Creating financial risk maps to study relationships in commodity markets

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Abstract:
In recent years, commodity markets have experienced rapid growth in liquidity and an influx of investors who are attracted to commodities purely as an investment (financial assets and securities), rather than as a means to support “real” economic activity via the hedging of risks (Vivian and Wohar, 2012). The large swings in gold, oil and wheat prices are associated with financial crashes, wars and adverse weather conditions. In this framework, commodity markets have attracted much attention in both academia and industry since the early 2000s, but some interesting open questions still remain unresolved.

First of all, large financial inflows into commodity markets, termed the “financialization of commodity markets”, has dramatically increased the correlation between a large number of commodities (Tang and Xiong, 2012). Though recent research provides some evidence of structural change in correlation, most of these studies do not fully account for the information of higher moments or model the joint distribution of futures returns, partly due to the paucity of flexible multivariate distributions in the literature. Since many assets such as stocks, bonds and commodities that historically show low correlation tended to crash together during the recent financial crisis, understanding time-varying co-movements of commodities becomes crucial from a risk management perspective.
Secondly, the transmission mechanism and co-movement of volatility between commodities is still not clear. Adams and Gluck (2015) show significant risk spillover from stocks to commodities, but they only measure spillover using value-at-risk and do not consider how shocks in one market may affect volatility in another. Modelling volatility spillover allows us to quantify the magnitude and direction of volatility shocks of various commodities with a causal interpretation, which is not readily available by modelling co-movements alone. As a result, measures of market connectedness based on volatility or risk spillover may help inform portfolio construction and diversification.

This paper attempts to study the dynamics of co-movements among different commodity risk measures by employing high dimensional correlation models, and to develop a variety of new connectedness measures for commodity markets based on financial risk mapping.

Understanding time-varying volatility and the volatility transmission mechanisms found across different types of markets has been essential to both international investors and policy-makers. Most related studies test volatility spillover among different key stock markets or between the crude oil market and financial markets (e.g., Arouri et al., 2012; Du et al., 2011; Hassan and Malik, 2007; He and Chen, 2011; Kumar et al., 2012; Lien and Yang, 2008; Malik and Ewing, 2009; Serra, 2011; Singh et al., 2010; Syllignakis and Kouretas, 2011; Yilmaz, 2010). Several empirical methods were used in these studies. For example, the Multivariate Generalized Autoregressive Conditional Heteroskedasticity (MGARCH) model was employed to analyse the relationship between political and economic news, on the one hand, and the conditional volatility of financial variables, on the other (Fornari et al., 2002), and the effect of macroeconomic shocks on financial sectors (Ewing et al., 2003). More recently, the vector autoregressive-Generalized Autoregressive Conditional Heteroskedasticity model (VAR-GARCH) has been widely used to examine temporal volatility spillovers between developed and emerging stock markets (Singh et al., 2010). Studies of volatility spillovers also have important implications for portfolio management, the development of accurate asset pricing models and the forecasting of future equity and the volatility of oil price returns (Malik and Hammoudeh, 2007). Moreover, previous studies focused on volatility spillovers by investigating volatility in emerging and developed financial markets (Wang and Wang, 2010; Yilmaz, 2010).

This paper makes two key contributions to the current literature. First, we explore the joint dynamics of the dependence structure of nine commodity indices during different distress periods. Tang and Xiong (2012) find increasing correlation since 2004; however, they model the dynamics of correlations by means of rolling windows for all pairwise combinations of commodities one after another, which is inefficient as they do not explicitly take all the relevant information into account and their findings are not necessarily robust to the structural change in correlations. Adams and Gluck (2015) consider structural breaks in correlations but their sample only includes eight commodities, and they do not provide a joint estimation of the dependence structure in futures returns. Second, we investigate the propagation in these commodities as a measure of market connectedness, with a financial risk map created using Multidimensional Scaling (MDS) methodology, as in Fernández-Avilés and Montero (2016), based on the expected shortfall of index returns. Adams and Gluck (2015) study spillover in the left tails of return distributions (Value-at-Risk or VaR) and regress individual VaR on many other VaR, such as those of stock markets, commodity
markets and emerging markets. Their method directly models shocks from various markets to individual commodities. In contrast, we use indices of all commodity markets and expected shortfall (ES) as a risk measure because it is more coherent than VaR (See, Artzner et al, 1999).

The main body of literature focuses on the effect between energy and stock markets, but few studies have examined relationships within the different commodities markets. In this vein, Algerie and Leccadito (2017) find that the oil market contributes more to contagion than metal and food markets. Moreover, it emerges that there are spillovers from energy to food markets, and that oil is more important than biofuel in affecting food markets. Cheng and Wu (2016) report that the connectedness of commodity markets increased during the 2007-2009 financial crisis, but have since returned to pre-crisis levels. They also find that the recent downward movement of commodity prices does not necessarily indicate a stronger connection between commodity markets, which challenges recent studies on commodity financialization.

The paper which is most closely related to our research is that of De Nicola et al. (2016), who study the degree and evolution over time of unconditional and conditional correlations among energy and food commodities using a uniform-spacings estimation and testing approach, multivariate dynamic conditional correlation models, and a rolling regression procedure. They find that the price returns of energy and agricultural commodities are highly correlated, and that the overall level of co-movement among commodities increased in recent years, especially between energy and agricultural commodities, and in particular in the cases of maize and soybean oil, which are important inputs in the production of biofuels. In this paper, however, we compute a complete financial risk map for the commodity market using the multidimensional scaling on expected shortfall estimates.

Regarding the methodology, we employ multidimensional scaling to create financial risk maps. MDS can be used to reveal associations and structures in financial time series, without imposing any restrictions (for example, preconceptions about which factors may drive each dimension). One of the major advantages of MDS is that it represents the objects under study (in our case financial objects, or more specifically, risk measures based on commodity series returns) as points on a map, so that highly correlated objects will be close to each other on that map and objects that are weakly (or even negatively) correlated will be far apart. Therefore, the MDS maps can be interpreted intuitively (Neophytou and Mar-Molinero, 2001).

We consider monthly commodity index series for different sectors over the January 1970–December 2016 period, sourced from the World Bank database (https://www.quandl.com/collections/markets/commodities), with \( t = 564 \) being the number of monthly observations. We investigate nine different commodities indexes covering the following sectors: Energy, Metals and minerals, Beverages, Fats and oils, Fertilizers, Grains, Food, Raw materials, Timber. All price series are quoted in US dollars. The computational analysis was carried out with R statistical software (R Core Team, 2017). In this paper, we present a global (1970-2016) financial risk map, which highlights the following facts. First, the Energy index is plotted on the map as an outlier with very high risk; this index has the highest ES. Second, the indexes for Timber and Beverages are represented in a small cluster very far from Energy and the rest of the
indexes; they show the second highest ES. Fat and Oils lies alone, but very close to the other indexes. Finally, there is a large cluster comprising Fertilizers, Grains, Metals and Minerals, Food and Raw Materials, which are the indexes with the least risk. The main evidence suggests that the behaviour of the energy market differs from that of the other commodity markets for most of the distress period considered. Moreover, the commodity markets show an increase in co-movements in crisis periods.

**Keywords:** Commodity Market Indexes, Expected Shortfall, Financial risk maps, Multidimensional scaling.

**JEL codes:** G10, C10
References:


