Institution: King's College London

Unit of Assessment: Department of Mathematics

Title of case study: Credit risk modelling

1. Summary of the impact (indicative maximum 100 words)

Research of Professor Brigo in the areas of credit risk, pricing models for the valuation of counterparty risk, and the development of accurate calibration methods of various credit risk models has generated significant impact both on public policy and on practitioners and professional services. His models were implemented and his calibration methods adopted in the financial industry. The significance attached to his work by the industry also resulted in a collaboration with the German regulator (BAFIN). Further evidence of his impact can be found in the fact that a Court of Law based its analysis in a financial intermediation case on Brigo's research.

2. Underpinning research (indicative maximum 500 words)

Professor Brigo has been applying credit risk and pricing models to the valuation of counterparty credit risk, the so-called Credit Valuation Adjustment (CVA). This describes the modification in the price of a financial product due to the fact that a counterparty may default. CVA can be conceptualised as an option on a complex portfolio with a random maturity given by default time. Its valuation requires sophisticated hybrid models that need to be calibrated as accurately as possible to liquid market data. Prior to Prof. Brigo's research, CVA would be estimated through actuarial or basic statistical techniques, building on the apparatus for risk measurement. Since risk measurement is typically much less precise than pricing, such techniques were inadequate. The novel approach proposed by Brigo instead used the methodology of risk neutral valuation to study CVA. This allowed to model the possible statistical dependence between market risk and credit risk. As time evolved, new types of valuation adjustments emerged, including debit and funding adjustments, and the challenge has shifted in modelling all such risks consistently. Emphasis has been on the proper and precise calibration of dynamical models of different nature to market data, analysing both models in the reduced form framework and models in the firm value area.

In particular, one of his papers considered the calibration of firm value models introduced by Brigo et al. (see [1] in Section 3) to Lehman's Brothers' Credit Default Swap (CDS) data. Firm value models allow for an economic interpretation of default in terms of a default barrier, representing safety covenants. Typically, such models do not exhibit enough flexibility to calibrate the CDS data with precision, and are rarely used in the pricing and hedging arena for counterparty credit risk. However, in this paper Brigo and co-authors showed that this is not necessarily the case, since firm value models can be extended to curved barrier models that are fully analytically tractable and lead to robust and precise calibration of market CDS data. The analysis of the calibration of such models along Lehman's history, up to the default points, illustrated the economic information which could be extracted from the CDS market on the default dynamics of Lehman Brothers. Prior to Brigo's work, it was not known how to precisely calibrate firm value models to CDS data.

This kind of research has been part of the strategy of the financial mathematics group at King's College to close the gap between academic research in financial modelling and industry applications. Prof. Brigo took on the challenge at the level of counterparty credit, funding and liquidity risk, whereas other colleagues such as Dr Di Matteo engaged in collaborations with regulators (e.g. FSA) and asset managers such as Winton Capital.

Key researchers

- Professor Damiano Brigo
  - King's College London, 07/2010 – 09/2012
    as Gilbart Professor and Head of the Financial Mathematics group
- Dr Andrea Pallavicini
  - Head of Financial Engineering, Banca Leonardo, 2007-2011
  - Head of Equity, FX and Commodities models, Banca IMI, since 2011
- Dr Massimo Morini
  - Head of Credit Models, Banca IMI, since 2007.
- Marco Tarenghi
  - Banca Leonardo, 2008-2011
  - Mediobanca, since 2011

3. References to the research (indicative maximum of six references)

1. D. Brigo, M. Morini, M. Tarenghi, Credit calibration with structural models and equity return swap valuation under counterparty risk. In: Bielecki, Brigo and Patras (Editors), *Credit Risk Frontiers: Subprime crisis, Pricing and Hedging, CVA, MBS, Ratings and Liquidity*, Wiley/Bloomberg Press, 457-484, 2011. DOI: 10.1002/9781118531839.ch14.

2. D. Brigo, A. Capponi, A. Pallavicini, Arbitrage-free bilateral counterparty risk valuation under collateralization and application to Credit Default Swaps. *Mathematical Finance,* 2012. DOI: 10.1111/j.1467-9965.2012.00520.x.

3. D. Brigo, M.Morini, No-armageddon measure for arbitrage-free pricing of index options in a credit crisis. *Mathematical Finance*, 21, 573-593, 2011. DOI: 10.1111/j.1467-9965.2010.00444.x.

4. Details of the impact (indicative maximum 750 words)

In recent years, Damiano Brigo has been working on the formulation of accurate pricing models for the valuation of counterparty risk in an arbitrage free framework. Because of the practical relevance of this work, it generated substantial impact of various types, including impact on practitioners and professional services, and economic impact. Impact has been realised along three different dimensions as described below.

First and foremost, the significance and relevance of Brigo's research for the financial industry is shown by the fact that many of the counterparty risk models and techniques, introduced by him, are nowadays implemented in banks and related institutes. However, given the relative secrecy of the front office environments in banks, it is hard to document this in writing. Nevertheless, a few cases can be testified to by a former colleague (see Section 5).

A second dimension of Brigo's influence relates to his impact on public policy and services. This is demonstrated by the fact that he co-authored a report (see article [A] in Section 5), together with a regulator for the German Federal Financial Supervisory Authority (BAFIN), who is also a representative at the Basel III panel. This report was published in the official Bundesbank discussion paper series, which testifies to the significance attached by the Bundesbank to the findings of this

paper. Another report in a working paper series of a similar calibre has been published by the Bank of International Settlements (BIS) as a response to the consultative document "Fundamental review of the trading book" issued by BIS earlier on, see article [B] in Section 5.

Moreover, Brigo's research on the calibration of structural first-passage stochastic models to credit default swap data and the related application to Lehman Brothers' data, has had impact on public policy in the form of a verdict by an Italian Court of Law. In 2011, the court in Novara, Italy, retried a case of financial intermediation after the spectacular bankruptcy of Lehman Brothers Holdings Inc in September 2008. The court based its analysis on research of Brigo. In particular, the reasons for the judgement explicitly refer to Brigo's research article on credit calibration, which was an online published preprint version of article [1] in Section 3. The relevant part of the sentence translates as

> "... in a recent study two different mathematical models (AT1P and SBTV) have been applied to the CDS trend of Lehman, and this shows that, despite a worsening of the estimate, even from a mathematical point of view, based on the CDS patterns, the survival probability of Lehman, even near the default event, was still high."

Third, not in small part because of the fact that Brigo's models are implemented in banks, he has received numerous and regular invitations as plenary speaker to key industry events, as participant of round tables and as teacher of master-classes at major industry conferences. These master-classes are very specialized, and participation is expensive. Attendance is typically in the range 10 - 20, with participants attending to learn first hand about theory related to models implemented at their employers' institutions.

Although Brigo's research led to publications in leading academic journals, he has also been working on the application of his ideas in the financial industry. Relevant results have been published and discussed in the top industry magazines with the highest impact on practitioners and professional services (see Section 5). Brigo's reputation in the financial industry is further underlined by a variety of interviews in relevant newspapers and by his award as the most cited author in Risk Magazine 2010, one of the most influential industry magazines in the area of financial risk.

To put publications in industry magazines, and invitations to industry events into proper perspective, one should bear in mind that nowadays the interests of practitioners from the financial industry and academics working on financial mathematics diverge significantly. Hence, active involvements of academics in industry discussions are very rare. Indeed, Brigo is one of only a few examples of mathematicians whose expertise is not only highly rated in academia but also much sought after in the financial industry.

5. Sources to corroborate the impact (indicative maximum of 10 references)

In order not to exceed the maximum, the following list is very much restricted to a few references. Further details can be provided on request.

Publications in research paper series of central banks and regulators:

A. C. Albanese, D. Brigo, F. Oertel, Restructuring counterparty credit risk, Deutsche Bundesbank Discussion Paper 14/2013.

Affiliations of Oertel (BaFin) and Brigo in this article are new affiliations at time of printing rather than of submission. (corroborating document available on request)

B. D. Brigo, C. Nordio, Comments received on the consultative document "Fundamental review of the trading book", Bank for International Settlements, 2010. Document available on request; published at: http://www.bis.org/publ/bcbs219/cacomments.htm
Link to KCL-mirror of Bank for International Settlements 2010 Comments page.

Testimonial on Brigo's impact on practitioners and professional services:

- Head of Credit Models in Banca IMI (testimonial received and available on request).

Awards

- Most cited author in Risk Magazine (corroborating document available on request)

Evidence of influence in the financial industry (examples available on request):

- Invited (plenary) speaker at various industry events
- Teaching numerous training courses for practitioners
- Several invitations to round tables

Newspaper interviews and articles:

- Has Basel got its numbers wrong? Interview with Prof. Brigo, *The Banker*, 21/06/2011 (article available on request). The Banker is the Financial Times monthly international financial affairs publication and it is read in 150 countries around the world.
- The risk-free myth, profile interview with Prof. Brigo, *Risk Magazine*, March 2011 (article available on request).

Court sentence:

- Document (in Italian) available on request; relevant citation is on page 17.