



Macroeconomic determinants of stock volatility and volatility premiums



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ABSTRACT

How does stock market volatility relate to the business cycle? We develop, and estimate, a no-arbitrage model, and find that (i) the level and fluctuations of stock volatility are largely explained by business cycle factors and (ii) some unobserved factor contributes to nearly 20% to the overall variation in volatility, although not to its ups and downs. Instead, this “volatility of volatility” relates to the business cycle. Finally, volatility risk-premiums are strongly countercyclical, even more than stock volatility, and partially explain the large swings of the VIX index during the 2007–2009 subprime crisis, which our model captures in out-of-sample experiments.

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1. Introduction

Understanding the origins of stock market volatility has long been a topic of considerable interest to both policy makers and market practitioners. Policy makers are interested in the main determinants of volatility and in its spillover effects on real activity. Market practitioners are interested in the effects volatility exerts on the pricing and hedging of plain vanilla options and more exotic derivatives. In both cases, forecasting stock market volatility constitutes a formidable challenge but also a fundamental instrument to manage the risks faced by these institutions.

Many available models use latent factors to explain the dynamics of stock market volatility. For example, in the celebrated Heston's (1993) model, stock volatility is exogenously driven by some unobservable factor correlated with the asset returns. Yet such an unobservable factor does not bear an economic interpretation. Moreover, the model implies, by assumption, that volatility cannot be forecasted by macroeconomic factors such as industrial production or inflation. This circumstance is counterfactual. Indeed, there is strong evidence that stock market volatility has a very pronounced business cycle pattern, being higher during recessions than during expansions; see, e.g., Schwert (1989a,b), Hamilton and Lin (1996), or Brandt and Kang (2004).

In this paper, we develop a no-arbitrage model where stock market volatility is explicitly related to a number of macroeconomic and unobservable factors. The distinctive feature of this model is that stock volatility is linked to these factors by no-arbitrage restrictions. The model is also analytically convenient: under fairly standard conditions on the dynamics of the factors and risk-aversion corrections, our model is solved in closed-form, and is amenable to empirical work.

We use the model to quantitatively assess how market volatility and volatility-related risk-premiums change in response to business cycle conditions. Our model fully captures the procyclical nature of aggregate returns and the countercyclical behavior

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of stock volatility that we have been seeing in the data for a long time. It makes a fundamental prediction: macroeconomic factors can explain nearly 75% of the variation in the overall stock volatility. At the same time, our model, rigorously estimated through simulation-based inference methods, shows that the presence of some unobservable and persistent factor is needed to sustain the level of stock volatility that matches its empirical counterpart. Moreover, our model reveals that macroeconomic factors substantially help explain the variability of stock volatility around its level—the volatility of volatility. That such a “vol-vol” might be related to the business cycle is indeed a plausible hypothesis, although clearly, the ups and downs stock volatility experiences over the business cycle are a prediction of the model in line with the data, not a restriction imposed while estimating the model. Such a new property we uncover, and model, brings practical implications. For example, business cycle forecasters might learn that not only does stock market volatility have predicting power, as discussed below; “vol-vol” is also a potential predictor of the business cycle.

Our second set of results relates to volatility-related risk-premiums. The volatility risk-premium is the difference between the expectation of future market volatility under the risk-neutral and the true probability. It quantifies how a representative agent is willing to pay to be ensured against the event that volatility will raise beyond his own expectations. Thus, it is a very intuitive and general measure of risk-aversion. We find that this volatility risk-premium is strongly countercyclical, even more so than stock volatility. Precisely, volatility risk-premiums are typically not very volatile, although in bad times, they may increase to extremely high levels, and quite quickly. We undertake a stress test of the model over a particularly uncertain period, which includes the 2007–2009 subprime turmoil. Ours is a stress test, as (i) we estimate the model using post-war data up to 2006 and (ii) feed the previously estimated model with macroeconomic data related to the subprime crisis. We compare the model's predictions for the crisis with the actual behavior of both stock volatility and the new VIX index, maintained by the Chicago Board Options Exchange (CBOE), which is, theoretically, the risk-adjusted expectation of future volatility within one month. The model tracks the dramatic movements in this index, and predicts that countercyclical volatility risk-premiums are largely responsible for the large swings in the VIX occurred during the crisis. In fact, we show that over this crisis, as well as in previous recessions, movements in the VIX index are determined by changes in such countercyclical risk-premiums, not by changes in the expected volatility.

1.1. Related literature

1.1.1. Stock volatility and volatility risk-premiums

The cyclical properties of aggregate stock market volatility have been the focus of the recent empirical research, although early work relating stock volatility to macroeconomic variables dates back to King et al. (1994), who rely on a no-arbitrage model. In a comprehensive international study, Engle and Rangel (2008) find that high frequency aggregate stock volatility has both a short-run and long-run component, and suggest that the long-run component is related to the business cycle. Adrian and Rosenberg (2008) show that the short- and long-run components of aggregate volatility are both priced, cross-sectionally. They also relate the long-run component of aggregate volatility to the business cycle. Finally, Campbell et al. (2001), Bloom (2009), Bloom et al. (2009) and Fornari and Mele (2010) show that capital market uncertainty helps explain future fluctuations in real economic activity. Our focus on volatility risk-premiums relates, instead, to the seminal work of Dumas (1995), Bakshi and Madan (2000), Britten-Jones and Neuberger (2000), and Carr and Madan (2001), which has more recently stimulated an increasing interest in these premiums dynamics and determinants (see, for example, Bakshi and Madan, 2006; Carr and Wu, 2009). Notably, in seminal work, Bollerslev and Zhou (2006) and Bollerslev et al. (2011) unveil a strong relation between volatility risk-premiums and a number of macroeconomic factors.

Our contribution hinges upon, and expands, over this growing literature, in that we formulate and estimate a fully-specified no-arbitrage model relating the dynamics of stock volatility and volatility risk-premiums to business cycle, and additional unobservable, factors. With the exception of King et al. (1994) and Adrian and Rosenberg (2008), who still have a focus different from ours, the predicting relations in the previous papers, while certainly useful, are still part of reduced-form statistical models. In out-of-sample experiments of the subprime crisis, our no-arbitrage framework will be shown to be considerably richer than that based on predictive linear regressions. For example, compared to our model's predictions about stock volatility and the VIX index, predictions from linear regressions are substantially flat over the subprime crisis.

The only antecedent to our paper is Bollerslev et al. (2009), who develop a consumption-based rationale for volatility risk-premiums, although then, the authors use this rationale only as a guidance to the estimation of reduced-form predictability regressions conditioned on the volatility risk-premium. In recent independent work discussed below, Drechsler and Yaron (2011) investigate the properties of the volatility risk-premium, implied by a calibrated consumption-based model with long-run risks. The authors, however, are not concerned with the cross-equation restrictions relating the volatility risk-premium to state variables driving low frequency stock market fluctuations which, instead, constitute the central topic of our paper.

1.1.2. No-arbitrage regressions

In recent years, there has been a significant surge of interest in consumption-based explanations of aggregate stock market volatility (see, for example, Campbell and Cochrane, 1999; Bansal and Yaron, 2004, Tauchen, 2005, Mele, 2007, or the two surveys in Campbell, 2003 and Mehra and Prescott, 2003). These explanations are important because they highlight the main economic mechanisms through which markets and preferences affect equilibrium asset prices and, hence, stock volatility. In our framework, cross-equations restrictions arise through the weaker requirement of absence of

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