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Stress-testing for portfolios of commodity futures

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A B S T R A C T

In this paper, we perform stress-testing for a portfolio of commodity futures which mimics the dynamics of the DJ–UBS index. We identify extreme events that impacted commodity prices over time and look at correlation structures in a dynamic way, with copula functions. In line with Basel III financial regulations, we derive baseline, historical, and hybrid scenarios and discussed their advantages and shortfalls. We find that the financialization of commodity markets led to an increase in correlations and in the probability for joint extremes. However, we identify structural breaks in commodity markets that temporarily led to a breakdown of expected statistical patterns and of traditional dependence structures among commodities. This fact shows the need for forward-looking stress testing techniques, like hybrid and hypothetical scenarios, as encouraged by financial regulators.

1. Introduction

1.1. Overview and motivation

Investments in commodities have grown rapidly over the last years mainly via commodity futures and commodity index funds (Müller et al., 1998) and many institutional managers have embraced commodities as a profitable alternative asset (Daskalaki and Skiadopoulos, 2011). Recent literature has established that commodity futures can serve as diversification instruments in conventional portfolios because of their low correlations with equities and bonds (Füss et al., 2010). These characteristics could encourage investors to choose commodities as a refuge during periods of stress in traditional asset markets, especially if macroeconomic shocks tend to impact commodity and stock prices in opposite directions (Silvennoinen and Thorp, 2013). Apart from their hedging function for commercial traders, commodities are now regarded by investors as good alternative investments due to their historically low correlations with other asset classes.

One of the consequences of the increasing financialization of commodities, especially through the introduction of commodity indices (Tang and Xiong, 2012) is the increase of volatility shocks in these markets. Recent studies documented that volatility shocks in commodity markets have significant effects on the financial markets (Aloui and Mabrouk, 2010; Driesprong et al., 2008). In addition, the growing presence of index funds in commodity markets integrates the commodity — with the stock and bond markets (Silvennoinen and Thorp, 2013). This high price volatility has led to a growing concern of the public and in policy circles as to whether financialization has distorted commodity prices, and whether more government regulation in these markets is warranted (Basak and Pavlova, 2013; Cheng and Xiong, forthcoming).

For this reason, forecasting futures prices of commodities and managing their associated risks have become a crucial issue for central governments, businesses and corporations. In the empirical literature on commodity markets the focus has generally been on: i) financialization of commodity markets (Basak and Pavlova, 2013; Cheng and Xiong, forthcoming; Singleton, 2014); ii) the effect of commodity prices and in particular oil prices on the economy and stock markets (see Delatte and Lopez, 2013; Driesprong et al., 2008; Narayan et al., 2013); iii) commodity futures pricing (see Brooks et al., 2013); iv) relationship between the commodity futures market and the commodity spot market (Coppola, 2008; Narayan and Sharma, 2011); v) forecasting the volatility of commodity futures market (Kang and Yoon, 2013; Sadorsky, 2006); and vi) risk management for commodity markets (Chkili et al., 2014; Ghorbel and Trabelsi, 2014).

Our paper focuses only on the risk management and extends the literature on risk measurement techniques applied to commodity markets. Given the exponential growth of investments in commodity indices by institutional investors, the question of adequate risk management tools for those indices in the context of a broader portfolio of financial securities is of great interest. Thus, a good knowledge of commodity futures pricing helps investors to understand the underlying risks and enables them to compose optimal portfolios (Brooks et al., 2013). In the volatile world of commodity markets, quantifying and mitigating price risks present a number of challenges due to the time dependence in volatility, non-linear dynamics and heavy tails in returns (Bali and Neftci, 2003; Mandelbrot, 1963; Müller et al., 1998; Nomikos and Pouliasis, 2011). Consequently, many forecasting models, risk

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measurement techniques and hedging tools have been developed during the last decades (Aloui and Mabrouk, 2010). Their main purpose is to provide financial institutions, risk managers and commodity traders with a technical approach to quantify financial and commodity risks.

Value-at-Risk (VaR) and stress testing have emerged as two of the most popular risk management tools. A stress test is a risk management tool used to evaluate the potential impact on portfolio values of unlikely, although plausible events or movements in a set of financial variables (Lopez, 2005). It is further designed to explore the tails of the distribution of losses beyond the threshold (typically 99%) used in Value-at-Risk (VaR) analysis (Alexander and Sheedy, 2008). Stress testing has become a major financial methodology in the risk management field, not only because it can assist financial institutions in understanding the effect of stress scenarios, but also because it can help with calculating risk measures that focus on extreme market conditions (So et al., 2013). Over the last two decades, many investors have suffered sizeable losses due to extreme events. Examples of such events include the 1987 crash, the Asian and Russian crises of 1997 and 1998, the burst of the dot-com bubble in 2000, the failure of Lehman Brothers in 2008, and the European debt crisis. Since the occurrence of these events, the importance of risk management has been extensively recognized by investors when deciding the amount of risk they are willing to bear (Alexander and Baptista, 2009).

Under Basel II, risk managers performed stress testing based on historical scenarios, defined based on the losses experienced during a historical period of market stress. However, in this way, the maximum simulated loss is bounded to the historically observed loss and this stress testing technique cannot extrapolate beyond that. It became therefore obvious after the recent financial crisis that the stress testing techniques must be reviewed. Thus, Basel III proposes forward-looking stress scenarios like hypothetical or hybrid scenarios. In this paper, we will discuss the advantages of forward-looking stress scenarios versus historical ones and discuss extensively the implications for risk managers. The severity of the current global financial crisis determined a deep review of risk management practices by regulators in attempting to reduce the fragility of financial systems (see BIS, 2010). The current global financial crisis showed that the backward-looking historical data was of limited use in anticipating market turbulence (Basu, 2011).

Another major flaw of traditional financial theory is the overreliance on correlations as a tool to track dependencies between different assets. An inappropriate model for dependence structures among the risk factors can lead to suboptimal portfolios and inaccurate assessments of risk exposures (BIS, 2009; Kole et al., 2007). The historical data provide substantial evidence of extreme levels of co-movement in financial returns during episodes of financial turmoil and, therefore, the correlation matrix of the underlying asset returns of a portfolio can change dramatically when a financial crisis occurs. In adverse situations, correlations can move to unexpectedly extreme levels either upwards or downwards (see Bhansali and Wise, 2001). Traditionally, correlation is used to describe the dependency between random variables, but recent studies have ascertained the superiority of copulas, as they offer much more edibility than the correlation approach (Embrechts et al., 2011; Weiss, 2011). Copula models have become a major tool in statistics for modeling and analyzing dependence structures between random variables and it has been often used for risk management purposes, and especially for stress testing, due to the fact that in contrast to linear correlation a copula captures the complete dependence structure inherent in a random vector. Copulas allow capturing stylized facts of financial returns such as fat tails and skewness. Moreover, copulas are not a number such as correlation, but functions, which allow them to accurately map varying levels of dependency between assets, and more specifically to capture tail dependency.

Financial risk management typically deals with low-probability events in the tails of return distributions. It is therefore important to be able to model the extreme events accurately. Traditional risk management models, however, might fail to give us accurate estimates and forecasts of the tails because they usually focus on the whole distribution, of which the tails are just small portions. Extreme value theory based risk management, on the other hand, focuses directly on the tails and could therefore potentially give us better estimates and forecasts of risk (Byström, 2005). The modeling of extreme events is the central issue in extreme value theory (EVT), and the main purpose of the theory is to provide asymptotic models for the tails of a distribution. EVT helps forecasting much more accurately the potential returns of a portfolio through robust stress-testing methods (Aepli, 2014).

Despite the rise of commodity indices, EVT and copula applications for stress testing purposes have rarely been used for commodities. The vast majority of papers applying EVT to finance employ time series from the stock market. The second most frequent source of data is probably exchange rates, but there are articles dealing with almost any kind of data, from equity returns and interest rates to energy and commodity market data and up to credit derivative data (Rocco, 2014). To our knowledge, EVT and copulas have been extensively applied to equities and currency portfolios (see Gencay and Selcuk, 2004; Haile and Pozo, 2006; Patton, 2006), but rarely to portfolios of commodity futures.

In this paper, we will show how EVT can be used to properly estimate the distribution of commodity futures, by focusing on a portfolio composed of the ten most important commodity futures in the DJ–UBS index. We apply a combined approach of extreme value theory (EVT) for modeling the risk factors and we look at the dependency structures in a dynamic way, with copula functions. We further perform stress testing in accordance with Basel III regulations. Our study contributes to the empirical literature on the risk management in several ways. First, we focus on one portfolio of commodities that are in the focus of financial investors over the last years. We show the importance of identifying extreme events in the evolution of risk factors and compute their impact on the final profit and loss distribution. Second, we show clear examples of the value added of hybrid and hypothetical forward-looking scenarios versus historical ones. This is of great importance for practitioners, since often financial regulations are restricted to theoretical discussions and lack in empirical support. Third, we bring evidence that the overreliance on historical simple correlations can induce misleading stress testing results. As further implications, joint forecasting models based on historical correlations have serious drawbacks in accurately forecasting the profit and loss in times of market stress.

1.2. Literature overview on stress testing

In this subsection, we give an overview of the existing literature on stress testing methodologies for futures prices. One comprehensive example of complex stress testing techniques for portfolios of futures can be found in Aepli (2011). The authors built an intuitive stress testing tool that helps risk managers to perform forward-looking scenario analysis, in line with the requirements of the post-crisis financial regulations.

Examples of studies that applied EVT and copulas to commodity prices are Aepli (2014), Byström (2005), Grégoire et al. (2008), and Marimoutou et al. (2009). These studies compared the performance of EVT to conventional models such as GARCH, Historical Simulation and Filtered Historical Simulation on oil markets and their results indicate that conditional extreme value theory and Filtered Historical Simulation procedures offer a major improvement over the traditional methods.

Giot and Laurent (2003) assessed the performance of RiskMetrics, skewed Student APARCH and skewed Student ARCH models to measure VaR of returns in commodity spot and futures markets. The skewed Student APARCH model provides the best performance in all cases. Ghorbel and Trabelsi (2014) provided a comparative study of the predictive ability of energy two- and three-dimensional portfolio VaR estimates by employing various estimation techniques. Their results show that Filtered Historical Simulation, conditional EVT and