resulting from structural features, and servicer or asset manager quality are ignored in deriving the results reported below.

Sensitivity analysis

In what follows, asset-level PD and correlation assumptions are "shocked" to gauge the sensitivity of tranche ratings to deteriorations in credit conditions, with various scenarios inspired by actions taken by rating agencies in the unfolding subprime crisis. Shocks are assumed to affect a maximum of 45% of the pool's assets, the average share of subprime RMBSs in a typical structured finance CDO (Graph 1).[11] The first set of scenarios introduces PD stresses in which the affected pool assets are downgraded by either one or six notches (on Moody's rating scale).[12] In the second set of scenarios, it is assumed that 45%

[10] This special feature does not address these issues directly. Nevertheless, the results of the sensitivity analysis suggest that miscalibration of the credit fundamentals of underlying assets could have significant implications for the ratings of CDO tranches.

[11] Obviously, if the share of pool assets that are subject to credit deterioration increases, the impact on ratings of CDO tranches is greater.

[12] In response to the onset of the subprime crisis, all three major rating agencies decided to make adjustments to their rating methodologies for structured finance CDOs, mainly by stressing PD inputs in the credit risk assessment. In particular, Fitch Ratings increased all rating-implied PDs for subprime RMBSs issued since 2005 by 125%, while Moody's downgraded subprime RMBSs by between zero and six notches depending on vintage year and rating. Standard & Poor's, in turn, downgraded the ratings of subprime RMBSs issued between the first quarter of 2005 and mid-July 2007 by between zero and two notches.

of the CDO pool's assets are subject to increased exposure to the systemic risk factor, which raises the corresponding pairwise asset return correlations from 15% to 45% and 65%.[13] A third and final set of scenarios allows for joint shocks to both PDs and asset return correlations (Table 2).[14] The main findings are as follows.

... CDO tranche ratings can change by much more than ...

First, the impact of PD shocks on CDO tranche ratings depends on the magnitude and clustering of the shocks and tends to be non-linear. For instance, one-notch downgrades of 45% of the pool's underlying assets have only a small impact on tranche ratings (downgrades at most by one notch; see scenario 1). By contrast, six-notch downgrades on the same group of assets can cause mezzanine tranches to be downgraded by as much as 10 notches (scenario 3). Interestingly, multi-notch downgrades for a small set of pool assets have greater effects than single-notch downgrades for a large set of assets, even when the total number of notch downgrades is similar (scenario 2 vs scenario 1; Table 2). This finding, dubbed the *dispersion effect*, results from the non-linear relationship between rating grades and rating-implied PDs, which leads to greater changes in PD per notch for multi-notch relative to single-notch downgrades. As a result, a higher dispersion in ratings of the underlying assets implies a higher average PD and increases the risk across CDO tranches.

... corporate ratings

Second, correlation stresses can trigger significant downgrades for mezzanine and senior tranches, *even in the absence of downgrades in the underlying pool*. For instance, an increase in within-group correlation from 15% to 65% changes the rating of tranche [15, 30] from Aaa to A3, the same effect as if 45% of the underlying assets were downgraded by six notches (scenario 5 vs scenario 3; Table 2). The reason for this effect is that higher correlations do not affect expected loss but push probability mass into the tails of the loss distribution. Therefore, the equity tranche tends to benefit (because the probability of zero default increases) at the expense of senior tranches.

Third, the impact of credit fundamentals on CDO ratings depends on tranche specifications, including seniority and thickness (ie the difference between detachment and attachment points). The equity tranche is adversely affected by increases in PD, but benefits from increases in asset return correlations, as noted above. By contrast, mezzanine and senior tranches are vulnerable to increases in both PDs and correlations. The impact on ratings is usually most remarkable for mezzanine tranches, for which the loss distribution is most sensitive to changes in credit fundamentals. In addition, a comparison between the two like-rated, tailor-made, mezzanine tranches reveals that the thinner one depends more on credit fundamentals. This reflects the increased importance of the credit quality of any one collateral asset for tranches that can be wiped out by a small rise in pool losses.

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[13] These assumptions appear to be deemed conservative by the rating agencies. See, for example, Moody's (2005).

[14] Empirical studies suggest that default correlation increases when the credit quality of underlying assets deteriorates.

Tranche downgrades: sensitivity analysis

In notches relative to baseline tranche ratings

	Original rating	PD shocks (# assets x # notches)			Correlation shocks (# assets x correlation)		Joint shocks (# assets x # notches x correlation)	
		1 (45x1)	2 (7x6)	3 (45x6)	4 (45x45)	5 (45x65)	6 (7x6x45)	7 (45x6x45)
[0.0, 3.0]	B3	–1	–3	–4	0	0	–2	–3
[3.0, 7.0]	Baa2	–1	**–2**	**–9**	**–2**	**–3**	**–4**	**–9**
[7.0, 10.0]	A1	–1	–2	**–10**	–4	–5	–3	**–13**
[10.0, 15.0]	Aa1	–1	–1	**–9**	–5	–7	–2	**–14**
[15.0, 30.0]	Aaa	0	0	–6	–3	–6	0	**–12**
[30.0, 100.0]	Aaa	0	0	0	0	0	0	0
Tailor-made tranches								
[2.6, 5.0]	Baa3	**–1**	**–3**	**–9**	**–2**	**–2**	**–4**	**–9**
[0.9, 25.0]	Baa3	**–1**	**–2**	**–7**	**–1**	**–1**	**–3**	**–7**

"# assets" refers to the number of underlying assets that are exposed to PD or correlation shocks; "# notches" refers to the degree of PD shocks, ie the number of notch downgrades with which each of these assets will be faced; "correlation" refers to the new pairwise correlation within the group of underlying assets that experience shocks. The bold results represent tranche downgrades from investment grade to speculative grade.

Source: Authors' calculations. Table 2

Lastly, the sensitivity analysis sheds some light on the severity of credit shocks necessary to push Aaa-rated senior tranches into sub-investment grade territory. While the most senior Aaa tranche appears to be quite safe, downgrades can be quite pronounced for more junior tranches with the same rating. For instance, it takes six notch downgrades on 45% of pool assets and a within-group correlation of 45% for the rating of the [15, 30] Aaa tranche to be lowered to Ba2. This partly explains the large magnitude of downgrades of CDO tranches in 2007 (see footnote 3), when more than 125 CDOs experienced collateral downgrades in excess of 45% of the underlying pool.

Simulating rating migrations

This subsection introduces an additional perspective to the preceding analysis of CDO tranche ratings by comparing the migration rates of these tranches with those of corporate bonds with the same original rating. Given that mezzanine tranches have received much attention recently, the baseline results reported below relate to the two tailor-made CDO tranches that share the same Baa3 rating (Table 1).

Rating migrations of CDO tranches differ substantially from …

The simulation of migration rates of CDO ratings is implemented as follows. Consistent with the above analysis, the hypothetical CDO pool is assumed to consist of 100 identical underlying assets. The credit quality of these assets is assumed to change over time, subject to the typical rating transition probabilities of Baa3-rated corporate issuers observed during 1983–2003 (as reported by Moody's (2004)) and the asset return correlation specified above. The realisation of credit quality of the underlying assets is simulated 1,000 times and, in each simulation, the credit rating of CDO tranches is

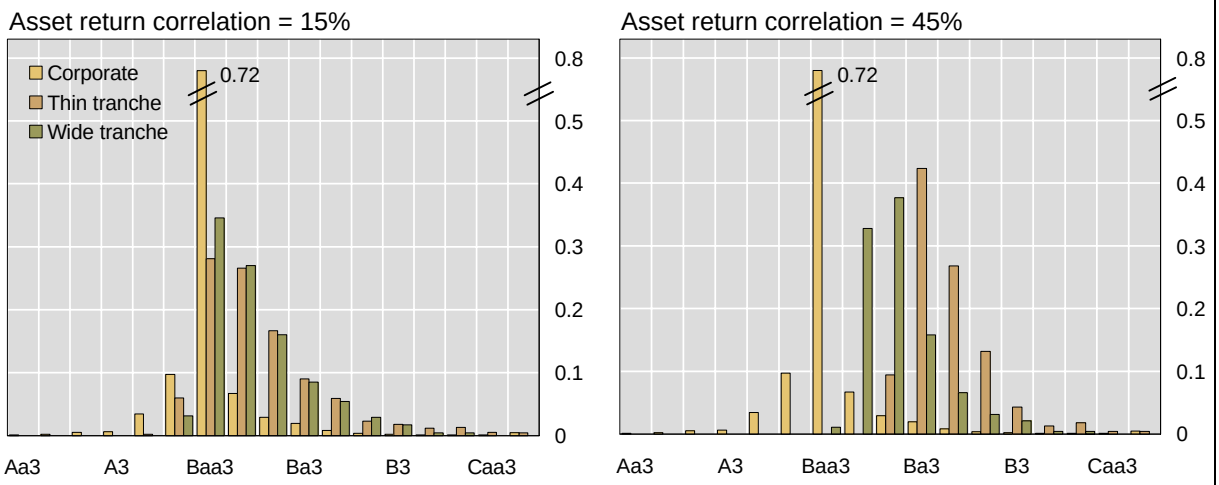
reassessed accordingly. The results are then aggregated to obtain simulated migration rates, and compared with observed migration rates of Baa3-rated corporate issuers (Graph 2).

... rating migrations of corporate bonds

The one-year rating transitions for CDO tranches can be strikingly different from those of corporate bonds, in terms of the likelihood, direction and size of rating changes. Specifically, the two mezzanine tranches examined here are more likely to face rating revisions than the like-rated corporate exposures. In addition, when revisions occur for CDO tranches, downgrades are more likely than upgrades and the probability of large-scale downgrades is not negligible. By contrast, rating revisions for Baa3 corporate bonds tend to be symmetric and of a limited scale.[15] Moreover, the downgrade risk of CDO tranches is more pronounced when the asset return correlation is higher, suggesting that tranches are particularly vulnerable when the credit deterioration of underlying assets is mainly driven by increased exposure to systematic risk (eg during a cyclical downturn). Lastly, the migration rates depend on tranche specification. Comparing the two like-rated tranches, the thinner one is more sensitive to changes in credit conditions, which is consistent with the sensitivity analysis conducted above.

Migration rates: hypothetical CDO tranches

CDO vs corporate exposures



The two panels plot the rating transition probabilities of corporate bonds and two tailor-made CDO tranches (defined in Table 1) with the original rating of Baa3. The hypothetical CDO consists of 100 identical underlying assets with the same Baa3 rating. At each time, the realisation of credit quality of the 100 assets is simulated on the basis of the transition probabilities of Baa3 corporate issuers and a prespecified asset return correlation. The realised credit quality is fed into the CDO pool to infer new ratings for the CDO tranches. The simulation is repeated 1,000 times to plot the rating migration of the two CDO tranches.

Sources: Moody's; authors' calculations. Graph 2

[15] These results are in partial accordance with studies of historical rating transitions (eg Moody's (2007a)). On the one hand, such studies reveal that rating changes are more seldom for CDO products than for corporate bonds. On the other, when historical CDO tranche ratings do change, the changes tend to be roughly twice as large as those of corporate bond ratings. Two factors may explain why this article derives a relatively higher probability of changes of tranche ratings. First, the analysis here assumes that ratings depend solely on estimated expected losses and ignores other potentially important factors. It also ignores any lags introduced by the rating surveillance process. Second, given that available rating histories are too short to embody a full credit cycle, observed migration rates might be biased away from long-run averages.

The high likelihood of CDO tranche downgrades, particularly significant downgrades, is attributable to two factors. First, the dispersion effect suggests that a higher dispersion in ratings translates into a deterioration of the average credit quality of the underlying pool. That is, a one-notch downgrade increases the implied average PD by more than a one-notch upgrade would decrease it. Second, as seen in the above sensitivity analysis, the structuring process redistributes losses across tranches. As a result, credit quality deterioration tends to have an amplified effect on particularly vulnerable CDO tranches, eg the thin mezzanine tranche.

From ratings to credit VaR

The preceding analysis shows that the sensitivity of ratings to changes in credit fundamentals (and, thus, to the business cycle) can be substantially stronger in the case of structured finance instruments than in the case of corporate bonds. The reason is that, being determined solely by estimates of average losses, ratings are only loosely related to other measures of credit risk. Credit VaR is one such measure, which, representing a high level of credit losses that can be exceeded only with a small probability, is of particular importance to market participants and supervisors.

It is thus useful to analyse how the tranching of structured finance instruments affects the relationship between ratings and VaR. In conducting such an analysis, this section focuses on the marginal contributions of two types of assets to the VaR of a hypothetical portfolio (which is kept in the background). The first asset is a corporate bond. The second asset is a CDO tranche whose collateral is based on a homogeneous pool of corporate bonds with the same PD and dependence on the common factor as the first asset.[16]

The rest of this section considers the marginal VaRs (henceforth MVaRs) of the two asset types from three different angles.[17] The first subsection compares MVaR *levels* across asset types, keeping the corresponding rating constant. The second subsection considers the *sensitivity* of tranche and corporate bond MVaRs to changes in PDs and default correlations. Lastly, the third subsection analyses how the difference between these MVaRs depends on the degree of *diversification* in the pool underlying the CDO.

Tranching and the level of MVaR

Tranching may increase VaR levels ...

Even when a CDO tranche and a corporate bond share the same rating, MVaR measures point to differences in the credit risk of each security. Referring to the example introduced in the previous section, a Baa3-rated corporate bond has an MVaR of 3.26%, which is more than *10 times* smaller than the 35% MVaR of a CDO tranche with the same rating (Table 3). This is a consequence

[16] The higher is the dependence on the common factor, the higher are asset-return correlations and the more correlated are default events.

[17] See the box on page 98 for theoretical underpinnings of the MVaR of a CDO tranche.

Credit VaR: sensitivity analysis

In per cent

	Original expected loss	Original credit VaR	PD shocks			Correlation shocks		Joint shocks	
			Scenario						
			1	2	3	4	5	6	7
Corporate	0.23	3.26	4.30	4.96	14.20	7.30	11.80	6.43	23.60
Tranches									
[2.6, 5.0]	0.23	35.36	59.64	74.86	100.00	96.51	100.00	95.47	100.00
[0.9, 25.0]	0.23	9.90	14.05	16.91	55.19	26.77	45.20	22.99	93.11

Original expected loss and VaR as well as shock scenarios 1 to 7 are based on the same credit risk parameters as those underlying Table 2. In addition, VaR numbers refer to perfectly granular portfolios comprising homogeneous corporate exposures or CDO tranches. The underlying pool of a CDO comprises 100 corporate exposures. Numbers in square brackets refer to the attachment and detachment points of the respective tranche. Table 3

of the tranching process, which concentrates the underlying credit risk in the more junior tranches.

That said, the difference between corporate and tranche MVaRs would be smaller if the tranche's detachment and attachment points were further apart (ie if the tranche were "thicker"). Table 3 illustrates this by considering two "nested" and like-rated CDO tranches. Since most of the extra collateral underpinning the thicker tranche is affected only after the entire collateral of the thinner tranche is wiped out,[18] the probability of a large loss on the thicker tranche is lower. In terms of this specific example, the "thicker" tranche features an MVaR that is less than one third of the MVaR of the "thinner" one, but is still much higher than that of the like-rated corporate bond.

Tranching, risk fundamentals and MVaR

... and the sensitivity of VaR to credit fundamentals ...

The different nature of the credit risk underlying corporate bonds and CDO tranches also affects the sensitivity of MVaR to changes in risk fundamentals (PD and default correlations). Quite naturally, deteriorating fundamentals would raise the MVaR of each member in a pool of corporate bonds and, thus, the *overall* risk of the CDO based on this pool. However, the sensitivity of MVaR to fundamentals changes substantially with tranche seniority, reflecting the high degree of non-linearity introduced by the structuring process.

Tranche seniority that implies a moderate value of the MVaR would also imply high sensitivity of this value to changes in fundamentals (Table 3, third to last columns). If 7% of the corporate bonds underlying a CDO are downgraded by six notches as a result of a positive PD shock, the average MVaR of these securities increases by half to almost 5% (scenario 2). In parallel, the MVaR of a mezzanine tranche of this CDO more than doubles, from the initially moderate 35% to 75%. The downside risk of this tranche has, however, little

[18] This is because the difference between the attachment points of the two nested tranches is smaller than the difference between their detachment points. Had the two differences been the same, non-linearity of the loss distribution would have led to a higher PD (and, thus, a lower rating) for the thicker tranche. However, by introducing more senior collateral into the thicker tranche, the larger difference between the two detachment points lowers this tranche's PD to that of the thinner tranche.

room to increase further if fundamentals were to continue to deteriorate. Thus, a transition from scenario 2 to scenario 3, in which 45% of the underlying pool is downgraded by six notches, increases the MVaR of the tranche by (only) one third, to 100%. In this scenario, the average MVaR of the underlying corporate securities nearly triples to 14%.

Diversification and the MVaR of a CDO tranche

... in ways that depend on pool granularity

Smaller diversification of the CDO's underlying pool, also known as coarser granularity, increases the MVaR of low-risk tranches, but decreases the MVaR of high-risk tranches (see box). Coarser granularity increases both the

Derivation and features of the marginal VaR of a CDO tranche[①]

This box analyses the marginal contribution of a CDO tranche to portfolio VaR. For the calculation of its marginal VaR (henceforth MVaR), the tranche is treated as one of many credit-risky assets in an investment portfolio. It is assumed that the risk of this portfolio is governed by a single common factor and that the impact of idiosyncratic risk factors is diversified away owing to the large number of constituent assets (ie the portfolio is "perfectly granular"). Given these assumptions, the credit VaR of the portfolio equals the sum of the MVaRs of the individual assets included in the portfolio.

Furthermore, such an MVaR depends only on features specific to the particular asset, which allows the rest of the portfolio to be kept in the background. Concretely, the MVaR equals the expected loss on the asset over some horizon, conditional on a sufficiently adverse realisation of the common risk factor. This MVaR increases as credit fundamentals deteriorate, eg as the asset's PD or dependence on the common factor increases.

In order to build intuition about the MVaR of a CDO tranche, it is useful to consider a special case, in which the pool underlying the CDO is comprised of a very large number of homogeneous corporate bonds that are affected by a single common risk factor. When this factor is at the value used for calculating MVaR, the loss (per unit of exposure) on the perfectly granular pool would (by construction) be exactly equal to the MVaR of a constituent corporate bond. This loss wipes out the entire collateral of any CDO tranche with a detachment point lower than the corporate bond MVaR. Hence, the MVaR of such a tranche is 100% of the tranche's principal. However, since the same loss does not affect the collateral of any tranche with an attachment point higher than the corporate bond MVaR, the MVaR of such a tranche is 0%. Finally, a tranche with attachment and detachment points that straddle the corporate bond MVaR has an MVaR that falls between these two extremes.

This analysis is visualised by the red line in Graph 3 (left-hand panel). This line shows that conditional losses of a tranche increase one for one with its detachment point as long as this point is lower than the corporate bond MVaR. In addition, conditional losses on a tranche do not change if the detachment point changes above the corporate bond MVaR (which marks the kink of the line). Thus, the MVaR of a CDO tranche (as a share of the tranche's principal) equals the difference between the heights of the line at the detachment and attachment points divided by the difference between the detachment and attachment points. This ratio is the "slope" of the particular line segment.

Relaxing the assumption that the CDO's underlying pool is perfectly granular reveals additional insights. Coarse granularity introduces idiosyncratic risk, which affects the MVaR of a tranche in a way that depends strongly on the seniority of this tranche (Graph 3, left-hand panel, green and blue lines). For example, the MVaR of a junior tranche, with detachment/attachment points A^j/D^j, decreases as a result of coarser granularity. In terms of the plot, coarser granularity depresses the slope of the line segment associated with this tranche. However, the opposite is true for a senior tranche, with detachment/attachment points A^s/D^s.

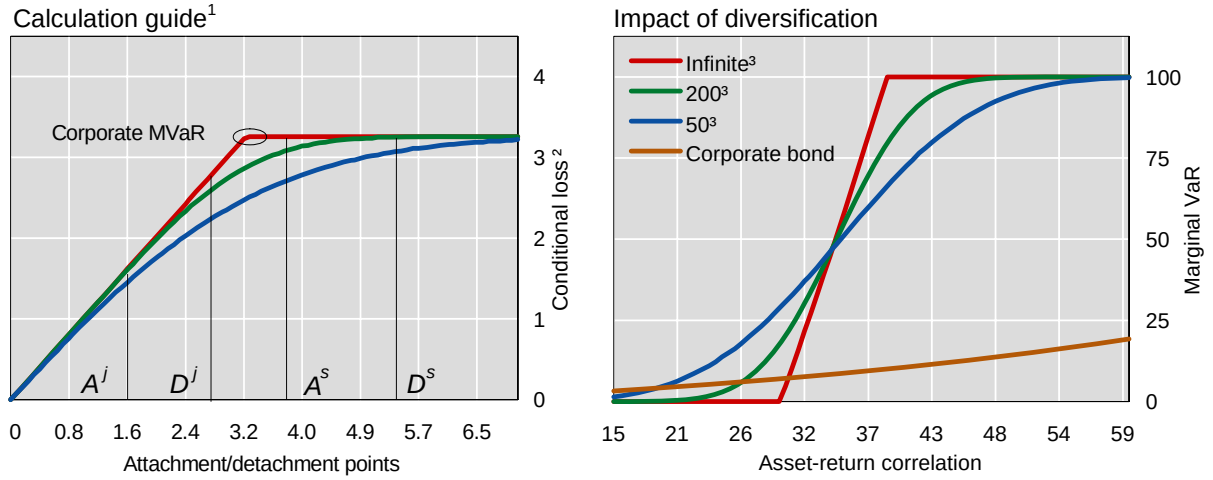
① For further detail on the main analytical results reported in this box, see Gordy (2003), who analyses portfolios of corporate exposures, and Gordy and Jones (2003), who conduct a similar analysis in the structured finance universe.

beneficial (ie loss-mitigating) and adverse (loss-enhancing) components of idiosyncratic (or asset-specific) risk in the underlying pool. The MVaR of a low-risk tranche, initially close to 0%, could be lowered only slightly by the beneficial component but would be raised substantially by the adverse component of idiosyncratic risk. Conversely, a high-risk tranche could only benefit from extra idiosyncratic risk and, thus, its MVaR decreases when granularity becomes coarser.

An important, albeit seemingly counterintuitive, implication of these results is that finer granularity in the underlying pool may render a CDO tranche more vulnerable to a change in credit fundamentals. This is illustrated by Graph 3 (right-hand panel), which focuses on a particular tranche and captures shocks to fundamentals via the level of asset-return correlations. When this level is relatively low (ie up to 30%), the tranche is a low-risk asset whose MVaR is lower than that of an underlying corporate bond if pool granularity is sufficiently fine. However, a small rise in correlations transforms the tranche into a high-risk security, whose MVaR is inflated by finer granularity. For example, if the underlying pool is perfectly granular (ie the number of underlying assets is infinite) and there is a 2 percentage point increase in correlations (from 29% to 31%), the MVaR of the tranche jumps from 0% to 15%, much above the MVaR of an underlying corporate bond.[19] Importantly, the increase in MVaR would have been much more muted, from 17% to 26%, under the coarser granularity implied by 200 assets in the underlying pool.

Marginal value-at-risk of a CDO tranche

In per cent



[1] The MVaR associated with a CDO tranche that has an attachment point *A* and a detachment point *D* equals the average slope of a line section delineated by points *A* and *D* on the horizontal axis. [2] Conditional loss is non-random only in the case of an infinite number of bonds in the CDO's underlying pool. In the other cases, the graph plots the expected value of this loss. [3] The number of homogeneous corporate bonds underlying a CDO contract. These bonds' credit risk parameters, which are shared by the corporate bond (the brown line), are reported in Table 1.

Source: Authors' calculations. Graph 3

[19] Greater asset-return correlation can be the result of stronger dependence of these returns on the common factor or higher volatility of this factor. Alternatively, greater asset-return correlation can surface when estimation errors are corrected for. Tarashev and Zhu (2008)

Conclusion

Recent, large-scale downgrades on structured finance CDOs are a reminder of the fact that rating transitions for structured finance products can be much more pronounced than what has historically been observed for more traditional credit instruments.

The preceding analysis suggests that at least two reasons can be put forward to explain such a pattern. First, the tranching process results in a non-linear relationship between the credit quality of underlying assets and that of tranched products. This can lead to a higher probability of rating downgrades as well as to more pronounced downgrades of CDO tranches than of corporate bonds. Second, ratings of tranched products are more sensitive to changes in the systematic risk factor than are ratings for corporate bonds. This implies that tranching will tend to leverage the cyclical deterioration of CDO credit quality relative to what is observed for underlying assets.

The same effect applies to other tranched instruments and is likely to be more pronounced for products that are themselves based on other tranched exposures (such as the structured finance CDOs reviewed above). In the current context, if ongoing adjustments in credit quality and related downgrades of collateral assets continue, further rapid rating migrations of CDO tranches (and, indeed, tranches of other securitisations) are to be expected.

A related observation is that measures of credit VaR can differ substantially across like-rated instruments, both with regard to levels and in terms of sensitivities to changes in credit fundamentals. As has been pointed out elsewhere, this implies that ratings are not an appropriate metric to fully capture and summarise the risks embodied in structured instruments. While this may be obvious for risk factors that are not covered by ratings (such as liquidity), investors need to appreciate that this also applies to default risk in that EL and PD do not give an indication of the higher moments of the loss distribution. These higher moments have important implications for rating transition behaviour and valuation, particularly for tranched instruments. Undue reliance on ratings, therefore, can lead to mispriced and mismanaged risk exposures as well as unfavourable market dynamics if these exposures have to be unwound.

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show that, given the limitation of data available in real-word situations, plausible small-sample errors in correlation estimates can be as high as 4 percentage points.

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Recent initiatives by the Basel-based committees and groups[1]

During the period under review, the Basel-based committees and groups continued ongoing work and undertook new initiatives in a number of areas in view of the recent financial market turmoil. In particular, the Financial Stability Forum (FSF) released an interim report on market and institutional resilience. In addition, the Committee on the Global Financial System (CGFS) published a collection of papers illustrating the ways in which the BIS international financial statistics are used, and the Markets Committee released a compendium on its member central banks' monetary policy frameworks and operations. Table 1 provides an overview of these and other developments.

Committee on the Global Financial System

CGFS publishes conference papers ...

On 19 December 2007, the CGFS published a paper entitled *Research on global financial stability: the use of BIS international financial statistics.* The BIS statistics on international bank lending, collected by central banks under the auspices of the Euro-currency Standing Committee at the BIS (the predecessor committee of the CGFS) starting in the late 1970s, have long been used to monitor risk exposures in the international financial system. For instance, these statistics provided clear and timely warnings about the scale and nature of external bank debt accumulation before almost all of the crises that hit the emerging markets from the early 1980s. As international financial intermediation has evolved over the years, the scope of these statistics has been gradually broadened beyond bank lending to cover debt securities, syndicated credit facilities, and derivatives. The consolidated banking statistics have been enhanced, allowing exposures to be monitored on an ultimate risk basis.

These statistics are being used increasingly in economic research on questions related to global financial stability. However, it had been clear for some time that different researchers using these statistics were not always aware of each other's work. The CGFS therefore decided to sponsor a

[1] This document provides an overview of major initiatives by Basel-based committees and groups during the period under review, and is not necessarily a comprehensive survey of such initiatives.

Initiatives by Basel-based committees and groups

Press releases and publications over the period under review

Body	Initiative	Thematic focus	Date
CGFS	*Research on global financial stability: the use of BIS international financial statistics*	• Purposes of and ways of using the BIS international financial statistics	December 2007
		• Call for papers for the second workshop on research on global financial stability	February 2007
Markets Committee	*Monetary policy frameworks and central bank market operations*	• Information on selected central banks' monetary policy decision-making bodies, policy implementation, market operations and monetary policy communication	December 2007
FSF	*Statement welcoming the hedge fund manager initiative on best practice standards*		January 2008
	Market and institutional resilience	• Interim report	February 2008

Source: Relevant bodies' websites (www.bis.org, www.fsforum.org). Table 1

workshop on research based on the BIS international financial statistics and to publish the results. The publication is a collection of the papers presented at the workshop, held in Basel in December 2006. The papers show the variety of purposes for which the statistics can be used: gauging the risks of crises in emerging markets; monitoring bank exposures at a country, regional or global level; assessing the components and determinants of such exposures; identifying the factors underlying cross-border investment; and tracking hedge fund activity and carry trades. One conclusion of the workshop discussions was that it would be useful to have regular meetings in future about the uses of the BIS statistics, for example every 18 months to two years, concentrating on particular themes. The second workshop is planned for December 2008, with the *call for papers* posted on the BIS website.

... on uses of the BIS international financial statistics

Markets Committee

One of the missions of the Markets Committee[2] is to offer central banks a forum for discussing the specifics of their own market operations. An important feature that has been constantly highlighted by the discussions is that central banks' decisions and actions are shaped by the frameworks in which they operate. While these monetary policy frameworks share a number of

[2] The Markets Committee comprises senior officials responsible for market operations at central banks of the G10 and some of the largest non-G10 economies. Formerly known as the Committee on Gold and Foreign Exchange, it was established in 1962 following the setting-up of the so-called Gold Pool. Subsequently, members continued to meet at the BIS for open and informal exchanges of views. Over the years, the focus of these discussions has shifted towards coverage of recent developments in financial markets, an exchange of views on possible future trends, and consideration of the short-run implications of particular current events for the functioning of these markets and central bank operations.

similarities across countries, there are also noticeable differences, in particular at the operational level. Monetary policy frameworks also evolve.

Markets Committee publishes compendium on monetary policy frameworks and market operations

To facilitate its discussions, the Markets Committee condensed the information on the monetary policy frameworks and market operations of its members into a single, easily accessible document. This *Compendium* – published on 17 December 2007 – includes information on four main aspects: monetary policy committees (or similar decision-making bodies); policy implementation; market operations; and monetary policy communication. The Committee believes that sharing such information with market participants and the public at large could also enhance market transparency and the understanding of central bank actions. The information will be regularly updated.

Financial Stability Forum

On 22 January, the FSF made a *statement* welcoming the Hedge Fund Working Group's issuance of best practice standards. According to the FSF Chairman, the report represents an important step towards improved disclosure practices and market discipline in this sector. As such, the standards can play a role in helping to enhance resilience and mitigate systemic risk.

FSF welcomes hedge fund best practice standards …

The initiative, together with the parallel work to develop best practices by a committee established by the US President's Working Group on Financial Markets, takes forward one of the recommendations that the FSF made in its *Update on highly leveraged institutions* in May 2007[3] and in the subsequent *progress report*,[4] namely that the global hedge fund industry should review and enhance existing sound practice benchmarks for hedge fund managers in the light of expectations for improved practices set out by the official and private sectors.

… and produces interim report on market and institutional resilience

The FSF's Working Group on Market and Institutional Resilience, which was set up in September 2007 to analyse the underlying causes of the recent market turbulence, identify weaknesses and develop recommendations, submitted an interim report to G7 Finance Ministers and Central Bank Governors on 9 February. The report examines current conditions in the financial system, reviews the adjustments that have taken place in markets, lists the underlying causes and weaknesses that the Group has identified so far as having contributed to the crisis, and sets out broad policy directions for strengthening the resilience of key elements of the financial system. The Group is developing specific recommendations for its final report in April.

The interim report noted that while conditions in money markets had eased since the autumn, markets had become increasingly worried about the impact of asset price declines and anticipated credit impairment on financial institutions' capital and lending capacity. The recovery of the financial sector

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[3] See "Recent initiatives by the Basel-based committees and groups", *BIS Quarterly Review*, September 2007, pp 95–101.

[4] See "Recent initiatives by the Basel-based committees and groups", *BIS Quarterly Review*, December 2007, pp 97–102.

would depend, at least in part, on greater market confidence in the creditworthiness and robustness of financial institutions and that the downside risks to economic activity had been contained. The policy directions proposed in the report relate to the following areas: supervisory frameworks and oversight; underpinnings of the originate-to-distribute model; the uses and role of credit ratings; market transparency; supervisory and regulatory responsiveness to risks; and authorities' ability to respond to crises.