Statement of Research Interests

Overview

My research interests are in financial engineering, mathematical and computational finance. My dissertation focuses on stochastic modeling of credit and equity risk. The celebrated Black-Scholes-Merton option pricing model (Black & Scholes 1973, Merton 1973) set the mathematical foundation for pricing options and other financial securities. However, the accumulated empirical evidence, including the current and on-going problems in the credit markets, have made it clear that some of the fundamental assumptions in the original Black–Scholes–Merton framework do not hold. On one hand, assumptions such as continuity of the stock price process and the constant volatility of the stock returns contradict market evidence that shows that unexpected news can abruptly shift stock prices and that assets become more volatile as their prices drop. On the other hand, credit risk, or the risk of an obligor failing to repay the principal and interests on his/her issued debt in a timely manner is also absent in the Black–Scholes framework, since it assumes that the stock price is a stochastic process with infinite lifetime. My dissertation research consolidates the credit and equity risk into a unified class of models called *hybrid credit-equity models*. Using time-changed Markov process and the spectral theory, I develop a rich class of analytical tractable models that include jumps, stochastic volatility, and default. As part of this research, I have developed an analytical methodology to price an insurance-type financial instrument that provides protection if the underlying firm defaults *or* if its stock price drops significantly (the so-called *equity default swap* (EDS)). My current research is devoted to developing models of correlated defaults in a multi-firm setting where I study the so-called "clustering effect" in which adverse market conditions could potentially trigger defaults of multiple firms at the same time.

Industry Research

Prior to pursuing my doctoral degree, I conducted financial engineering research as a practitioner, working for *Algorithmics Inc.*, one of the largest risk management systems firms which provides software applications and consulting to major investment and commercial banks and hedge funds. During my PhD studies, I have also worked summers at State Street in Boston and Citadel in Chicago (one of the largest hedge funds in the world). I believe that my academic research is well complemented by my industry experience, and that the latter will bring an integrated perspective to my teaching as well.

During my years at Algorithmics I did a variety of applied research projects ranging from *asset management* to *credit risk* to *distributed computing* and worked with many partners and clients of Algorithmics such as the Mexican Exchange, State Street Bank, IBM, and HP. In particular, I developed an interest rate curve methodology applied to the Mexican Market. This methodology was based on the Nelson-Siegel term structure. In credit risk, I developed a calibration methodology for single name default probability curves. This methodology obtains the term structure and default probability curves from stripped bonds and credit default swaps of names with similar credit worthiness. Subsequently, single name curves were implied as linear combinations of the curves previously constructed via OLS for each individual bond and credit default swap at various maturities. In the area of asset management, I built prototype models for performance attribution and tracking error contributions. These models form part of Algorithmics' software applications that are deployed at several major global financial institutions. In the area of distributed computing, I participated in the software re-engineering project that allowed us to decrease the computation time of risk reports by 75% by studying the optimal work balance of distributing simulation batches across a grid.

The objective of my research project at Citadel was to identify sources of systematic risk common to corporate bonds of different credit quality. This was done by analyzing different idiosyncratic factors in the balance sheet and systematic indicators at the industry and sector levels. In addition, I analyzed factors that are issue specific, such as optionality of bonds, liquidity indicators for each bond, etc.

Academic Research

Pricing Equity Default Swaps

The first part of my dissertation is dedicated to the pricing of an insurance-type financial instrument that delivers a protection payment if the underlying firm's stock price drops to or below a certain level L (in practice often set at 30% of the stock price at contract inception). The event of stock price decline to the level L is called a *triggering event*. In an *Equity Default Swap* contract (EDS), the seller delivers a protection payment if a triggering event occurs before the expiration date. In exchange, the buyer promises to pay insurance premiums in periodic installments up to the time that a triggering event occurs, including the interest accrued from the previous payment date up to the triggering event time. This instrument, although similar to a *Credit Default Swap* (CDS), has some advantages over the CDS. In particular, EDS are based on the stock price (an observable state variable) to determine the triggering event.

The stock price is modeled as a jump-to-default extended constant elasticity of variance (JDCEV) process. The JDCEV model is an extension of the CEV process with default intensity that is an affine function of the instantaneous stock variance. In the JDCEV model, the variance is a negative power function of the stock price, which is in agreement with the observed volatility skew curves and the leverage effect, since as the stock price drops the local volatility increases. On the other hand, since the default intensity is an affine function of variance, it achieves the effect of increasing the default intensity as the stock price drops as a precursor to the firm's default on it's debt. The problem of finding the no-arbitrage *swap rate* at which the EDS buyer makes the premium payments mathematically reduces to a first passage time problem for a diffusion process with killing through a barrier. I solve this problem using the eigenfunction expansion method and obtain an analytical solution for the swap rate.

Time Changed Markov Processes in Unified Credit-Equity Modeling

In the second part of my dissertation I develop a novel class of hybrid credit-equity models with state-dependent jumps, local-stochastic volatility, and default intensity based on time changes of Markov processes with killing. The defaultable stock price process is modeled as a time changed Markov diffusion process with state-dependent local volatility and killing rate (default intensity). We model a stock price process as a time changed diffusion process with killing time. Jumps and stochastic volatility are introduced by time changing the diffusion process with killing with a stochastic clock $\mathcal{T}_t$ which can be a Lévy subordinator, an absolutely continuous process or a combination or a composition of both. When the stochastic clock is a Lévy subordinator (non-decreasing Lévy process with positive jumps and non-negative drift), the time-changed process acquires jumps. When the stochastic clock is absolutely continuous (a integral of an activity rate process), the time changed process acquires stochastic volatility. Finally, composite time changes induce both jumps and stochastic volatility into the time changed process.

When the Laplace transform of the stochastic clock is known in closed form, and when the underlying diffusion process with killing (to be time changed) possesses an analytical solution for the spectral representation of its transition density, we show that the time changed process is also analytically tractable. We thus construct a rich class of analytically tractable hybrid credit-equity models with jumps, local-stochastic volatility, and default.

Correlated Defaults: a multivariate time change approach (research in progress)

The credit market events over the past year have made it clear that multiple defaults can occur in short periods of time, if not simultaneously; in the credit literature this is referred to as "default clustering". For instance, firms with managerial linkage (e.g., parent-subsidiary) or with contractual bondage (e.g., customer-supplier) have a higher joint default probability since the factors that affect the performance of one also affects the other. Recent empirical research conducted by Lando & Nielsen (2008) suggests that default clustering can be explained by firm specific variables. If it is possible to model how balance sheets are affected by credit events of other obligors, then there is no need for unobserved factors (frailty) to explain default clustering. Furthermore, Jorion and Zhang (2007) analyze how credit spread correlations are affected by different credit events: Chapter 7 and Chapter 11 bankruptcies and jump events. They find that the effect of jumps in correlation is the highest and it is caused mainly by the surprise element of a jump.

I am currently developing a novel framework for modeling correlated defaults where it is possible to capture these features. Time changing multi-parameter Markov processes with multivariate subordinators leads to jump-diffusion Markov processes that are correlated through their jump measures. In financial terms, this means that under normal conditions the processes evolve (diffuse) independently, as in the case of firm specific variables. However, when unpredictable shocks arrive, these processes will shift the default intensity of multiple firms simultaneously, which can cause multiple defaults. By using the spectral method, I am able to obtain analytical solutions for probabilities of default and for default correlations in this class of models.

Future Research

I am fascinated by applications of probability theory, stochastic processes, and functional analysis in financial modeling. I am interested in the process of building financial models, starting from theoretical foundations, leading to developing specific models to solve concrete problems, and taking it all the way to implementation in financial practice. On the methodology side, I am interested in building stochastic models and in analytical, as well as computational, methods to solve them. I am particularly fascinated with the method of stochastic time changes and its applications in financial modeling.

On the applied side, I am particularly interested in credit markets. I plan to continue my work on integrated credit-equity models, as well as on modeling correlated defaults. I am interested in both theoretical and mathematical model development, as well as in empirical testing of the models. The on-going credit markets crisis raises many research questions in the area of credit risk modeling, and I look forward to be able to contribute to developing better credit risk management models and systems. I believe my current work on modeling default clustering is particularly important in the context of portfolio credit risk management. I am also interested in applying the method of stochastic time changes to other markets as well, including foreign exchange and energy markets, where jumps and stochastic volatility are an empirical reality.