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Third Quarter, 2009

Wall Street's Meltdown

"If it was so big, how come nobody saw it coming?"

Queen Elizabeth, visiting the London School of Economics, November 2008

". . . it really showed how different the real world was from our models."

Professor Stephen Figlewski, Stern School of Business, New York University

$$Pr[T_a<1,T_b<1]=\Phi_2(\Phi^{-1}(F_a(1)),\Phi^{-1}(F_b(1)),y)$$

Gaussian Copula Default Function Formula, used extensively on Wall Street 2000 - 2008

Last year's crisis appears to have subsided. The financial system is regaining its footing, the economy is recovering and the mood among investors of all stripes is much improved. A disaster of monstrous proportions was narrowly averted and Wall Street seems to be breathing a collective, if premature, sigh of relief.

After any harrowing event, it is always a good idea to look back and examine what happened and why. Even if it is some time before we are completely out of the woods, there are still lessons to be learned. And there is no better teacher than experience.

Some observers point to Congressional legislation in the 1970s that forced banks to change their mortgage lending practices. Others blame structural faults within the government sponsored entities that support residential mortgage lending (i.e., "Fannie Mae" and "Freddie Mac"). And still others note that over the last 125 years or so, financial crises on Wall Street seem to occur with depressing regularity.

Without a doubt, a number of elements contributed to the meltdown. However, it does appear that a significant factor underlying the crisis was Wall Street's quick adoption and exuberant use of a formula that originated in the world of actuarial science.

The Gaussian Copula Default Function Formula

The formula shown at the top of this page was created by David X. Li, a Chinese national who traveled to Canada in 1987 with a group of fellow statisticians to take business courses at Laval University in Quebec. Over the ensuing years, Li concentrated on actuarial science, earning two master's degrees and a doctorate in statistics before landing on Wall Street in 1997.

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Actuarial science is the study of statistics involving life and death, and actuaries use statistical methods to assess risk. For example, actuaries in the insurance industry construct models to develop life expectancy tables for specific population groups. The price of risk, or the insurance premium, can then be determined.

In the late 1990s, some of Li's colleagues in academia were working on a way to predict the "broken heart syndrome," a long-observed phenomenon in which the surviving spouse tends to die at faster than expected rates following a spouse's death. Life insurance companies were quite interested in developing a way of predicting this risk.

At the same time, investment banks on Wall Street were extending the concept of collateralized debt obligations, or "CDOs." The first CDO was issued in 1987 by Drexel Burnham Lambert and at that time, CDOs were comprised of various types of assets such as credit card debt, car loans, mortgage and subprime mortgage debt as well as corporate bonds. By the late 1990s, Wall Street was considering pooling corporate bonds together into a CDO and then selling separate slices, or "tranches," from the pool. The hard part was figuring out how to price each slice.

Li realized that the problems his friends in academia and his colleagues on Wall Street were working on were very similar. The risk of a surviving spouse's death was similar to the risk of a bond defaulting in a pool of bonds after a first bond had defaulted. He thought of using copulas, mathematical functions which plot the interdependence of variables, to predict default rates and hence prices. He published his ideas in *The Journal of Fixed Income* in 2000.

Wall Street was enchanted. At the time, Li's work was described as a watershed event. Copulas became the "new thing" -- a wildly popular, simple but elegant solution to a tricky financial conundrum. Many investment houses built their own computer models based on Li's ideas and the most widely used copula became known as the Gaussian Copula Default Function Formula. "Gaussian" is after the 19th century German statistician Carl Friedrich Gauss. The normal distribution of a bell curve is also known as a "Gaussian Distribution."

By 2003, Li was the toast of Wall Street. He had become director and global head of derivatives research at Citigroup and, later that year at the annual "Quant Congress," he ran through his ideas and formula in front of a packed room. One attendee recalled that "the presentation was a riot of equations, mathematical lemmas, arching curves and matrices of numbers."

CDOs evolved from securities with their inherent risk spread out among different types of assets, to securities based on only one asset class, to "synthetic CDOs" with no real underlying assets. Because of the attractive risk-return tradeoff, CDOs built entirely out of subprime mortgage debt became the rage. With the formula, computerized models and innovative off-balance sheet financing, Wall Street was able to turn high-risk subprime mortgages into triple-A-rated securities -- a rating reserved for the best of the best.

<u>"This Time It's Different"</u>

During the early 2000s, interest rates were at historically low levels. The lower quality rated, and therefore riskier, tranches of CDOs paid out higher rates of interest-- an enticing trade-off for banks, institutional investors, hedge funds and others reaching for yield. Because debt was cheap, speculators stampeded into real estate, driving up home prices. In less than five years, nationwide housing prices increased 100%.

The market for CDOs exploded, growing from tens of billions of dollars in 2000 to an estimated two trillion by 2007. It was a very attractive and lucrative market for all participants. A growing economy as well as constantly increasing home prices across the nation seemed to validate the entire concept. In addition, it was widely believed that diversified financial markets meant that asset bubbles were unlikely and that if they did occur, the consequences would certainly be less severe than in the past.

With the growth of the CDO market, a shadow banking system developed, consisting of investment banks, hedge funds, private equity funds and other participants. The system was outside the reach of government regulators and, more importantly, it was invisible, even to its participants, because of the widespread use of Wall Street's clever off-balance sheet architecture to house the securities. Eventually, this shadow banking system became larger than the nation's core, regulated banking system.

The CDO market's growth was explosive for another reason -- the trend of globalization. Just as economies around the world had become more dependent on each other, financing around the world had become more interconnected. In the past, financing was generally limited to local markets by local banks. Any financing obtained from U.S. banks was seen as a stabilizing counterweight to local and regional developments.

But this time, CDOs were sold around the world, bought by foreign banks, institutional investors, pension funds and others. When the financial crisis hit, the CDOs obtained with financing from the U.S. turned out to be anything but stabilizing.

By late 2006, mortgage default rates had started to swell and by mid-2007, homeowners across the country were defaulting on their mortgages. The CDO market was unraveling but Wall Street was not alarmed. Their computerized models indicated that everything was fine, or at least still within the normal range of expectations.

The collapse of Bear Stearns in March 2008 was the first shock. The Wall Street investment firm had pioneered the use of asset-backed securities and was heavily exposed to subprime mortgages. As the financial crisis developed, it became increasingly clear that something was very wrong. Wall Street's models were not adequately capturing what was happening in the real world.

In the fall of 2008, the shadow banking system, the heart of the CDO market, collapsed. The U.S.'s core banking system was threatened, and the crisis spread around the world. Reverberations are still being felt and it may be some time before financial health is fully restored.

In Retrospect

David X. Li returned to China in 2007 and has not commented publicly since. Recently, one of his former professors recalled a popular saying in statistics: "All models are wrong, but some are useful." In just seven years, the Gaussian Copula Default Function Formula leapt from the pages of a financial journal into some of Wall Street's most widely used computer models. From there, CDOs were sold in just about every corner of the world.

In hindsight, there were a number of problems with the formula and the way it was used that should have been obvious, even to Wall Street. But the market was so lucrative, with each step of the CDO food chain profiting handsomely that there was little incentive to think twice, and no incentive to forego the business.

Whenever he was asked, Li himself warned that the formula was not really appropriate for the way in which it was being used on Wall Street. Actuarial science deals with the binary outcomes of life or death. The CDO markets were based on the complicated, messy, real and sometimes random world of mortgages and economics -- a world more prone to extreme scenarios than any formula or model.

Wall Street has had a long fascination with computerized models, quantitative finance and financial engineering. This was undoubtedly a factor in the speed with which Li's ideas were adopted and implemented. Another was the influx of "quants," Wall Street's nickname for practitioners of quantitative finance, during the 1990s. The collapse of the Soviet Union and the end of the arms race meant that job opportunities for mathematicians and physicists were limited. With the spreading use of technology and computers, many of them found homes on Wall Street, especially at firms looking for a competitive edge.

As the new century began, the Gaussian Copula Default Function Formula became a competitive edge. It allowed the creation of a seemingly authoritative single number denoting risk. Interestingly, Wall Street's penchant for an unequivocal risk number likely originated during the Crash of 1987. The then-head of JP Morgan began the practice of quantifying how much the firm would lose if the following day was a bad one in the financial markets. Other firms quickly copied and adopted the idea.

Another problem was the data used to construct the models, i.e. housing data from the 1980s and 1990s. This was the only data then in existence, but these markets were very different from the grossly inflated housing market of the 2000s. Also, exotic derivative financial instruments were not widely used during the 1990s and thus did not distort the markets as they did later. As one observer noted "the development of the model had, ironically, changed the nature of the reality it was modeling."

Most financial innovations have problems of one sort or another, especially in their earliest versions. For the Great Meltdown, the bottom line is that few on Wall Street understood the formula, fewer still understood what they were selling, and no one understood what they were buying. Undoubtedly, this is the most important lesson of all.