Journal of Banking & Finance 33 (2009) 652–661

Contents lists available at ScienceDirect

Journal of Banking & Finance

journal homepage: www.elsevier.com/locate/jbf

Identifying volatility risk premia from fixed income Asian options ☆

Caio Almeida [a,*], José Vicente [b]

[a] Graduate School of Economics, Getulio Vargas Foundation, Praia de Botafogo, 190, 11th Floor, Botafogo, Rio de Janeiro, Brazil
[b] Research Department, Central Bank of Brazil and Faculdades Ibmec, RJ, Brazil

ARTICLE INFO

Article history:
Received 28 July 2008
Accepted 29 November 2008
Available online 16 December 2008

JEL classification:
C13
G12
G13

Keywords:
Asian options
Risk premium
Stochastic volatility
Incomplete markets

ABSTRACT

Fixed income options are frequently adopted by companies to hedge interest rate risk. Their payoff dependence on the cumulative short-term rate makes them particularly informative about interest rate volatility risk. Based on a joint dataset of bonds and Asian interest rate options, we study the interrelations between bond and volatility risk premia in a major emerging fixed income market. We propose a dynamic term structure model that generates an incomplete market compatible with a preliminary empirical analysis of the dataset. Approximation formulas for at-the-money Asian option prices avoid the use of computationally intensive Fourier transform methods, allowing for an efficient implementation of the model. The model generates a bond risk premium strongly correlated with a widely accepted emerging market benchmark index (EMBI-Global), and a negative volatility risk premium, consistent with the use of Asian options as insurance in this market.

1. Introduction

Interest rate Asian options[1] are frequently quoted by financial houses and largely adopted by banks and corporations to hedge financial costs (Chacko and Das, 2002; Bakshi and Madan, 2002). They are attractive as cheaper alternatives to regular options such as caps, floors and collars, and their potential use as hedging instruments makes them particularly informative about risk premium. In fact, with a payoff structure directly depending on the integral of the short-term rate, they contain useful information on how investors perceive and price volatility risks.[2,3] But, how can we use such options to learn more about interest rate risks?

In this work, we try to answer this question by analyzing the risk premium structure of bonds and Asian interest rate options through the lens of a dynamic term structure model. Risk premium is estimated from joint data on interest rate Asian options and bond prices, and its behavior is analyzed through the implied stochastic discount factor that connects the two markets in the dynamic model.

Although the pricing of Asian options has tremendously developed with the recent Fourier inversion techniques proposed in Bakshi and Madan (2000), and in Chacko and Das (2002), the insertion of such options in the estimation process of a dynamic model remains unexplored. This is the first work that studies risk premium properties of Asian options, and we do so by providing efficient approximation formulas for at-the-money Asian option prices. Those analytical formulas prove useful in identifying volatility premium when the model is estimated. Their main advantage is to avoid an inversion

☆ We are grateful to Marco Bonomo, Luis Braido, Carlos da Costa, Marcelo Fernandes, René Garcia, Scott Joslin, Walter Novaes, and an anonymous referee for their comments and suggestions on earlier versions of the paper. We also thank seminar participants at Pontifícia Universidade Católica do Rio de Janeiro, the Fifth Brazilian Meeting of Finance, the XI School of Time Series and Econometrics, the XXVII Brazilian Meeting of Econometrics, and the 2006 Workshop on Mathematical Economics held at IMPA. The views expressed are those of the authors and do not necessarily reflect the views of the Central Bank of Brazil. The first author gratefully acknowledges support given by CNPq-Brazil.

* Corresponding author. Tel.: +55 21 2559 5828; fax: +55 21 2553 8821.
E-mail addresses: calmeida@fgv.br (C. Almeida), jose.valentim@bcb.gov.br (J. Vicente).

[1] Options that have payoffs depending on the average (or integral) of the short-term rate. Previous papers pricing fixed income Asian options include Geman and Yor (1993), Longstaff (1995), Chacko and Das (2002) among others.

[2] Carr et al. (forthcoming) show, under the Black and Scholes model, that arithmetic Asian call option prices increase with the level of volatility.

[3] Anticipating the necessity of an explicit market measure of volatility risk premium, Brenner et al. (2006) suggested the creation of an option on a straddle to hedge volatility risk. Such instrument, when it exists, provides a direct estimate of volatility risk premium. Nevertheless, to our knowledge, it is not regularly available in fixed income markets.

0378-4266/$ - see front matter
doi:10.1016/j.jbankfin.2008.11.011

of a Fourier or Laplace transform to obtain option prices, which is fundamental when extracting the state vector within the dynamic term structure model.

Note that identifying volatility risk premium should be crucial to reconcile option implied volatilities with observed volatilities in spot markets (Pan, 2002). Thus, our efficient approach could be of direct use to risk managers in search of correctly marking to market interest rate risk factors appearing in integrated fixed income markets. Moreover, by adopting equity data Chernov (2007) showed that a correct estimation of volatility risk premium results in better predictions of future volatility. Therefore, an efficient estimation of volatility risk premium appears to be also relevant to portfolio managers and policymakers since both are clearly interested in forecasting future volatility.

A preliminary empirical analysis of the joint dataset of bonds and at-the-money Asian options suggests that those options are not redundant and that volatility is an important source of incompleteness of the bond market. Based on this information, we propose an affine term structure model (Duffie and Kan, 1996) with unspanned stochastic volatility (USV; Collin Dufresne and Goldstein, 2002) to analyze the risk premium structure of this joint dataset. In the proposed model, volatility of the short-term rate is stochastic and is represented by a Cox et al. (1985) process (CIR process). The price of volatility risk is a time-varying process which implies that the term structure of volatility premia is a joint function of the average cross section of bond yields and of the time series of at-the-money option prices. Volatility of the stochastic discount factor is represented by multiple sources of risk related to term structure movements and to the volatility of the short-term rate.

The incomplete market structure generated by unspanned stochastic volatility is strongly supported by innumerous studies, including those by Collin Dufresne and Goldstein (2002), Heidari and Wu (2003), Li and Zhao (2006), Collin Dufresne et al. (2005) and Han (2007), among others. However, Joslin (2006) has recently observed that a certain subset of USV affine models is not able to reproduce simultaneously the term structure of US yield volatilities and implied volatilities of bond options. This inability is due to restrictions in the mean reversion rates of term structure latent factors that appear in those models. Fortunately, those restrictions are attenuated under term structures with shorter maturities, which is the case of our dataset.[4] This allows our model to succeed in reproducing both bond volatilities and option implied volatilities observed in real data. Moreover, in order to further analyze the adequacy of the proposed model, we perform simulations of the economy implied by its dynamics. Our simulations generate bond and Asian option prices, consistently reproducing the preliminary empirical results that motivated the adoption of an incomplete market model.

Empirical results indicate that bond risk premium[5] is positive during most of the sample period and strongly correlated with an important benchmark for emerging markets debt premium, the EMBI-Global J.P. Morgan index. Model-implied volatility perfectly captures the level of an EGARCH benchmark (see Fig. 5), indicating that volatility risk premium is correctly estimated. Volatility risk premium is a negative and volatile time-varying process, consistent with results observed in equity and currency markets.[6] The positive covariation between the volatility and the stochastic discount factor suggests that the Asian options work as insurance instruments, precisely as suggested by Longstaff (1995), Bakshi and Madan (2002) and Chacko and Das (2002). In addition, volatility risk premium explains a significant portion of bond risk premium (negative correlation of 32.5%), a result related to Bollerslev and Zhou (2006) who find a variance risk premium explaining more than 15% of equity market portfolio excess returns.

Although many authors have studied volatility risk premium in the context of equity and currency markets, the same is not true for fixed income markets. Only two other papers also address this question in the context of interest rates. Fornari (2008) estimates the price of volatility risks from interest rate swaptions on Dollar, Euro, and Pound rates. Based on an asymmetric GARCH model, for all studied markets he finds a negative (and time-varying) volatility risk premium. Despite the similarity of results between his work and ours, the two methodologies adopted are quite distinct. While he extracts volatility premium directly from swaption data only, we extract volatility premium from simultaneously bond and option data, under a continuous time dynamic term structure model that integrates the two markets. Closer in spirit to our paper, Joslin (2007) estimates different affine models based on joint data on US bonds and swaptions, finding support for a negative volatility risk premium, also in line with our results. However, his empirical results support a class of weakly spanned volatility models as opposed to unspanned stochastic volatility models. In contrast, our results indicate that the USV model is able to fit well stylized facts of the joint bond/Asian option markets. Our distinguishing contribution relies on offering a parsimonious and computationally efficient arbitrage-free model to price the volatility risk of Asian options.

The rest of the paper is organized as follows: Section 2 describes the data adopted in the empirical analysis. Section 3 presents the dynamic model and the pricing of zero-coupon bonds and Asian options. In Section 4, the model is estimated by adopting a joint dataset on bonds and options, its ability to correctly price options is tested, and an analysis of model-implied risk premia is provided. Section 5 concludes with some remarks and topics for future research. An online Appendix located at http://www.fgv.br/professor/calmeida[7] contains the proofs of the lemmas used to price IDI options under the proposed USV model, as well as expressions for bond conditional variances.

2. Data and market description

2.1. ID-Futures

The one-day inter-bank deposit future contract (ID-Future) with maturity T is a future contract whose underlying asset is the accumulated daily ID rate[8] capitalized between the trading time $t(t \leqslant T)$ and T. The contract size corresponds to R$ 100,000,00 (one hundred thousand Brazilian Reals) discounted by the accumulated rate negotiated between the buyer and the seller of the contract.

This contract is very similar to a zero-coupon bond, except that it pays margin adjustments every day. Each daily cash flow is the difference between the settlement price[9] on the current day and the settlement price on the day before corrected by the ID rate of the day before.

[4] The dataset is composed of bonds and Asian interest rate options traded in a major emerging market: the Brazilian fixed income market. We explore the fact that in this market Asian options are regularly traded and officially offered by one of the biggest exchanges for futures and options in the world – the Brazilian Mercantile Futures Exchange (BM&F).

[5] The results presented are related to an arbitrarily fixed-maturity of one-year. Providing results to any other maturity would be immediate.

[6] Pan (2002), Eraker (2004) and Garcia et al. (2006) obtain a negative volatility risk premium when estimating variations of Heston (1993) model with or without jumps in prices, and/or volatility. Chernov and Ghysels (2000) find a negative volatility risk premium (positive market price) for most of their sample period.

[7] Also available by e-mail upon request.

[8] The ID rate is the average one-day inter-bank borrowing/lending rate, calculated by CETIP (Central of Custody and Financial Settlement of Securities) every workday. The ID rate is expressed in effective rate per annum, based on 252 business days.

[9] The settlement price at time t of an ID-Future with maturity T is equal to R$ 100,000,00 discounted by its closing price quotation.