Nomura Fixed Income Research

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Model Risk Update

Margins of Error and Scenario Analysis

29 November 2005

Jobs Involving Risk		
• alligator farmer	• forward air controller	• nuclear waste handler
• arctic explorer	• high tension linemen	• rodeo clown
• avalanche ranger	• Hollywood stunt actor	• secret agent
• bomb disposal specialist	• infantry scout	• smoke jumper
• cliff diver	• lion tamer	• storm chaser
• deep sea diver	• NASCAR driver	• test pilot
• fixed income investor	• naval aviator	• trapeze artist

I. Introduction

If you are reading this paper, part of your job is probably about risk: measuring it, modeling it, monitoring it, managing it, or pricing it. Quantitative models are key items in your arsenal for confronting risk. Financial professionals can make the most of their simulation-based financial models when they fully understand the models' weaknesses as well as the models' strengths.

Margins of error and scenario analysis can boost understanding. Professionals should embrace a practical, "engineering" mindset toward using simulation-based models. By doing so, they can better understand the precision and reliability of the models and improve their chances for making effective business decisions.

Much to the chagrin of some structured finance professionals, the real world continues to deliver surprises. It behaves with greater complexity than today's simulation-based models can capture. Unexpected spread movements in structured credit products following the May 2005 downgrades of the U.S. automakers supplied a vivid reminder. Margins of error and scenario analysis are tools that can help "financial engineers" deal with their models' limitations.

We have previously addressed simulation-based models as a possible cause for the disappointment experienced in high-yield corporate CDOs and in ABS backed by aircraft leases, franchise loans, and mutual fund 12b-1 fees.[1] Simulation based-models for those areas seemed to underestimate losses . However, the problem arguably was not in the models themselves. Rather it may have been in their application. Professionals may have overestimated their models' precision. Alternatively, they may have overestimated the range of market conditions in which the models could provide reliable results.

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[1] *What a Coincidence? – One Reason Why CDOs and ABS Backed by Aircraft, Franchise Loans, and 12b-1 Fees Performed Poorly in 2002*, Nomura fixed income research (19 May 2002).

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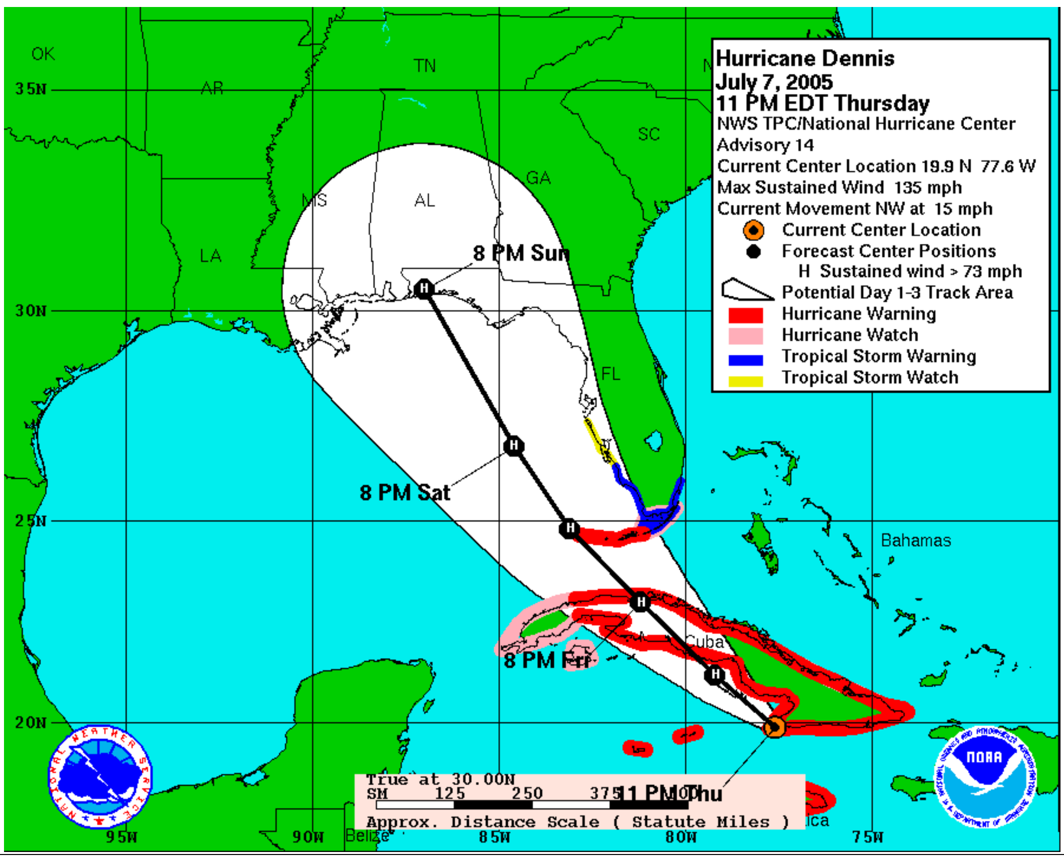
In either case, market participants might have avoided some disappointment if they had had greater awareness of their models' limitations. Margins of error and testing with historical stress cases might have helped them to achieve that awareness.

II. Margins of Error (Confidence Intervals)

Engineers and scientists use "margins of error" or "confidence intervals" to express the uncertainty or limited precision in an observation, a specification, or a prediction. For example, an engineer designing interchangeable parts for a machine might specify that a component must have a diameter of 0.5 inches, with a manufacturing tolerance of 0.005 inches. He would express that specification as 0.5 ± 0.005 inches. Similarly, a chemist weighing the products of a reaction might record his observation as 12.36 ± 0.01 grams. In that case, the margin of error likely would reflect the limited precision of the chemist's scale. When the National Weather Service (NWS) issues a hurricane advisory, it provides *both* (1) a projected central path for the storm and (2) a "potential track area." The potential track area denotes the margin of error around the projected central track. Exhibit 1 shows an example.

Exhibit 1



Source: National Weather Service, http://www.nhc.noaa.gov/archive/2005/graphics/AT04/14.AL0405W.GIF

Exhibit 1 shows the Thursday, 7 July 2005, 11:00 pm NWS advisory for Hurricane Dennis. The advisory called for a projected central track that would have brought the storm ashore near Pensacola, Florida. However, the advisory indicated a wide margin of error around the projected central track. The potential track area extended from the Gulf Coast of Florida in the east, all the way past New Orleans in the west. Many users of NWS hurricane advisories rely more heavily on the potential track areas than on the projected central tracks. Indeed, the great value of the NWS forecasts comes from the explicit and useful margins of error that the NWS provides around the projected central tracks of hurricanes.[2]

In structured finance, a familiar example where margins of error appear prominently is in S&P's periodic review of automated valuation models (AVMs) for residential real estate.[3] Mortgage lenders sometimes use estimates from those models in lieu of traditional real estate appraisals when they make mortgage loans. S&P monitors the accuracy of AVMs to decide whether loans originated in reliance on AVMs require more credit enhancement than loans originated with traditional appraisals. S&P considers the margins of error on AVMs to make that determination.

Quantitative models for other structured finance applications could be more useful if they provided realistic margins of error around their predictions. The margins of error should be based on the size of the errors that a model actually made (or would have made had it actually been used) in the past. The outputs of almost any pricing or valuation model can be compared with the actual prices at which trades have occurred. That comparison is the model's track record. Developers should use the track record to create confidence intervals. That is similar to what the NWS does for producing the potential track areas of its hurricane forecasts.[4] Developers should not simply base margins of error on the assumed statistical distributions of underlying variables. Doing so can cause more harm than good by misleading users of the model about the true reliability of their model's predictions.

Structured finance professionals who use models to estimate security values should favor models that offer margins of error in a fashion similar to the NWS hurricane forecasts. For example, a financial simulation model that attempts to estimate the value of a CDO tranche through simulation becomes more helpful if users understand whether its estimates are reliable within 0.25%, 1%, 5%, or 10%. More pointedly, the user of a model wants to understand how frequently the model produces large errors that can lead to costly mistakes and bad decisions.

In some areas, even the best possible model may have a wide margin of error. This can happen if the modeled phenomenon is either chaotic (*i.e.* having outcomes that change exponentially with changes in initial conditions) or non-stationary (*i.e.*, governed by processes that can change over time). Weather seems to be an example of the former type of phenomena, while mortgage prepayments arguably are an example of the latter.[5]

Wide margins of error generally are present in models of phenomena that are subject to the influence of human behavior. For example, lenders frequently introduce new mortgage products and consumers learn how to manipulate their credit scores. Those behaviors create a shifting landscape that leads to wide margins of error in models to predict defaults and losses. Even the correlation of risk among assets can be non-stationary.[6] That can expand the margins of error in models for gauging the credit risk of CDOs or similar credit portfolios. Financial professionals should not expect their quantitative models to achieve the same degree of precision as models of physical systems.

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[2] As it turned out, the NWS projected central track for Hurricane Dennis was highly accurate. The storm made landfall just east of the projected track shortly before 4:00 pm on Sunday, 10 July 2005 (about four hours earlier than the NWS had projected three days earlier). *See* http://www.nhc.noaa.gov/archive/2005/DENNIS_graphics.shtml. The NWS was not nearly as successful in predicting the path of Hurricane Wilma in October. As of October 18, the NWS projected that Wilma would pass well to the east of Cancun, Mexico. Three days later the storm slammed directly into Cancun with devastating effect. *See* http://www.nhc.noaa.gov/archive/2005/WILMA_graphics.shtml.

[3] Albergo, L. and M. Parriss, *U.S. RMBS Automated Valuation Models Are Becoming More Accurate*, Standard & Poor's special report (14 Oct. 2004); Albergo, L. and M. Parriss, *The Complexity of U.S. Automated Valuation Model Testing*, Standard & Poor's special report (29 Dec. 2004).

[4] The National Hurricane Center (NHC) constructs the potential track area for a storm based on the average track forecast errors in recent years. The NHC publishes extensive information about on the accuracy of its storm track forecasts over varying time horizons. *See* http://www.nhc.noaa.gov/verification/.

[5] *How the Events of 9/11 Affect Thinking about Risk* at 6, Nomura fixed income research, (updated 20 Feb 2002).

[6] For a discussion of time-varying correlation and the treatment of correlation in selected areas of structured finance see *What a Coincidence?, supra*, note 1.

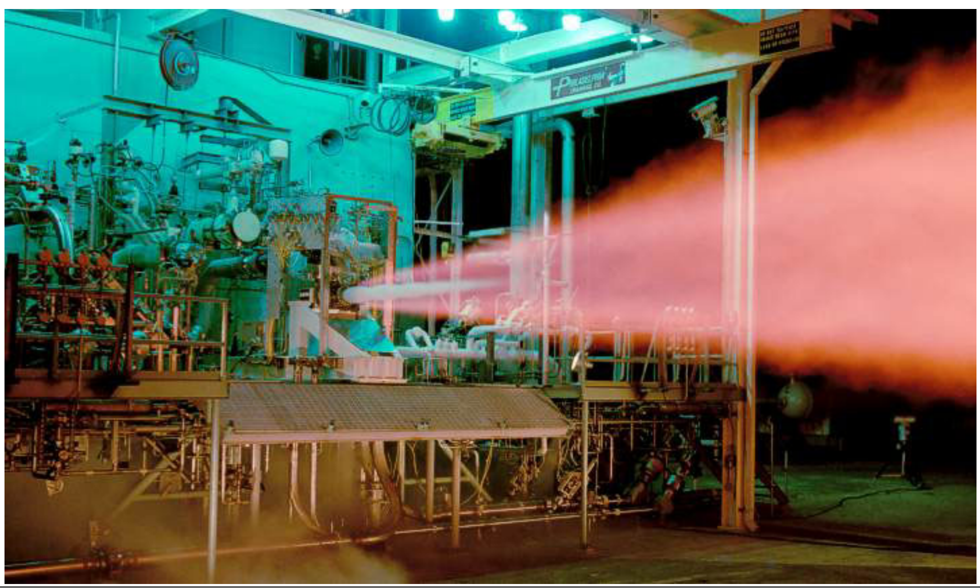
Finally, professionals should use margins of error cautiously because they can be wrong if the business environment is changing quickly. Margins of error are inherently backward looking. Professionals must assess the environment to see whether conditions have changed in ways that make a model's past track record an unreliable indicator of its future performance. If the environment has changed to such a degree, extra caution would be warranted in using the model for making real world decisions.

III. Scenario Analysis – Stress Testing

Scenario analysis simply addresses a series of "what if" questions. Scenario analysis asks: What output does a model produce in scenario A, and what about scenarios B, C, and D? The answers do not depend on the likelihoods of the different scenarios. In that respect, scenario analysis, by itself, is inherently an incomplete solution. However, it allows financial professionals (as well as non-financial engineers) to focus on key scenarios to which they ascribe special significance. In particular, it allows them to focus on the impact of scenarios which they may feel are unlikely but which could produce highly disappointing outcomes.

Like margins of errors, engineers and scientists often use real-world testing to determine the true performance and reliability of their designs. Consider aircraft and space vehicles. Engineers subject aircraft and space vehicles to extensive flight-testing before declaring their designs "operational." Test flights reveal a design's performance envelope; showing how it handles under easy conditions and under the stress of operating at or near its limits. However, even before flight-testing, engineers sometimes test critical components individually. For example, Exhibit 2 shows a pre-flight test of a critical component of the Space Shuttle.

Exhibit 2



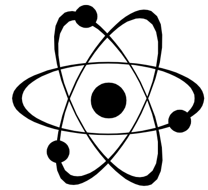
Source: EDF, Inc., http://www.edfinc.com/pages/shuttlepump.htm

The photo shows a ground test of a Space Shuttle main engine liquid oxygen (LOX) turbopump. Testing is critical to assure that the component can deliver the required performance. The LOX turbopump for each of the Shuttle's main engines produces 26,800 horsepower of pumping action and spins at 23,700 revolutions per minute. Each of the corresponding fuel turbopumps delivers 76,000 hp – the power of 28 locomotives – and spins at an even more incredible 36,200 rpms. Collectively, the pumps for the Shuttle's main engines pump at a rate that would drain an average family-sized swimming pool in 25 seconds. Burning LOX and fuel from the pumps, the Shuttle's three main engines produce just over 37 million hp.[7]

Testing the components of the of the Space Shuttle engines allows engineers to develop confidence that their designs can meet the performance and reliability expectations of NASA and the astronauts. Without such testing, the engineers generally would *not* assume that their designs actually accomplish their intended objectives. Indeed, as one author has described it:

> Engineers know that the first (and second and third) time a complex system is tested it won't work. It's not supposed to. The whole point of the test is to find out what bugs there are in the system so that they can be removed. There is a fundamental mismatch between the way engineers and the general public look at this issue. For example, the widespread ridicule to which the American space program was subjected in the 1960s, when rocket after rocked exploded on the launch pad, simply showed that the public didn't understand the purpose of the tests. Once the bugs were eliminated, of course, the ridicule disappeared in the success of the Apollo program.[8]

Testing Theory to Practice



By the late 1930s, scientists realized that neutrons could be used to trigger nuclear fission and that fusion reactions could release tremendous amounts of energy. Thy realized that the conversion of mass into energy would follow Einstein's famous equation, $E=mc^2$. On 2 December 1942, under the direction of Dr. Enrico Fermi, U.S. scientists initiated the first man-made, self-sustaining nuclear chain reaction. They performed the experiment under the seats of the University of Chicago football stadium. The experiment was a key element of the wartime Manhattan Project and a precursor to the whole nuclear power industry. The Chicago atomic pile is an excellent example of a theory proving its worth through a real world test.

A similar example involves the Boeing 777-300ER jetliner. Twin-engine commercial jetliners like the Boeing 777 must meet "extended-range twin-engine operation performance standards" (ETOPS) in order to gain certification for flights over oceans, deserts, or other remote areas. The key test for certification requires that a twin-engine jetliner fly with just one of its engines, simulating a malfunction in the other. On 15 October 2003, a Boeing 777-300ER flew for more than five hours with one of its engines shut down. The test directly addressed the scenario of an engine failure over remote sections of the Pacific Ocean.[9]

Financial engineers who design simulation models for use in structured finance sometimes might benefit from following the lead of regular engineers. They could employ scenario analysis (stress testing) on their designs to ascertain the limits of reliability and performance. More specifically, they should determine whether their models (or strategies based on the models) would have met their design objectives during past periods of market stress. For example, they might determine whether the models would have remained predictive or useful to professionals during times like the stagflation and oil embargo of the 1970s, the Houston real estate bust of the 1980s, the southern California real estate bust of the early 1990s, and the Asian and Russian debt crises of the late 1990s.

Naturally, scenario analysis can be used to evaluate a model only if the model accepts inputs for which historical data from relevant stress periods is available. For the U.S., available types of data include macroeconomic data (*e.g.*, unemployment, inflation, GDP growth), corporate bond default rates, real estate prices, commodity prices, and currency exchange rates, as well as some performance measures relating to residential mortgage loans, consumer debt, and small business loans. Users should be skeptical if a model uses no inputs for which data from relevant stress periods exists. In such a case, there may be no practical way to assess the model under conditions more stressful than those implicitly represented in its development sample.

Scenario analysis using actual, historical stress cases potentially addresses two modeling pitfalls. First, it discloses whether a *theoretical* model bears a sufficient connection to reality to meet the needs of the model's users. Even a seemingly reasonable theory can be deficient when put into

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[7] Pratt & Whitney Corporation website, http://www.pratt-whitney.com/prod_space_turbopumps.asp. The Boeing Company website, http://www.boeing.com/defense-space/space/propul/SSMEamaz.html.

[8] Trefil, J., THE NATURE OF SCIENCE at 283-4, Houghton Mifflin (2003).

[9] The Boeing Company website, http://www.boeing.com/commercial/777family/pf/pf_milestones.html. Few aircraft seek ETOPS ratings longer than three hours. A three-hour ETOPS rating allows operation over roughly 95% of the Earth's surface.

practice. For example, classical physics provides useful theoretical framework for describing the world of our everyday experience. However, it becomes an inadequate theory under unusual or "stressful" conditions. Quantum mechanics replaces classical physics in the realm of the very small and the theory of relativity replaces it in realm of the very large or the very fast.

Second, scenario analysis sometimes can reveal whether a model relies too heavily on historical averages and possibly ignores historical extremes. Sometimes, developers must rely on averages and short-term development samples (*e.g.*, three years). The development samples may not include important "outliers" relating to periods of stress. Testing a model (or model-based strategy) with specific historical test cases shows whether the model would satisfy its users' expectations under those conditions. If it would not, the developers either should warn the users about the model's limitations or refrain from declaring their model "operational."

One example where rigorous stress testing might have advantageously augmented simulations is aircraft securitizations. Until 2002, the entire experience of the jet aviation aircraft sector had been relatively stress free. The simulation models based on the sector's actual experience could not capture the impact of an event like the 9/11 terrorist attacks. However, investors and other market participants might not have been so surprised by the sudden reversal of fortunes had they considered the longer and more stressful experiences of the shipping and railroad sectors. Applying stress-period price declines from those areas to jet aircraft might have given some warning about the vulnerability of aircraft ABS.

Another structured finance example where simulations may over-emphasize averages is option-adjusted spread (OAS) models for mortgage-backed securities. OAS models attempt to estimate the value of securities by projecting future cash flows under a variety of interest rate scenarios. A typical OAS model uses an "interest rate process" to generate multiple hypothetical paths of future interest rates. For each such path, the OAS model uses a "prepayment model" to estimate the level of mortgage loan prepayments in each future month. The prepayment model produces a hypothetical cash flow corresponding to each scenario. The OAS model applies a fixed spread over benchmark interest rates to calculate a simulated price for the security under each scenario, as well as the average of the simulated prices across all scenarios. The OAS model then adjusts the fixed spread and repeats the calculation process until the average of the simulated prices across all scenarios converges to the actual market price of the security. The reported OAS is the fixed spread that equates the average of the simulated prices to the actual market price of the security.

The cash flows on some types of mortgage-backed securities are extremely sensitive to the rate of mortgage loan prepayments. For such a security, the calculated price under different simulated interest rate scenarios can differ enormously. Under some scenarios the security might have a low modeled price (suggesting that the actual price might be too high) while under others it might have a very high modeled price (suggesting that the actual price might be attractively low). In fact, there might be no individual scenario in which the modeled price equaled the average over all scenarios. For such a security, the OAS derived via simulation may be valuable for comparing the subject security to other similar instruments, but it may not help an investor to develop meaningful expectations about how the security will really perform. For that, the investor should analyze the security under specific scenarios. The investor naturally would want to know the range of conditions under which the investment produces attractive returns as well as the range under which it might produce unacceptable losses. Thus, using scenario analysis to complement the OAS simulation process can lead to better decisions.

IV. Complexity

In structured finance, model risk seems to increase with transactional complexity. Professionals tend to increase transactional complexity in ways that amplify model risk. Therefore, the value of explicit margins of error and of scenario analysis also increases with transactional complexity.

For example, a CDO-squared embodies more model risk than a single-layered CDO because each layer contributes its own measure of model risk. Thus, the margin of error on projected performance or valuation is even wider for a CDO-squared than for a single-layered CDO.[10]

Stripped MBS (SMBS) and thin mezzanine tranches are other examples of how complexity increases sensitivity to model risk. Modeled valuations of such securities are highly sensitive to the assumed timing and level of prepayments, or losses, or both. Small changes in assumptions can lead to large changes in estimated values. The structural leverage added by stripping or tranching is the source of the risk.

Similarly, the modeled valuation of a net interest margin (NIM) securitization is particularly sensitive to model risk. A NIM securitization embodies the right to receive residual cash flows from one or more underlying securitizations. If there are multiple underlying residual interests, each one contributes a measure of incremental model risk. Moreover, each residual interest may have multiple sources of cash flow, each of which has its own sensitivities. In a typical case, cash flow for a residual interest might include (1) all excess spread, (2) unused overcollateralization remaining at the termination of the underlying deal, (3) prepayment penalties, and, in some cases, (4) cash flow on classes specifically created to enhance the residual for the NIM.

V. A Trend toward More Simulation

The May 2005 episode of structured product spread volatility was just the latest in a long string of reminders that many financial models are far from perfect. Just three years ago, the market got a similar reminder from the poor credit performance of corporate CDOs and various types of ABS (*e.g.*, aircraft, franchise loans, and 12b-1 fees). Before that, the terrorist attacks on 9/11 were a reminder that some important real-world risks seemingly lie beyond the reasonable bounds of quantitative risk modeling. And before that, there were numerous other examples…[11] Nonetheless, both developers and users of financial models continue to embrace many of the same methods that have brought them disappointments in the past.

Indeed, reliance on simulation-based models seems to be growing. Financial professionals seem to believe increasingly that simulation-based models should have an ever larger role in controlling risk, maximizing returns, and pricing securities. Journals devoted to quantitative finance abound,[12] as do

[10] Whetten, M. and M. Adelson, *CDOs-Squared Demystified*, Nomura fixed income research (4 Feb 2005).

[11] For additional examples see *How the Events of 9/11 Affect Thinking about Risk*, *supra* note 5, at 4-7.

[12] The following table lists selected journals that focus primarily on quantitative finance:

Journal Name	Website	Country
Applied Mathematical Finance	http://www.tandf.co.uk/journals/titles/1350486X.asp	UK
Computational Finance, J. of	http://www.thejournalofcomputationalfinance.com	UK
Derivatives, J. of	http://www.iijod.com	USA
Financial and Quantitative Analysis, J. of	http://depts.washington.edu/jfqa/	USA
Finance and Stochastics	http://www.math.ethz.ch/~finasto/	Germany
Mathematical Economics, J. of	http://www.elsevier.com/wps/find/journaldescription.cws_home/505577/description#description	UK & Netherlands
Mathematical Finance	http://www.blackwellpublishing.com/journal.asp?ref=0960-1627	USA
Quantitative Finance	http://www.tandf.co.uk/journals/titles/14697688.asp	UK
Risk	http://www.risk.net/	UK

Internet websites[13] More and more universities offer programs in quantitative finance or financial engineering.[14] Simulation methods seem to be gaining greater attention in all those forums.

The real world of finance surely will suffer if practitioners fail to temper their reliance on simulation-based models with skepticism and appreciation of model risk. Using margins of error and scenario analysis should help professionals sustain awareness on the limitations of their models. With such awareness in hand, professionals will be equipped to make better decisions.

VI. Conclusion

It seems that a major breakthrough will be necessary before simulation-based models for structured finance applications improve significantly. Perhaps such a breakthrough will eventually come in the treatment of correlation or in the ability to capture subtle, transient, and non-linear factors. On the other hand, perhaps today's simulation-based models are nearly as good as they will ever get. Either way, however, there are practical implications for structured finance professionals: (1) create realistic margins of error for simulation-based models and (2) test simulation-based models with scenario analysis.

Finance professionals must remain mindful that their discipline is not merely an academic exercise. The limitations of theories and models have real-world consequences. Dealing with such limitations is an essential part of what financial professionals do. At the end of day, it is always a professional – not a model – that bears responsibility for making decisions.

— E N D —

[13] The following websites are devoted primarily to quantitative finance: (1) http://www.defaultrisk.com, (2) http://www.gloriamundi.org, (3) http://www.wilmott.com, (4) http://www.fenews.com, and (5) http://www.contingencyanalysis.com.

[14] For a listing of selected graduate programs see the Global Derivatives website at http://www.global-derivatives.com/schools/quantfinanceprograms.php.

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- Bond Portfolio Credit Analysis … The CDO Approach (24 May 2005)

ABS/CDO

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- Correlation Redux (17 Oct 2005)
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- Constant Maturity CDS (CMCDS) – A Guide (20 May 2005)
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- CDOs-Squared Demystified (4 Feb 2005)
- Student Loan ABS 101 (26 Jan 2005)

MBS

- Overview of the ARMs Market (23 Nov 2005)
- GNMA Project Loan Prepayment Report (12 Oct 2005)
- FHA/VA Monthly (12 Apr 2005)
- Some Investment Characteristics of GNMA Project Loan Securities (4 Apr 2005)

Strategy

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- Stagflation – Waiting in the Wings (18 Oct 2005)
- GM Strikes Deal with UAW, GMAC Sale Looms (17 Oct 2005)
- Bank Holdings Update – October 2005 (14 Oct 2005)
- CDS: Ford Motor Credit vs. GMAC – Post Delphi Bankruptcy (12 Oct 2005)
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- MBS/ABS: US Consumer FICO Score Update (11 Oct 2005)
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