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Example: Lehman Brothers

See (Brigo et al., 2012):

<http://arxiv.org/abs/0912.3028>, <http://arxiv.org/abs/0912.3031>,

<http://arxiv.org/abs/0912.4404>.

The collapse of Lehman Brothers is notorious, as it triggered the Crash of 2007/8 (recall MATL480, Problems/Solutions 1b Q3):

August 23, 2007: Lehman announces that it is going to shut one of its home-lending units (BNC Mortgage) and lay off 1,200 employees. The bank says it would take a \$ 52m charge to third-quarter earnings.

March 18, 2008: Lehman announces better than expected first-quarter results (but profits have more than halved).

June 9, 2008: Lehman confirms the booking of a \$ 2.8b loss and announces plans to raise \$ 6b in fresh capital by selling stock. Lehman shares lose more than 9 % in afternoon trade.

June 12, 2008: Lehman shakes up its management; its chief operating officer, president and chief financial officer are removed from their posts.

August 28, 2008: Lehman prepares to lay off 1,500 people. The Lehman executives have been knocking on doors all over the world seeking a capital infusion.

September 9, 2008: Lehman shares fall 45 %.

September 14, 2008: Lehman files for bankruptcy protection and moves towards liquidation, having failed to find a buyer.

Until the end, rating agencies (Standard and Poors, S&P, in this case) maintained a good rating for Lehman: see

[http://ww2.cfo.com.banking-capital-markets/2008/09/rating-itself-sp-defends-lehmans a/](http://ww2.cfo.com.banking-capital-markets/2008/09/rating-itself-sp-defends-lehmans-a/)

From published transition matrices, the \mathbb{P} -probability that an S&P A rated name defaults within a year is

$\mathbb{P}(\text{S \& P rated name defaults within 1y}) = 0$ in 2005/6/7, 0.38% in 2008.

Compare with the CDS market: the \mathbb{Q} -default probability in 1y is 21 % for Lehman. There is thus a *huge risk premium* – 0.38 % v. 21 % – between \mathbb{P} and \mathbb{Q} here. This is a regular feature: market-implied \mathbb{Q} -default probabilities are always larger than fundamental history-based ones under \mathbb{P} (I.2).

6. Corporate bonds; credit rating; credit scoring; toxic debt

Corporate bonds

The bond market splits, into two: *government bonds* ('gilts', in UK), regarded as free of default risk with major developed countries (UK, US etc.), though not for, say, third-world countries, and *corporate bonds*. Here the money is to be lent to a *company* (corporation, US), and companies can default – companies can go bankrupt, and disappear (countries cannot ...). So investors considering buying a corporate bond will, naturally, want to know as much as possible about the company's *credit-worthiness*.

In the past, it was only big established firms that could raise capital by issuing their own bonds. Smaller or less-established firms thereby felt excluded (unable to raise capital, and so unable to expand, re-equip etc.) This unsatisfied demand created a potential market. 'Nature abhors a vacuum', and this market was eventually created.

Junk bonds

This term was introduced in the USA in the 1980s, for high-risk, high-yield bonds issued by companies that would not previously have been able to raise capital in this way (see above). The driving force behind them was the "junk-bond king", the financier Michael Milken (1946-). Convicted in 1989 and serving two years in prison, he was the inspiration behind the part played by Michael Douglas in the 1987 film *Wall Street*, Gordon Gekko (a suitably reptilian name – a gekko is a kind of lizard).

Junk bonds were regarded as a boon by companies newly enabled to issue them (and Milken as a hero). They were much used as securities used to leverage (finance on borrowed money) hostile takeovers ('buyouts', US) in the 1980s. The term is used nowadays for bonds rated BB or lower (see below).

Credit rating

Investors find it convenient to have some 'third-party' assessment of the credit-worthiness of a firm whose bonds they are considering purchasing. These are typically given in letter-grade terms modelled on student grades: AAA (triple A), AA, A, B, BB, ..., and the analogy with student grades is

apt. With classified degrees, as in the UK now (probably not indefinitely: this may be replaced by the American system of use of transcripts), the university puts its reputation behind the degree class. This spares an employer having to use time (scarce) and judgement (of the perhaps too unfamiliar) to form his own assessment, based on applicant-supplied information.

A number of firms began to specialise in providing such ratings; this role was recognised in 1975 by the SEC (Securities and Exchange Commission). The main three today are Standard & Poor's (S&P, as with the index), Moody's and Fitch.

We have seen in the Lehman example that the ratings agencies did not pick up the dramatic slide of Lehman towards insolvency. Their credit ratings for Lehman, which remained good, increasingly departed from reality.

This raises the question of *conflict of interest*. Firms *pay* the agencies to carry out their credit rating. The agency thus acquires an interest (perhaps unconscious) in keeping the firm's business by giving or keeping a good grade.

One of the predisposing factors behind the Crash, and one of the main reasons why it took the world by surprise, was the maintenance of good grades by increasingly unsound companies. Recall HMQ's famous question to academia (at the LSE; taken up by the Fellows of the British Academy): "Why weren't we warned?" See "Read this" on the MATL480 link on my homepage. The basic problem of conflict of interest remains unresolved, but public confidence in credit ratings has never recovered.

Credit scoring

Banks make their money by lending to customers (individual or corporate) at a higher rate of interest than they pay to their customers' savings accounts. When a firm, or a person, asks for a loan, the bank will need to assess their credit-worthiness. There may well be an established relationship with the firm or person, in which case their track record is there for the bank, and will be the main basis for judgement. Without such a track record (and, for safety's sake, even with), the bank will ask the applicant to supply a lot of background information to help it make its decision. Thus a person or couple might be asked for such things as:

age; marital/family status; health record; employment status and record; income; home-ownership status (and value of home if owned), etc.

These things are called *covariates* in statistical language: they vary, with (= co, from cum = with, Latin) – are relevant to – the question of loan-

worthiness.

There is an entire area of Statistics concerned with such covariates – Regression, and the Linear Model (NHB, SMF, IV). It turns out that what is needed here is an extension of this, to Generalised Linear Models (GLMs). The connection was first made in 1972 by Cox (Professor Sir David (D. R.) Cox FRS (1924-), then Professor of Statistics at Imperial College London) in his *proportional hazards model* in Survival Analysis, the area relevant to life insurance. The analogy between death and default is clear, and so proportional hazards became widely used by banks in assigning *credit scores* to loan applicants. This is a thriving and important area; the leading expert is Professor David (D. J.) Hand FBA (1950-), formerly also Professor of Statistics at Imperial.

Toxic debt

This very expressive phrase was coined by a journalist during the Crash of 2007/08, to explain why and how the Crash had happened.

Many of the CDOs that banks and finance houses owned were based on assets in the sub-prime mortgage area. When the sub-prime bubble burst, the value of vast holdings of CDOs burst with it – with devastating consequences: the Crash. In the words of Warren Buffett (the world’s most famous investor, the ‘Sage of Omaha’): ‘When the tide goes out, you see who’s been swimming naked’.

It rapidly transpired that the boards of the big banks involved had no proper appreciation of the dangers (sketched above) that they had been running. They wanted to know what their CDOs and other such assets were worth – and no one could tell them. It was a great shock to banks to realise that they had no idea what their assets were worth – a historically new situation. Worse: they realised that – as other institutions had been responding to the same supposed opportunities – other banks didn’t know what their own assets were worth either. The result was a sudden collapse in the confidence of banks *in both themselves and other banks*. The result was that banks abruptly stopped lending – even (or perhaps, particularly) *to each other*. Now inter-bank lending is one of the things that provides the liquidity that keeps the wheels of finance turning. When this was withdrawn, the wheels stopped turning – as with an engine deprived of adequate lubrication.

Collateralised debt obligations (CDOs)

A CDO is a structured financial product that pools together cash-flow-generating assets (mortgages, bonds, loans etc.), and repackages this asset pool into discrete *tranches*, that can be sold to investors. The senior tranches have priority – get repaid first – in case of default; they thus have higher credit ratings, but offer lower coupon rates. Conversely, the junior tranches have lower credit ratings, but offer higher coupon rates to compensate for this.

CDOs split, into *mortgage-backed securities (MBS)*, and *asset-backed securities (ABS)*. The underlying process is called *securitization*.

Securitization

Securitization is the name given to the search in recent decades for new opportunities for profit, based on identifying risks that people or firms will want protection from (or insurance against). Of course, taking risks is risky: it could go wrong. But, ‘nothing venture, nothing win’: businesses know that they cannot make profits without engaging in market activity, and this is risky. Business (at least in some sectors – investment banking, for example) has an appetite for risk, for this reason. As a result, there are now all kinds of (fairly) new derivatives:

weather derivatives;
catastrophe derivatives (‘cat bonds’);
volatility derivatives (VIX index), etc.

As background here: catastrophes such as major US hurricanes were one of the triggers of the Lloyds scandal. So too were asbestos claims: asbestos was widely used in the construction industry (because it is an excellent thermal insulator, so was used for fire-proofing); it was not then realised that it is highly carcinogenic – inhalation of asbestos fibres can cause cancers (of the lung and throat, etc.).

When large numbers of large claims were made against participants in Lloyds, it emerged that risks had been laid off, and then laid off again, repeatedly, resulting in long chains of inter-dependence, sometimes doubling back on themselves. The result was obviously highly unstable, and when the collapse came, many names (individual participants) were driven into bankruptcy, as were some syndicates. At the lower levels, there was clearly a lack on any adequate ‘big picture’. At the higher levels, there was obviously a lack of proper oversight (within Lloyds), and regulation (outside it).

7. Concluding remarks

Sub-prime mortgages

A generation or so ago, home ownership was largely only accessible to the fairly affluent: most people rented. (This situation is returning now, particularly in SE England, where house prices are notoriously high, but leave that to one side here.) This held both in the UK and the US. That changed in the UK in the 1980s (Thatcher: council house sales), and in the US in the 1990s. As with credit scoring and credit rating, applicants for mortgages were assessed for credit-worthiness (or affordability, to them, of the sum they wished to borrow); those not judged well enough able to repay – those less affluent – were unsuccessful and disappointed. This applied to very large numbers of Americans. This large and unsatisfied demand had two effects:

- (i) It led banks to identify a new and exploitable, and potentially profitable, market. This was no doubt influenced by Milken and junk bonds (Milken became extremely rich, before his criminal conviction).
- (ii) It led the US Government (Clinton's two terms, 1992-2000) to look favourably on moving to satisfy this demand. This was partly for good humanitarian reasons – spreading the blessings of affluence more widely – and partly in the hope of reaping a political reward from the grateful parts of the electorate.

A modest move in this direction might have worked. But once this movement started, it created a 'bandwagon effect'. Sub-prime mortgages became 'flavour of the month' in large parts of the US business/banking/investment community. They were extended to many applicants who clearly had no hope of repaying, on clearly unsuitable properties (examples on the Internet). The result was a house-price bubble in the US. Bubbles burst. When this bubble burst, it triggered the Crash.

Globalization

This term has come into general use to describe the increasing interconnectedness of the planet, its people and its economies, since the 1980s. Driving forces include:

- (i) The collapse of the USSR in 1989-91, and of most of the Communist world thereafter, leading (until the emergence of China to challenge the US) of a unipolar world, with one super-power, the USA.

(ii) The conviction among the prevailing consensus post-1980 (Thatcher, Reagan; Milton Friedman, the intellectual underpinning of much of this; Greenspan; the philosopher Ayn Rand (a friend of Greenspan, and an impassioned advocate of unbridled self-interest); the ‘Chicago Boys’ (followers of Friedman in Economics, who now dominate academic Economics Departments)) that ‘their way is the right way/the only way’ (TINA – There is no alternative: Thatcher; cf. ‘There is no such thing as society’: Thatcher). (Again, compare: ‘Government isn’t the solution – government is the problem’, Reagan.) This was much enhanced by the fall of Communism in 1991: “We won the Cold War”.

(iii) The move towards deregulation (e.g., the Big Bang in the City of London in 1986, by which Thatcher abolished the old division between brokers (who negotiated deals) and jobbers (who executed them). This has led to economies, but also to conflicts of interest (‘Chinese Walls’ within firms, which are not as water-tight as they need to be ...).

(iv) The Internet, and the World-Wide Web. This has greatly increased the ease of financial transactions at world level. It has also led to the risk of tidal waves of ‘hot money’ slopping round the world and destabilising economies. Again, it has also made it much easier to hide money off-shore, used for tax avoidance/evasion, but also by criminals and terrorists.

Globalization has made the rich richer, and left the poor behind. The resulting political resentments have had effects such as Brexit (below) and Trump. Its most prominent advocates gather regularly for the Global Economic Forum, which meets at the Swiss resort of Davos.

To return to *interest rates*: globalization has made it easier to transfer money from one currency area to another, and so increased the importance of FX markets.

Regulation

Although it may be easy to ‘be wise with the benefit of (a decade’s worth) of hindsight’, there is nothing at all deep in the above, and (one might think) nothing that should have surprised any competent professional in the area at the time. The fact that the top management of the top financial institutions were as surprised by all this as ordinary members of the public came as a shock to everyone.

Banks – ‘Wall Street’ – serve a necessary role in providing the finance that keeps the wheels of the economy – ‘Main Street’ – turning. When banks fail

so publicly and so badly, it is clearly necessary for the health of the nation's economy for government to step in – to act as lender of last resort (e.g., for the big US institutions *other* than Lehman who were in need, including the Big Three motor manufacturers, Ford, General Motors (GM) and Chrysler), and to impose minimum standards of proper procedures so as to avoid this happening again. This is the *Troubled Asset Recovery Program (TARP)*.

In the US, the Federal Reserve (Fed) and SEC play this role. The Fed was chaired by Alan Greenspan (1926-) for five terms (1987-2006), under four presidents (Reagan, Bush Sr, Clinton, Bush Jr). He presided over the long asset-price bubble that burst in the Crash; in particular, over the sub-prime mortgage expansion (or explosion, perhaps). During his term of office, he was 'the world's favourite central banker'. His reputation has not survived the Crash and its aftermath well. He was succeeded by Ben Bernanke (1953-); two terms, 2006-14 (Bush Jr and Obama). Perhaps fortunately, Bernanke's doctoral thesis was on the USA's recovery from the Wall Street Crash and the Slump that followed it. Janet Yellen (1946-) served one term (2014-18), under Obama and Trump. She had the delicate task of trying to judge when and how the Fed could move towards more historically normal *interest rates*. She was succeeded (2 Feb 2018) by Jerome Powell (1953-).

The present extremely low interest rates (in the US, as here) resemble a life-support machine. If one takes a patient off this too soon, it may kill him. If one leaves him on it indefinitely, it prolongs his life, but in a 'permanently vegetative state'. This analogy is used here to make quite clear what the issues are, in what might otherwise seem a rather arcane debate, best left to experts.

One dramatic illustration of the need for regulation came right at the beginning of this course: the LIBOR/Lie-bor scandal, involving the big London banks. There have been a number of others – mis-selling scandals, PPI (payment protection insurance), etc. Very recently, there has been a high-profile case between the US Government and Deutsche Bank, in which Deutsche has admitted blame and is trying to negotiate downwards a fine of billions. Note that Deutsche is Germany's biggest bank, and Germany is the leading EU nation (even before the UK's exit: Germany is still a major manufacturing nation, as the UK was from the Industrial Revolution to Thatcher and is no longer). It is frightening that such a big, important and apparently reputable bank, based in such a big and important country, cannot be trusted to behave itself. The moral is clear: regulation, backed by legal sanction, is essential.

Conflict of interest

We have touched on several conflicts of interest above: the credit-rating agencies, who have a financial interest in keeping their customers happy with (perhaps unrealistically good) credit ratings; the post-Big Bang City of London, when Chinese Walls designed to mimic the old separation of tasks between jobbers and brokers do not work; you may be able to suggest others.

Greece, the euro and Goldman Sachs.

The euro was introduced in 2000. Its motivation was political: the then Chancellor of Germany, Helmut Kohl, feared that Germany's evident pre-eminence in Europe (obvious today, and no problem, in my view) might lead to a re-emergence of the 'German problem' (the fear Germany could perhaps still inspire in Europe, based on WWI, WWII and the Nazi past). His solution was to 'dissolve Germany within Europe', and this was the driving force behind the euro.

The economies of the eurozone are too diverse to live comfortably together with *one* currency, and **one interest rate**. The stresses will increase with time, like the movements of tectonic plates that trigger earthquakes. The UK stayed out of the eurozone (rightly in my view), thanks to the then Chancellor (of the Exchequer), Gordon Brown, and his colleague Ed Balls. The euro is doomed in the long run on these grounds alone, in my view. Moral: do not try to achieve a *political* aim (preventing the re-emergence of a 'German problem') by *economic* means (the euro).

Greece entered the euro zone, despite its being even less suited to euro membership than the UK. The results have been disastrous for Greece. The word Grexit was coined for the possibility of Greece leaving the eurozone (though not perhaps the EU) long before Brexit.

Greek entry was facilitated by Goldman Sachs. It is an open secret that the Greek case for entry was essentially dishonest and fraudulent, and that Germany and the EU 'looked the other way'.

Goldman Sachs remains a major player on the US (and so the world) financial stage. It facilitated the disaster of Greek entry – for the money it received, in fees. Others pick up the bill. As far as I am aware, this matter is not subject to regulatory investigation. This underlines the difficulty of achieving effective and timely regulation.

QE and its costs

In addition to extremely low interest rates, the other main measure used by governments (US and UK) has been quantitative easing (QE) – essentially, the creation of electronic money, to recharge the banks’ balance sheets and enable/encourage them (some form of coercion may be needed ...) to perform their main task – *lending*. This has not worked well. Banks have simply sat on the money, rather than lending it, so business continues to be starved of funds. Further, with interest rates so low, the inducement to save – put money in the bank – has never been so low, or for so long. So, those with funds to spare have done the only other obvious thing with them – *bought assets*. This has had two effects:

(i) By increasing the demand for shares, it has sent share prices up. The Footsie has reached record levels. This does *not* mean – as it would have done pre-Crash – that the economy is booming, and being successful – it isn’t. It simply reflects the ongoing abnormality of very low interest rates over an extended period.

(ii) It has widened inequality, and reduced social mobility. For, those with money to invest in shares are the already affluent – and these have made windfall profits as their shares have gone up. This has widened the gap with the non-affluent, thereby exacerbating political tensions. The resulting political pressures are one of the main causes of the 2016 Brexit vote, for example.

Bankers and Brexit

We close with an example of the Law of Unintended Consequences. Bankers have come in for a great deal of criticism since the Crash, much of it justified. This has been an extremely uncomfortable experience for them. Crash-induced pressures have now led (or are now leading) to Brexit. London-based banks are loudly making plans to relocate some/all of their operations so as to stay within the EU (whose main financial centres are Paris and Frankfurt). This would cost the UK Government tax revenue, and hit London particularly hard. The UK Government, and the Mayor of London are both (from opposite parties) launching a ‘charm offensive’ to try to persuade banks to stay here. It’s an ill wind that blows no one any good, as the wise English saying has it.

The trader's view

The amount of trading in the financial services industry in general, and in the bond markets in particular, is enormous. This course (like this MSc in general) is aimed at *quants* (quantitative analysts), and focuses on theory, plus computing and numerics for implementation. In addition, there is the *analysis* side: those who understand the world in general, the ‘big picture’ that drives everything, including markets, are at a premium — they can *predict* market movements, and so advise clients. There is also the *back-office* side: implementing transactions, and making sure that payments are properly made. And there is the *trading* side. Many academics in mathematical finance have also been *practitioners* in the financial services industry (including, for example, my friends Rüdiger Kiesel, my co-author of Bingham & Kiesel, [BK], and Damiano Brigo, co-author of the course text Brigo & Mercurio [BM] and my colleague and Head of Section in the Mathematics Department at Imperial College London. Ex-practitioners know the way traders think (and indeed, know traders, and can consult them).

I am a straight mathematician, and have never worked in the industry (or outside a university). But, I am now related by marriage to a bond trader, and met him socially at a family celebration recently. I mentioned that I have taught mathematical finance for decades, and now teach interest-rate theory, and asked him for any comments or advice. He smiled, and said that the bond-market trader's view could be summarised in three words: *price*, *yield*, *spread*. The *price* of a bond (MATL481) is as important as the price of an option (MATL480), and that of the things you and I buy every day. The *yield* curve is what MATL481 specifically is about. The *spread* is the gap between prices: the bid-ask spread (the difference between buying and selling: in a bureau de change for foreign currency, in wholesale v retail, etc.), the difference that a government with a clean record on default and a stable currency, economy and political system will have to pay to raise money, compared to one without these, the difference between interest rates with and without credit risk taken into account, etc. The interplay between these three things is what drives trades. What lies behind these three things, and their interactions, is what drives the financial services industry, and lies behind this course, and this MSc.

Postscript

Interest rates form a very important subject in practice, as we have seen. There are vast sums of money involved – trillions. So even small improvements can reap rich rewards – and by the same token, even small failures of performance can result in large losses. This is major-league stuff!

The theory is mathematically very interesting. This course, MATL481, follows on very naturally from its predecessor, MATL480 last semester – which we have had many occasions to use, throughout. And the subject is far too important not to teach in an MSc on financial mathematics. It is, perhaps, somewhat harder than MATL480, if only because it may be conceptually unfamiliar – I don't suppose any of you has prior experience of the interest-rate world – and has rather a lot of new terminology. This is a pity, but is a fact of life (think of starting a new language from scratch! – it's just the same with starting a new subject).

The world of interest rates has changed dramatically, twice, in the last twenty years. The first change was the introduction of *market models* in 1997 – the subject of our longest chapter (V), and the core of the course. (The progress of a new area from nothing to dominating a field as important as this so quickly is unusual in a mathematical subject.) The second was the Crash of 2007/08, and its consequences. These include negative interest rates actually happening (unheard of before), Bank rate at a fraction of a percent for a decade, etc. This course prepares you to engage with all this.

This course – like the course text, [BM] – goes further into market models than most. As this is where the action is for practitioners, this may give you some competitive advantage if you seek to use this in the financial services industry – which may give you some encouragement when learning this material (and some compensation for all your hard work ...).

Calibration of models to data, and handling the vast amounts of data involved, require good computing and general IT skills. Lose no opportunity to develop these!

Because banks and finance houses already have operations in place to do all the tasks necessary for the various things we have described, and because the up-front investment is so large – in staff training, software, hardware etc. — they tend to be reluctant to change. Be prepared to be patient — and to learn new computer languages (e.g. $C\#$, in addition to $C/C++$, which you should already know). Change does come, if competitors are doing things better ... Good luck! NHB