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# Term structure estimation in the presence of autocorrelation

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ABSTRACT

This paper assesses the effects of autocorrelation on parameter estimates of affine term structure models (ATSM) when principal components analysis is used to extract factors. In contrast to recent studies, we design and run a Monte Carlo experiment that relies on the construction of a simulation design that is consistent with the data, rather than theory or observation, and find that parameter estimation from ATSM is precise in the presence of serial correlation in the measurement error term. Our findings show that parameter estimation of ATSM with principal component based factors is robust to autocorrelation misspecification.



## 1. Introduction

In the widely used class of affine term structure models (ATSM) of Duffie and Kan (1996), bond yields are assumed to rely on a low dimensional state space (Piazzesi, 2003, chap. 12). Several authors assume that this state space is comprised of certain yields or linear combinations of yields which are chosen to fit the model exactly (e.g., Chen & Scott, 1993; Duffee, 2002; Fisher & Gilles, 1996; Pearson & Sun, 1994).[1] Other yields are taken to be measured with independent and identically distributed (IID) error relative to the model. Since principal components analysis (PCA) is a widely used and easy to implement data reduction tool, it would seem that principal component based factors would provide both a convenient and reasonable specification for affine models. However, while reasonable and

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[1] We use ATSM to refer to dynamic term structure models in which the yield is an affine function of the state variable.

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convenient, a specification that uses PCA is reported to produce implied errors which are highly autocorrelated (Adrian et al., 2013; Duffee, 2011; Hamilton & Wu, 2012, 2014). A model which produces implied errors, computed as the difference between the actual yield and model-implied yield, that are highly autocorrelated contradicts the often assumed IID measurement error structure typically specified for the estimation of affine models.[2] In this paper, we design and run a Monte Carlo experiment to assess the impact of autocorrelation in measurement errors on parameter estimates obtained from the estimation of ATSM when PCA is used to extract factors.

We decide to limit our study to the class of ATSM of Duffie and Kan (1996) because it has been widely studied in the literature (Andersen & Benzoni, 2010; Cassola & Luis, 2003; Christensen, Diebold, & Rudebusch, 2009, 2011; Collin-Dufresne, Goldstein, & Jones, 2008; Cox, Ingersoll, & Ross, 1985; Dejong, 2000; Duarte, 2004; Duffee, 2002; Jegadeesh & Pennacchi, 1996; Langetieg, 1980; Peroni, 2012; Vasicek, 1977). Additionally, we recognize that serial correlation can be a potential issue for any ATSM (Dejong, 2000; Dempster & Tang, 2011; Juneja, 2013) regardless of whether pricing factors are latent, extracted using individual yields, or estimated from PCA. However, the recent increase in the popularity of application of PCA to extract factors for use in modeling ATSM motivates us to focus on PCA (Ang & Piazzesi, 2003; Collin-Dufresne et al., 2008; Graveline & Joslin, 2011; Joslin, Priebsch, & Singleton, 2010; Joslin, Singleton, & Zhu, 2011a; Joslin, Le, & Singleton, 2013a).[3] We study the Joslin, Singleton, and Zhu (2011) (hereafter, JSZ) normalization of the class of ATSM. The JSZ normalization retains all the basic properties of the affine term structure model and its usage enables us to conduct repeated optimizations over a large number of simulation trials using predominantly ordinary least squares estimations, which significantly reduces the computational burden of the estimation relative to other normalizations of the affine term structure models contained in the class of Duffie and Kan (1996).

Our decision to focus on parameter estimation follows from recent work done by Dempster and Tang (2011) and Juneja (2013). Dempster and Tang (2011) design Monte Carlo experiments to assess the impact of serial and cross sectional correlation in measurement errors on parameter estimates obtained from Kalman filtering estimation of alternative affine term structure model specifications. The authors conclude that serial correlation in measurement errors do affect parameter estimates obtained from alternative affine term structure model specifications and propose a new specification to solve the problem. Our Monte Carlo experiment is constructed to be completely consistent with the data and not observation or econometric theory (Bauer, Rudebusch, & Wu, 2012; Dempster & Tang, 2011).

Approaches that are completely consistent with data and experimentation (e.g., data driven simulation methodologies) are advantageous relative to alternative approaches in cases where econometric modeling, economic analysis, and economic decisions are engaged separately (Yang & Cheng, 2010). In such cases, experimentation (e.g., data driven methods) yields more insight than an approach that is justified by theory or observation. This is because experimentation enables us to appropriately separate econometric modeling, economic analysis, and economic decisions. In the current study, the construction of an experiment enables us to first, build a simulated model for the term structure and generate serial correlation in measurement errors, which comprises econometric modeling, and second, provide estimates and analyze (e.g., run statistical tests) an ATSM in the presence of varying amounts of serial correlation. The latter is what comprises economic analysis. Thirdly, and finally, constructing the experiment enables us to draw conclusions regarding the precision of parameter estimates in the presence of varying amounts of serial correlation. The last one comprises economic decisions. All three of these steps are constructed separately and independently, but sequentially. This means that for a data driven approach, the parameter estimates for the model update following the update in the data and measurement error structure enabling us to assess the effects of serial

[2] In affine specifications, the measurement error is the difference between the actual yield and the yield predicted by the model (Fisher & Gilles, 1996).

[3] Raisman and Zohar (2004) and Adrian, Crump, and Moench (2013) also use PCA in the formal development of a term structure model. However, Raisman and Zohar (2004) model their factors using an ARIMA process and not an ATSM. As an alternative to pricing the term structure using a model contained within the class of affine term structure models of Duffie and Kan (1996); Adrian et al. (2013) propose a regression based approach to the pricing of interest rates.