Applied Nonparametric Regression Techniques: Estimating Prepayments on Fixed-Rate Mortgage-Backed Securities

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Abstract

We assess nonparametric kernel-density regression as a technique for estimating mortgage loan prepayments—one of the key components in pricing highly volatile mortgage-backed securities and their derivatives. The highly nonlinear and so-called irrational behavior of the prepayment function lends itself well to an estimator that is free of both functional and distributional assumptions. The technique is shown to exhibit superior out-of-sample predictive ability compared to both proportional-hazards and proprietary-practitioner models. Moreover, the best kernel model provides this improved predictive power utilizing a more parsimonious specification in terms of both data and covariates. We conclude that the technique may prove useful in other financial modeling applications, such as default modeling, and other derivative pricing problems where highly nonlinear relationships and optionality exist.

Key Words: mortgage, prepayment, nonparametric, kernel regression

1. Introduction

This article presents nonparametric kernel-density regression as a technique for modeling and predicting highly nonlinear functional relationships. We apply kernel regression to the problem of estimating mortgage prepayments. The primary advantage of nonparametric modeling is that it does not require restrictive assumptions such as prespecified functional forms or distributions. In this case, we find that the nonparametric kernel-density regression either demonstrates notable strengths or outperforms both proportional-hazards and other nonlinear models in terms of out-of-sample predictive ability and thus exhibits promise in uncovering implicit optionality in prepayment.

Valuation of mortgages and mortgage-backed securities (MBS) requires both a term structure and a prepayment model. We focus here on use of kernel-regression techniques to model only prepayments; the problem of evaluating a joint model of MBS pricing is beyond our scope. Specifically, we show how kernel-density estimation may be applied in
a regression framework to empirically predict prepayment probabilities as a function of option values, loan age, and the previous path of interest rates. We argue that the technique exhibits superior out-of-sample predictive ability with lower data overhead as compared to parametric proportional hazards and other nonlinear models.

Previous research has mostly focused on theoretical models with parametric specifications (Dunn and McConnell, 1981; Brennan and Schwartz, 1985; Green and Shoven, 1986). Schwartz and Torous (1989, 1993) use variations on the proportional-hazards approach together with a poisson regression to integrate prepayment into an overall valuation framework. Richard and Roll (1989) utilize nonlinear least squares to estimate prepayments based on a four-factor model.

More recent work has examined the effect of default on prepayment, but theoretical and empirical results indicate that the effects are limited. Among practitioner models in the public domain, proportional-hazards models with various baselines dominate. Notably, the Office of Federal Housing Enterprise Oversight (OFHEO) (1999) model utilizes a quadratic baseline proportional-hazards model with a segmented refinancing-incentive variable and variety of additional covariates to estimate loan-level prepayments. Due to the large number of loan-level observations, OFHEO groups continuous variables into categoricals to reduce estimation costs. Similar techniques are used by Follain, Huang, and Ondrich (FHO) (1999) in studying multi-family mortgage terminations.

Researchers have recently incorporated nonparametric techniques into financial modeling (Boudoukh et al., 1997; Ait-Sahalia, 1996). Maxam (1996) demonstrates the effectiveness of kernel techniques in modeling complex options-pricing functions, and LaCour-Little et al. (1999) apply kernel regression to a large loan-level data set using categorical-variables methods. Thus, nonparametric techniques are of increasing interest in multifactor financial modeling.

We build on this trend. Where previous models have specified functional forms and distributions in linear, nonlinear, and maximum-likelihood regression frameworks, our approach is free of both. Specifically, we employ a nonparametric kernel-density estimation technique to empirically estimate the underlying density and functional form of the prepayment function. This technique offers several advantages in capturing acknowledged optionality in prepayments such as premium burnout, seasoning, and the refinancing incentive without specifying a functional form or underlying distributions. The emphasis in parametric estimation is on obtaining the best estimators of model parameters, whereas in nonparametric estimation the emphasis is on obtaining a good estimate of the entire density function. The parametric versus nonparametric tradeoff is one of efficiency versus incorrect model specification. Recent theoretical advances, computational efficiency, and the availability of large data sets have resulted in an increase in the relative efficiency of kernel estimators.

The organization of the balance of the article is as follows. In Section 2, we present the technical details of the nonparametric density estimation. In Section 3, the mortgage prepayment problem is set up, and the relevant predictive factors are identified. Section 4 describes the data. Section 5 presents results and a comparison among our method and two competitors. Section 6 concludes with some suggested extensions.