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Generalized risk premia ☆

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ABSTRACT

This paper develops an optimal trading strategy explicitly linked to an agent's preferences and assessment of the distribution of asset returns. The price of this strategy is a portfolio of implied moments, and its expected excess returns naturally accommodate compensation for higher-order moment risk. Variance risk and the equity premium approximate it to first order and it nests cross-sectional asset pricing models such as the linear Capital Asset Pricing Model (CAPM). An empirical study in the US index market compares the investment behavior of an agent with recursive long-run risk preferences to one who merely uses an identically independently distributed time series model and takes market prices as given. The two agents exhibit very similar behavior during crises and can be distinguished mostly during calm periods.

1. Introduction

How would an investor who believes in stochastic volatility make her portfolio decisions between trading in the Standard and Poor's 500 index (S&P 500), bonds, and index options? How does an agent with recursive utility and a belief in long-run risk invest in option portfolios? Which kind of preferences does an agent reveal by only specifying time series dynamics for the index and taking prices as given? This paper provides a general framework to answer such questions by introducing a reference claim on the variance of the pricing kernel along with replicating trading strategies with preference-implied portfolio weights, the

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likelihood ratio swap. Similar to how moments can be computed by taking derivatives of the moment-generating function, compensation for moment risk appears order by order in a series representation of the risk premium on the likelihood ratio swap. Analogous to the variance swap which trades implied variance for realized variance, the likelihood ratio swap trades *implied pricing kernel variance* for *realized pricing kernel variance*. In a multivariate context it accommodates both the traditional, as well as a form of the Harvey and Siddique (2000) skew-aware CAPM, where the regression coefficients depend on market prices of options and hence vary with time.

I show how to make the likelihood ratio swap fully tradeable using a model and a panel of options. The resulting trading strategy prescribes portfolio weights on swaps written on conditional moments depending directly on the model parameters and the option-implied forward-neutral density. Since these swaps can be replicated from options and forwards alone, this construction ensures that the exposure implied by a model can be measured in a model-free way. The price of a likelihood ratio swap can be represented as a portfolio of implied moments. The likelihood ratio risk premium associated with the true, unobservable pricing kernel is proportional to first order to the equity and the variance premium. It also reveals that premia on higher conditional moments cannot be independent of each other.

Using data on the S&P 500 index, options written on it, and interest rate data from 1990–2014, I investigate two different types of agents through excess returns on their likelihood ratio swaps which trade their respective preferences optimally. One has Drechsler and Yaron (2011) long-run risk preferences. The other takes the pricing measure as given and merely employs a homoskedastic time series model. Both specifications yield a (different) optimal portfolio allocation in the S&P 500, swaps written on conditional moments of the S&P 500, and in the bond market. The two portfolio allocations generate excess returns the correlation between which is on average close to zero. During crisis times, when most of the action in the likelihood ratio swap portfolio is due to higher moments, the two portfolios co-move. During calm times the two agents disagree the most such that they take opposite sides in the market and their portfolio excess returns are negatively correlated. On average the preferences implied by the investor who just uses a time series model taking prevailing option prices as given, appear to be closer to the true, unknown pricing kernel, than the long-run risk model of Drechsler and Yaron (2011). This is in particular due to the long-run risk model performing badly during the credit crisis starting in 2007.

The strong relation between excess returns on the likelihood ratio swap with the equity and variance premium motivates a set of regressions using ex ante (implied) conditional moments as predictors. A regression of equity excess returns, variance excess returns, and the sum of the two with both classical and robust regressions on the first four implied moments yields adjusted R^2 in the range of 10%.

The theoretical framework employed in this study is rooted in the pricing kernel misspecification literature. It extends Hansen and Jagannathan (1997) and Li, Xu, and Zhang (2010) to time-series-only models in addition to full pricing kernel specifications using all the information contained in option prices. It extends Aït-Sahalia and Brandt (2008) to preferences which may not even be expressed in closed form, waiving the requirement of a solution to the martingale problem and having to approximate Arrow-Debreu securities. It makes the projection of the pricing kernel onto an asset fully tradeable and yields a criterion for model quality, taking into account that risk factors driving the economy are not independent of each other, noted in Harvey and Siddique (2000), Aït-Sahalia and Brandt (2001), and more recently in Chabi-Yo (2012). The technology is similar to Chapman (1997), who approximates the pricing kernel using orthonormal polynomials, with the difference that I make full use of conditional information. In Bekaert and Liu (2004) and Chabi-Yo, Garcia, and Renault (2008) it is argued that using conditioning information is important to improve inference and to alleviate pathologies in asset pricing. The polynomial expansion used in this paper is tradeable and has easily interpreted risk premia, an advantage over the pricing kernel expansion in terms of cumulants in Backus, Chernov, and Martin (2011) and Backus, Chernov, and Zin (2014).[1]

The paper is organized as follows. I start from the definition of the likelihood ratio swap in Section 2. Section 3 then explains how it can be replicated and traded using a model. It also develops connections to the asset pricing literature in a cross-sectional context. Section 4 assesses trading implications of long-run risk recursive preferences against preferences implied by a time series model and observable option prices. Section 5 concludes. Appendix A contains proofs for the claims made in the main text, Appendices B–D develop supplementary technical tools for Section 3. Appendix E provides details of the long-run risk model, and Appendix F contains additional tables.

2. Risk premia and the likelihood ratio swap

This section introduces a benchmark claim which forms the basis for assessing portfolio decisions corresponding to preferences. It also establishes the connection between trading strategies and risk premia.

Risk premia, whether in equity, bond, currency, or other asset markets, have largely been concerned with the first moment of returns with only a few exceptions investigating variance and skewness risk premia (Bakshi, Kapadia, and Madan, 2003; Carr and Wu, 2009; Kozhan, Neuberger, and Schneider, 2013, for instance). Researchers examine the predictability of excess returns to estimate the asset risk premium. An excess return can be interpreted as the profit from a trading strategy, which in the simplest case is to enter into a forward contract on an asset S at time 0, and hold it until expiry at time T. Denoting this forward by $F_{0,T}$ and the T-forward probability measure by $\mathbb{Q}_T$, the profit is

[1] The implications of using raw moments over central moments for risk premia are detailed in Section 3.2, Footnote 9.