Innovations in Mortgage Modeling: An Introduction

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This special issue presents a selection of recent methodological advances in the academic literature on mortgage performance and valuation. The articles include a range of modeling techniques from rational structural models applied to pool-level data and loan-level reduced-form, or behavioral, models of prepayment and default. Both classes of model are shown to be effective for evaluating innovations in contracting such as defeasance options in commercial mortgage contracts and hybrid residential mortgage products. Finally, the articles highlight a number of important methodological linkages between recent advances in mortgage modeling and those found in the valuation of other forms of risky debt such as corporate bonds.

The structural models presented here focus on pricing and modeling credit or call events that are specific to a particular class of borrower. These models focus on the underlying dynamics of interest rates and the assets that are the collateral on the mortgage. Credit (or call) events are triggered by random movements in the asset price relative to a threshold that is the exercise price on the option. By modeling credit or call events in terms of the underlying dynamics of asset prices and/or interest rates, the structural methodology functionally links option exercise events to the underlying fundamentals faced by the borrower. These articles build upon an extensive literature with a corporate debt focus: Leland (1994), Jarrow and Turnbull (1995), Longstaff and Schwartz (1995), Leland and Toft (1996), Anderson and Sundaresan (2000), Collin-Dufresne and Goldstein (2001) and Huang and Huang (2002), among many others. They also build upon important prior structural mortgage models including Dunn and McConnell (1981a,b), Timmis (1985), Johnston and van Drunen (1988), Kau et al. (1992), Stanton (1995), Kau et al. (1995) and Kau and Slawson (2002), among many others.

In contrast, reduced-form, or behavioral, approaches, do not explicitly model the value of the borrower’s assets and capital structure. Instead credit and/or

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call events are modeled as exogenously specified jump processes or hazard rates. These approaches emphasize empirical estimation of the random timing of option exercise events. Bond valuation requires computing conditional expectations under a risk-neutral probability of functionals of event timing and realized cash flows. Recent examples of the reduced-form approaches to the valuation of corporate risky debt include Jarrow and Turnbull (1995), Duffee (1998), Duffie and Singleton (1999), Collin-Dufresne and Solnik (2001) and Duffie and Lando (2001). Schwartz and Torous (1989) develop one of the first reduced-form mortgage-backed securities (MBS) valuation models in which prepayment was modeled as a function of a set of (nonmodel based) explanatory variables. Deng, Quigley and van Order (2000) developed a sophisticated competing risk reduced-form model of mortgage termination performance using loan-level data.

In many ways, the characteristics of mortgages and MBS make these instruments particularly suitable for developing and testing reduced-form models and multifactor structural valuation models. One advantage of mortgages over many other forms of defaultable and callable debt is that there are very extensive time series available on the prepayment and default experience of these bonds. In addition, the structure of mortgages and MBS is relatively simple. For mortgages, there is usually only one property that serves as collateral for the loan. For pass-through MBS, there is only one type of bond, so issues related to the seniority of the bonds do not apply. This stands in contrast to many other structured finance vehicles, such as collateralized debt obligations, which typically have complicated seniority structures, or corporate bonds, whose values depend upon the entire capital structure of the firm. Finally, when mortgage defaults are triggered for agency-insured MBS, such as Freddie Mac Participation Certificates or Ginnie Mae MBS, the principal recovery rates are 100%. In contrast, corporate bond recovery rates, for example, vary both in the cross-section and over time posing significant additional modeling challenges to researchers.

An important further advantage of mortgage and MBS valuation is that there are pricing data available across a wide range of vintages of mortgage pools (i.e., across a wide range of par-coupon rates). Recent advances in the development of national house price indexes and commercial real estate rent and price indexes also afford measures of the evolution of loan-to-value ratios for the real estate assets that are the collateral for the mortgages. These indexes and conventional methods of modeling the default-free term structure allow us to estimate the underlying exogenous factors driving the exercise of the prepayment and default options embedded in mortgages. Identifying a tractable set of underlying

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1 These data are available from the forward contract market and provide a reasonable benchmark for the evaluation of model-based pricing performance.
factors in the corporate bond market is a considerably greater challenge and the evaluation of default and prepayment is further complicated by the presence of various bond covenants, contractual constraints and the complicated capital structure of most corporations. For these reasons, both reduced-form and structural mortgage and MBS models may provide important general insights into the performance and valuation of defaultable and callable bonds that are not possible for other classes of risky bonds.

**Structural Model Contributions**

In this issue, Dierker, Quan and Torous (2005), Downing, Stanton and Wallace (2005), Dunn and Spatt (2005) and Longstaff (2005) all focus on structural models in which option exercise is modeled as endogenous decisions made by borrowers to minimize the present value of their current mortgage position or, in the case of defeasance, to maximize the rate of return earned on released equity. There are, however, important differences in these models. The key insight of Dunn and Spatt (2005) is that a borrower may refinance his or her loan multiple times, incurring costs each time, so that the optimal refinancing decisions must reflect an optimal dynamic strategy that takes into account the expected costs of all future refinancings. The article carefully derives important theoretical results concerning the optimal refinancing strategy and provides a recursive algorithm to solve for it. The most significant and surprising finding is Proposition 7 that establishes that, although the borrower may face multiple rounds of refinancing costs, the market value of the loan cannot exceed the call price plus one round of refinancing costs. These important theoretical insights are largely implemented by Longstaff (2005) who shows that a borrower objective of minimizing lifetime mortgage costs leads to deferred terminations that are especially pronounced if exogenous terminations are also likely.

The Downing, Stanton and Wallace (2005) model maintains a myopic borrower refinancing assumption; however, their model expands the set of exogenous pricing factors to include house price dynamics. The Longstaff (2005) and Downing, Stanton and Wallace (2005) models similarly introduce borrower frictions due to transaction costs and borrower heterogeneity. Both models deliver significant improvements in matching estimated prices to observed MBS prices and produce measures of bond price sensitivities that would be needed for hedging applications.

The Dierker, Quan and Torous (2005) model treats defeasance as an exchange option whereby the borrower gives up a portfolio of Treasury or agency securities and in return receives the market value of the commercial mortgage plus the liquidity benefits from accessed equity. Dierker, Quan and Torous (2005) and Longstaff (2005) both adapt the string market models of Longstaff
and Schwartz (1995) and Longstaff, Santa-Clara and Schwartz (2001b,a) for valuation. These models allow for realistic term structure dynamics in which the covariance structure among forward rates is specified directly. Because the observed term structure is matched exactly, Longstaff (2005) finds the model generates accurate market pricing for premium MBS using moderate and realistic assumptions about transaction costs and spreads facing borrowers. The Dierker, Quan and Torous (2005) implementation indicates important differences in the valuation of defeasance options across the largest metropolitan regions and mortgaged property types.

In contrast to the market models used above, the Downing, Stanton and Wallace (2005) model is based on an equilibrium term structure model (Cox, Ingersoll and Ross 1985) that accounts for the long-run relationship between the drift and volatility of the riskless spot rate and a long-run representation of house price dynamics. Their two-factor valuation model delivers reasonable representations of market prices for Freddie Mac Participation Certificates and finds option-adjusted spreads that range between 0 and 25 basis points.

**Reduced-Form Model Contributions**

The reduced-form models in the special issue include those of Ambrose, LaCour-Little and Huszar (2005), Deng, Pavlov and Yang (2005) and Titman, Tompaidis and Tsyplakov (2005). The Titman, Tompaidis and Tsyplakov (2005) article examines the cross-sectional and time-series determinants of commercial mortgage credit spreads as well as factors that may determine the contractual structure of the mortgage such as the loan-to-value ratio and maturity. Their empirical analysis of commercial mortgage spreads to Treasury bond rates is motivated by the predictions of recent theoretical models in which bonds will be riskier, and thus have higher spreads, if they are collateralized by assets with greater investment flexibility, more volatile prices, or higher payouts (see Titman and Torous 1989, Titman, Tompaidis and Tsyplakov 2004). Their empirical results are largely consistent with these theoretical predictions. They also suggest alternative specifications that address both the endogeneity of mortgage contractual characteristics and likely biases due to sample selection by lender clientele preferences and/or sample truncation due to the credit rationing of risk types over the business cycle. They note that their results are also comparable to research on corporate bond credit spreads (see Collin-Dufresne, Goldstein and Martin 2001) where change in leverage is a statistically significant determinant of changes in corporate credit spreads.

The Deng, Pavlov and Yang (2005) and Ambrose, LaCour-Little and Huszar (2005) articles provide empirical estimates of competing risk hazard models for prepayment and default. These models are motivated by theoretical
option-based models of mortgage terminations. The Deng, Pavlov and Yang (2005) empirical model revisits the finding in Deng, Quigley and van Order (2000) that only three mass points are required to estimate the distribution of unobserved heterogeneity in a maximum likelihood estimator of competing mortgage risks. Using recent loan-level data from the Los Angeles metropolitan area, Deng, Pavlov and Yang (2005) find that first stage residuals have an important omitted factor related to the spatial location of the mortgaged property. Their proposed correction for residual heterogeneity is an extension of specifications for limited dependent variable models with spatially autocorrelated residuals (see McMillen 1992, Pinske and Slade 1998). Their correction implicitly allows for an extensive array of unobservable borrower characteristics through a nonparametric $k$-nearest-neighbor weighting scheme to identify spatially correlated residuals. Their new heterogeneity-corrected three-stage maximum likelihood specification is shown to significantly improve the efficiency of their estimator.

Ambrose, LaCour-Little and Huszar (2005) fully exploit the significant strengths of reduced-form models in their analysis of hybrid residential mortgage contracts. These contracts contain features of both traditional fixed- and adjustable-rate products and include both prepayment and default options. The competing risk hazard framework flexibly accounts for particular points of significant interest within the mortgage holding period such as the dates at which the mortgages reset from fixed to floating payment schedules. Here again, the ability of these models to be scaled up to account for a variety of borrower risk characteristics and economic conditions is shown to provide a highly informative view of the financial factors that underlie prepayments and defaults.

**Conclusion**

The common goal of both reduced-form and structural modeling strategies is to account for all the embedded options in mortgage contracts either explicitly by modeling the underlying correlated processes (usually asset prices and term structure) or by treating the spread to the riskless rate as a proxy for all sources of risk. In order to apply and improve theoretical models, it is important to have an accurate understanding of the empirical performance of existing contracts and their pricing dynamics. All of the articles in the special issue suggest additional research questions that remain for future work and, thus, provide a useful blueprint for the next generation of innovations in this dynamic research area.

**References**


