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On the risk comovements between the crude oil market and U.S. dollar exchange rates☆

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ABSTRACT

This article examines the volatility dependence between crude oil market and four US dollar exchange rates by means of both fractional cointegration and copula techniques. The former exploits the long memory behavior of volatility processes to investigate whether they are tied through a common long-run equilibrium. The latter is complementary as it allows exploring whether the market volatility is linked over the short run. The cointegration results conclude in favor of long-run independence for the Canadian and Japanese exchange rates while few evidence of long-run dependence is found for the European and British exchange rates. Concerning the copula analysis, we conclude in favor of weak dependence when we consider the static copulas. Considering the time-varying copulas, it appears that dependence is sensitive to market conditions as we found increasing linkages just before the 2008 market collapse and more recently, in the aftermath of the European debt crisis.

1. Introduction

Since the US Dollar (USD) is the major invoicing currency for international crude oil trading, it is well established that oil prices and USD exchange rates display strong linkages (see Reboredo and Rivera-Castro, 2013). The renewed interest in oil price and USD relationships has been stimulated by suggestive comovements on these markets, particularly since the beginning of 2000. Such a junction has important implications on both the real economy and financial markets notably through their consequences on inflation dynamics, conduct of monetary policy, external imbalances, price setting and hedging strategies. Understanding how crude oil and foreign exchange markets interact is therefore of great interest for policymakers and investors.

Given that crude oil is internationally traded in USD, a weaker USD reduces oil prices for foreigners in terms of their home currency, leading to large sums of money flow to the oil market, thus driving up crude oil prices in USD. On the supply side, it tends to raise oil prices in order to stabilize the purchasing power of oil exporting countries. Empirical evidence on the effect of a weak dollar on the rise in oil prices is reported by, e.g. Beckmann and Czudaj (2013), Akram (2009), Zhang et al. (2008), and Yousefi and Wirjanto (2004). Conversely, the theoretical literature also points out the potential role of oil prices in determining exchange rate movements. Accordingly, increasing oil prices lead to exchange rate appreciation for oil-exporters and depreciation for oil-importers through positive changes in oil export revenues and energy import bills respectively (see e.g. Golub, 1983; Krugman, 1983). Consistently with this explanation, many empirical researches provide evidence of a significant causality running from oil prices to USD exchange rates (see e.g. Bénassy-Quéré et al., 2007; Chen and Chen, 2007; Huang and Guo, 2007; Coudert et al., 2008). Other studies such as Reboredo et al. (2014), Reboredo and Rivera-Castro (2013), Ding and Vo (2012) and Salisu and Mobolaji (2013) find bi-directional causality depending on the period under study. Finally, some copula-based studies analyze the dependence structure between these markets without investigating causality (see e.g. Reboredo, 2012; Wu et al., 2012; Aloui et al., 2013).

Most of these studies focus either on price or return relationships while only a few focus on volatility. For instance, Ding and Vo (2012) estimate a multivariate stochastic volatility (SV) model and find a bi-directional transmission between oil and foreign exchange markets. Soucek and Todorova (2014) propose a multivariate version of the heterogeneous autoregressive (HAR) model accounting for jumps and leverage effects and document significant spillovers between both markets. Finally, Salisu and Mobolaji (2013) investigate volatility transmission between oil prices and USD–Nigeria exchange rate by using a VAR-GARCH model accounting for structural breaks. Authors also find

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significant linkages between the two markets. One drawback of these papers is that they neglect the persistent nature of volatility as they assume an exponential rate of decay of the autocorrelation function. This long memory feature, that implies volatility long-run dynamics, has been widely documented in the literature (e.g. Bollerslev and Mikkelsen, 1996; Ding and Granger, 1996; Ding et al., 1993). Concerning more specifically the markets of interest in this paper see e.g. Andersen et al. (2001) for exchange rate volatility and Martens and Zein (2004) for crude oil volatility.

Since many financial and regulatory activities depend upon the perceived commonality in volatility movements, modeling adequately the long-run comovements among volatility series is crucial.[2] The objective of the paper is twofold. First, we aim to account for the persistent nature of the volatility series in investigating the commonalities that might exist between them in the long run, thereby implying to test for the presence of cointegration.[3] The need for distinguishing between the long- and short-run dynamics is important in several respects. For instance, the time horizon over which crude oil and exchange rate volatility series are linked should directly influence investors engaged in diversification activities between oil and USD-denominated financial assets (e.g. hedge against rising energy prices). Additionally, close attention must be paid to the time horizon as international oil price and exchange rate volatility forecasting results could be affected directly depending on whether the variables are linked over the long or short term. Finally, the interplay between oil prices and currency fluctuations could impact inflation, agent expectations and then, effectiveness of the monetary policy aimed at controlling oil inflationary effects. Accordingly, central banks aiming to ensure price and macroeconomic stability should consider whether oil and currency markets interact over a short or long time horizon when announcing their inflation targets. In this paper, we apply a comprehensive three-step methodology to test for fractional cointegration between the ex-post volatility series. This methodology consists in: (i) estimating and testing for the presence of true long memory (Qu, 2011; Shimotsu, 2010); (ii) testing for the equality of long memory parameters that implies to estimate the cointegrating rank (Nielsen and Shimotsu, 2007); and (iii) estimating the co-persistence system (Shimotsu, 2012).

Second, we examine the short-run dependence structure between USD and oil price volatility by means of static and dynamic copulas, concentrating on extreme and time-varying dependence. To the best of our knowledge, there exist no studies examining directly the dependence structure, particularly in the tails, between oil and foreign exchange market volatility series.[4] This issue is of importance because, during the 2008–09 financial turmoil, both markets have exhibited extreme conditions, suggesting potential extreme co-movements between their volatility processes. Given the long memory pattern observed in our data set, we devote particular attention to the treatment of the autocorrelation and derive the marginal distributions from the estimation of an HAR model. Finally, the joint distribution as well as tail and time-varying dependence are obtained from a panel of copula functions.[5]

To anticipate our main conclusions, we show that the dynamics underlying the volatility process on both markets are not tied together through a common equilibrium, suggesting that USD exchange rate and crude oil price fluctuations are segmented in the long run. Concerning the copula analysis, we find that dependence is in general weak but time-varying, with higher correlations before and during the financial crisis and more recently, in the aftermath of the European debt crisis.

The remainder of the paper is laid out as follows. Section 2 presents the data set. Section 3 details the strategy of estimation. Section 4 discusses the results and Section 5 concludes.

2. The data

Our data set runs from January 4, 2000 to April 16, 2014 and hence, the sample size is $n = 3560$. Oil log-squared returns are computed from the West Texas Intermediate (WTI) oil prices (in USD per barrel), extracted from the US Energy Information Agency (EIA). For exchange rates, we consider the USD rate against other major traded currencies that are the Canadian (CAD), European (EUR), Japan (YEN) and Great Britain (GBP) currencies, downloaded from the Federal Reserve Bank of St. Louis database (foreign currency per unit of USD). As an illustration, Fig. 1 displays the respective time path of the WTI oil price and USD/EUR exchange rate. As we can see, the WTI crude oil has experienced increasing price, rising continuously from about 25 USD per barrel to a historical peak of 145 USD per barrel in July 2008. Over the same period, the USD relative to the euro has depreciated by over 50%, suggesting extreme comovements between the two markets. Both have continued to evolve in the opposite direction when the financial crisis suddenly gained momentum at the end of 2008: oil prices fell sharply to 32 USD by December 2008 while the USD experienced an appreciation trend until February 2009. Since then, the WTI crude oil prices and USD have shown similar fluctuations. Moreover, these ascending and descending phases have been accompanied by episodes of substantial volatility (see Fig. 2), suggesting the existence of a common informative process linking the WTI crude oil and exchange rate volatility.

3. Empirical strategy

3.1. The long-run analysis

In their analysis of exchange rate volatility, Andersen et al. (2001) identify as a stylized fact the long memory behavior of ex-post volatility series. In line with the pioneer work of Bollerslev and Engle (1993), Andersen et al. (2003) also underline that volatility might be copersistent, i.e. fractionally cointegrated. In our analysis we account for this persistent nature for both, the crude oil and foreign exchange markets and then investigate whether the volatility series share a common long-run dynamics. Our fractional cointegration analysis operates in three steps.

In a first step, we estimate the integration orders of each individual volatility series, denoted δ, using the two-step exact local Whittle estimator of Shimotsu (2010) which accommodates both, stationary ($\delta < 0.5$) and non-stationary ($\delta \geq 0.5$) variables (recall that the process is mean reverting as long as $\delta < 1$). It is defined as $\hat{\delta} = \arg\min_{\delta} R(\delta)$ where

$$R(\delta) = \log\hat{G}(\delta) - 2\delta\frac{1}{m}\sum_{j=1}^{m}\log\lambda_j, \qquad \hat{G}(\delta) = \frac{1}{m}\sum_{j=1}^{m} I_{x(\delta)}\left(\lambda_j\right) \tag{1}$$

with $I_{x(\delta)}(\lambda_j)$ the periodogram of $(1-L)^{\delta}x_t$ evaluated at frequency $\lambda_j = (2\pi j)n^{-1}$. Concretely, this estimator consists in a semi-parametric frequency domain treatment of the autocovariance function, so that short-run dynamics are not modeled and our results are robust to misspecification. Indeed, the parameter δ is simply estimated by exploiting a degenerating band around the origin of the spectral density. However this procedure might be sensible to the choice of a bandwidth

[2] This is particularly true considering the recent financialization of commodity markets.

[3] Application of the cointegration theory to variances is not new and has been termed “co-persistence” by Bollerslev and Engle (1993), albeit these authors focus on conditional integrated variances. In more recent studies the co-persistence concept has been extended to fractional cointegration (see e.g. da Silva and Robinson, 2008; Christensen and Nielsen, 2006; Cassola and Morana, 2010; Rossi and Santucci de Magistris, 2013b,a).

[4] Actually, existing studies focusing on dependence in market returns need to model volatility (the GARCH class of models for instance) only to compute the marginal distribution of returns.

[5] See for an analogous choice Rossi and Santucci de Magistris (2013a).

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