



International stock market cointegration under the risk-neutral measure[☆]



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ABSTRACT

This paper investigates international cointegration and financial integration among equity market indexes using index option data, providing an ex-ante analysis through investor anticipations. Daily time series of risk-neutral variance, skewness, and kurtosis are constructed for five major indexes for three sub-periods between 2003 and 2013. Fractionally cointegrated VAR models are estimated at the international level, accounting for persistence in risk-neutral moments. Our results show that there exist international equilibria in risk-neutral moments defined by several cointegrating vectors. During the 2007–2009 global crisis period, these equilibria are characterized by an increase in persistence and in the speeds of adjustment. Moreover, for risk-neutral variance and skewness, all markets are included in the equilibria and none are weakly exogenous. Outside the global crisis period, the cointegration relationship is more fragmented, especially for higher-order moments. In particular, crash and tail risks are segmented during the European debt crisis.

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1. Introduction and motivation

1.1. Introduction

Common stochastic trends in international financial markets and financial integration have important implications for international diversification. In fact, gains to diversifying internationally are small if stock indexes share a common stochastic trend (Kasa, 1992), if indexes are financially integrated and systematic risk is priced similarly in several markets (e.g. Mittou, 1992; Berger & Pozzi, 2013), or if there are volatility spillovers across markets (Baele, 2005; Jiang, Konstantinidi, & Skiadopoulos, 2012; Karolyi, 1995). In this literature, several authors have looked at financial crises. For instance, Eurozone sovereign debt contagion has been documented recently, with time-varying effects (Suh, 2015) and sizable joint tail risks (Lucas, Schwaab, & Zhang, in press). Mollah, Quoreshi, and Zafirov (2016) have shown that contagion has spread from US markets to international markets during the global financial crisis and the Eurozone crisis.

In this paper, rather than use historical data, we propose a novel approach using option data to investigate the common trend in risks affecting five major indexes. As option-implied data on important stock indexes are very rich, this paper provides forward-looking measures of financial cointegration and financial integration across different dimensions of risk. This paper therefore fills a gap in the literature by combining two large and active literatures, namely on the time series analysis of market cointegration, and on the information content of risk-neutral distributions. We study how shocks spread internationally under the risk-neutral measure, which better reflects the impact of disturbances (e.g., Birru & Figlewski, 2012; Konstantinidi, Skiadopoulos, & Tzagkaraki, 2008). We obtain and analyze at a daily frequency the variance, skewness, and kurtosis of the risk-neutral distribution obtained from international equity index options. Following model estimation, we perform statistical tests of cointegration, exclusion (defined as financial integration) and weak exogeneity that highlight how and to what extent anticipations spread internationally.

Our results shed new light on financial cointegration and reveal the existence of an equilibrium relationship in international anticipations, in addition to the one reported in the literature for historical returns. Our results also show that risk-neutral variance is more integrated, with greater international linkages, than are risk-neutral skewness and kurtosis. Our evidence regarding higher-order moments allows us to further document the issue and reveals that anticipations are not as integrated as ex-post returns and that fear of crashes and tail risk are locally driven. In particular, the DAX and CAC indexes are excluded

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from the higher-order moment equilibria during the sovereign debt crisis. For all moments, persistence, speed of adjustment and financial integration increase during the 2007–2009 global crisis.

1.2. Review of the literature: the relevance of risk-neutral moments in cointegration analysis

This paper contributes to the literature on cointegration analysis, market integration, and volatility spillovers. Since Kasa (1992), who documented a common stochastic trend in the quarterly equity index prices of five developed countries, cointegration analysis has been used to assess stock market interdependence (Bessler & Yang, 2003; Darrat & Zhong, 2005). There is, in particular, a growing recent literature on the process of integration in European markets (Mylonidis & Kollias, 2010; Kim, Moshirian, & Wu, 2005; Demian, 2011; Syriopoulos, 2007). For example, despite the high correlation between market indexes, Lucey and Muckley (2011) have found evidence of valuable long-term diversification potential in European markets suggesting that other metrics of risk could be relevant. Related to our contribution based on risk-neutral variance, volatility spillovers also provide evidence of financial integration (e.g., Bekaert, Harvey, & Ng, 2005; Karolyi, 1995). Volatility spillovers can be driven by contagion (King & Wadhvani, 1990) and during the Eurozone crisis of 2010–2011, there was strong evidence of spillovers (Kohonen, 2013).

Nearly all studies of cointegration or volatility spillovers are, however, performed using ex-post realizations of prices or returns. Much less evidence has been uncovered to describe how forward-looking investor sentiment such as anticipations, fears, or the perception of crash and tail risk in financial markets might spill over across international markets ex-ante. This gap in the literature motivates looking at risk-neutral distributions implied from option data. Indeed, option data are informative to investors, especially in times leading to a crisis (Birru & Figlewski, 2012). For instance, incorporating option market information improves downside risk management (Brownlees, Engle, & Kelly, 2011) and portfolio selection (DeMiguel, Plyakha, Uppal, & Vilkov, 2013; Kempf, Korn, & Saßning, 2015; Kostakis, Panigirtzoglou, & Skiadopoulos, 2011).

Risk managers and policymakers are concerned with higher-order moments of return distributions. It is well understood in the literature that it is challenging to recover moments of the distribution using historical data, and that moments can be estimated more reliably using option data (Bali, Cakici, & Chabi-Yo, 2011; Birru & Figlewski, 2012; Conrad, Dittmar, & Ghysels, 2013; DeMiguel et al., 2013). Using these methods, risk-neutral moments have been shown to forecast realized returns and to have cross-sectional explanatory power (Bali & Murray, 2013; Chang, Christoffersen, Jacobs, & Vainberg, 2012; Conrad et al., 2013; Duan & Wei, 2009; Bollerslev, Osterrieder, Sizova, & Tauchen, 2013; Neumann & Skiadopoulos, 2013). Yet a comprehensive study of international linkages at the level of anticipations seems lacking.

In addition, our paper builds on a strand of the literature which suggests that *risk-neutral moments* in particular are related to important risk metrics in financial markets. Bakshi, Kapadia, and Madan (2003) find that when jump risk is priced in the markets, it is reflected in both the third and fourth risk-neutral moments. Duan and Wei (2009) and Dennis and Mayhew (2002) find that higher-order risk-neutral moments are driven by systematic risk. Risk-neutral moments also have a meaningful economic interpretation in terms of interdependence across borders. Risk-neutral variance is associated with market expectations of near-term volatility. The VIX in the U.S. is considered to be an investor “fear gauge” (Whaley, 2000; Malz, 2013; Panigirtzoglou & Skiadopoulos, 2004). Higher-order risk-neutral moments also have an economic interpretation in terms of internationally-linked risk. Risk-neutral skewness represents the risk of negative asymmetric returns, and has been related to “crash-phobia” risk (see e.g. Jackwerth, 2000; Rubinstein, 1994). Risk-neutral kurtosis relates to tail risk or the risk associated with extreme observations under the risk-neutral measure. Both risk-neutral skewness and risk-neutral kurtosis are also related to jump risk (Pan, 2002).

1.3. Contributions to the literature

Based on this literature, we aim to measure the interdependence of investor anticipations internationally, using index option market data. Studying international time series of risk-neutral moments therefore provides a novel ex-ante measure of market cointegration and integration. Moreover, given the relevance of risk-neutral moments, this paper is distinctive for studying moments while most of the existing studies on this subject have been conducted on prices or returns.

Thus, we aim to further clarify the question of financial cointegration by disaggregating the problem into different dimensions of risk captured by variance, skewness, and kurtosis. Investigating individual moments allows us to identify which characteristic of the distribution drives the cointegrating relationship. Intuitively, each moment relates to a different type of risk that a manager might want to hedge, or alternatively get exposure to. Our contributions to the financial literature have practical implications in terms of hedging and diversification. Our results show a strong and binding equilibrium during the crisis, which suggests a lower potential for diversification and a higher degree of financial integration. However, the international equilibria for higher-order moments are more fragmented than for risk-neutral variance. These findings enrich the literature by showing there are underestimated potential benefits of international diversification for anticipations of crash risk and tail risk, but also that during the crisis period these diversification benefits are more limited.

2. Data

First, the methodology to recover the daily time series of risk-neutral moments used in the analysis is presented in this section, in a sequential order. The approach is based on Birru and Figlewski (2012).

a) Raw options data for each day and descriptive statistics

Index options data are extracted from the OptionMetrics Ivy DB database for the United States (S&P 500) and its European version for Germany (DAX), Great Britain (FTSE), France (CAC40), and Switzerland (SMI). The chosen indexes are relevant for our purposes and comparable in terms of risk, as they represent subsets of large and liquid stocks in each country. As Germany and France are often seen as the economic locomotives of the Euro currency zone, we should expect investor anticipations to be integrated across the two markets, but whether it is the case remains an empirical question. The British market and the London exchange are important to international markets, allowing us to study changes in anticipations of a large open economy outside the Eurozone. Finally, the introduction of Switzerland in the analysis provides evidence regarding smaller open economies that are outside the Eurozone, but which are deeply affected by the international flow of funds.

Table 1 presents descriptive statistics associated with the options for each index. The selected option markets are comparable in terms of the number of options traded on average each day, and in terms of implied volatility and the number of strikes per day. Given the similarities reported at the market level, the resulting risk-neutral distributions show exhibit similar levels of precisions.

Mylonidis and Kollias (2010) describe possible changes in the long-run relationship of the Eurozone market integration. To account for this possibility and to further document the differences in persistence and equilibrium relationships during crises, we divide our sample in three sub-periods: the pre-crisis period (2003/04/14 to 2007/06/21), the crisis period (2007/06/22 to 2009/06/30) and the post crisis period (2009/07/01 to 2013/12/31). The date June 22, 2007 which begins the second sub-period is chosen to reflect when it became clear to financial markets that Bear Sterns' problems were significant (e.g., the necessary \$3.2 billion secured loan) and it was considered then “an early sign of problems in the mortgage market” (Financial Times, March 22, 2008).

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