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Causality in distribution between European stock markets and commodity prices: Using independence test based on the empirical copula

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Abstract

The aim of the paper is to investigate dynamic linkages between the main European stock markets and two commodity prices: crude oil and gold. For the empirical analysis we use daily data from the period January 2, 1998 to June 30, 2014. To investigate Granger causality a nonparametric test based on the empirical copula is used, which was proposed by Genest and Rémillard (2004). The analysis is conducted in rolling windows. There are tree main findings of the study. First, relations between commodity prices and stock markets are not stable in time. Second, commodity prices do not Granger cause the European stock market indexes. Third, only the price of gold depends on past values of stock market indexes for almost all sub-periods.

Keywords: Granger causality in distribution, nonparametric test based on the empirical copula, European stock markets, crude oil, gold

JEL Classification: C58, G15, Q02

1. Introduction

Understanding the dynamics of share prices and stock market indices is important for professionals from both a practical and theoretical point of view, especially in periods when financial instruments undergo high volatility. Last decades show that commodity prices are a significant factor affecting share prices and, consequently, stock market indices. Theoretically, such dependencies are caused by the fact that share prices correspond to a discounted sum of expected futures cash-flows. Thus, they reflect economics conditions tightly connected with commodity prices. However, it is more important that financial market liberalization has made commodities an attractive form of investment. Low interest rates and expectations connected with inflation encourage some investors to invest their capital in raw materials, while others use commodities to diversify their portfolios. That is why, mutual relations between commodity prices and a stock market are vital for them. Crude oil and gold occupy a special position in the commodity market. Crude oil is a strategic energy source in advanced economies, and it is also the world's most commonly traded commodity, while gold is a precious metal most often chosen by investors. The role of gold for investors is especially important during periods of high volatility, and it is described as a 'safe haven' from an increasing risk in financial markets (Baur and McDermott, 2010).

Subject literature abounds in studies which deal with the relationship between oil price changes and stock prices. The majority of these studies examine the Asian-Pacific region (Cong et al., 2008; Narayan and Narayan, 2010; Nguyen and Bhatti, 2012; Broadstock et al., 2012; Zhu et al., 2014). Several researchers investigate the relationship between oil prices and stock returns of the GCC (Gulf Cooperation Council) countries (Mohanty et al., 2011; Hammoudeh and Choi 2006; Arouri et al., 2011; Arouri and Rault, 2012). Park and Ratti (2008) find that oil price shocks have a negative impact on real stock returns in the U.S. and 13 European countries. Arouri (2011) analyzes oil prices and stock returns in Europe. Similarly, Śmiech and Papież (2013) analyzes fossil fuel prices, exchange rate, stock market on the European market, whereas Creti et al. (2013) examine the links between commodities returns and stock returns on the U.S. Data. Souček (2013) compares market activity for three of the major futures contracts in the U.S.: the stock index S&P 500, light sweet crude oil, and gold. The analyses of dependencies also cover emerging markets (Aloui et al., 2012) and Central and Eastern European (CEE) countries (Mohanty et al., 2010; Aloui et al., 2013).

The existing literature various estimation techniques and testing methodologies are used in an effort to investigate the relationship between commodity prices (oil, gold prices) and stock markets. Park and Ratti (2008) use a VAR model. Many authors use the family of

GARCH models, specifically bivariate GARCH (Cifarelli and Paladino, 2010; Arouri et al., 2011; Arouri, 2011; Papież and Śmiech, 2012), generalised VAR-GARCH (Arouri et al., 2012; Mensi et al., 2013) and multivariate GARCH (Creti et al. (2013) use dynamic conditional correlation (DCC) GARCH).

Copula functions are commonly used to analyse dependencies between financial data. The analysis is performed in two steps: during the first one time series are filtered to obtain i.i.d series, while during the second one copula functions are selected for marginal distributions obtained earlier. Recently, copula approach has been widely used to capture dependencies of financial series. Li (2000), Patton (2006), Granger et al. (2006), Chen and Fan (2006) are early examples of this approach. Generally, there are two main areas of interest in financial applications of copula models. First, copula functions are used to describe dependence between pairs (usually) of series in order to have benefit of portfolio diversification and to measure co-movement of financial instruments or a contagion effect. Relations between oil prices and stock market in this context were studied for the U.S. by Geman and Khauoubi (2008), for China and Vietnam by Nguyen and Bhatti (2012), and for various countries by Sukcharoen et al. (2014). Aloui et al. (2013) used time-varying copula to focus on the oil–stock market relationship for six major transition markets in the Central and Eastern European region. Wen et al. (2012) studied a contagion effect between stock prices and crude oil during the recent financial crisis. Second, a copula function can be used for Granger causality analysis and information transmission (usually volatility transmission). To the best of our knowledge, there are only several studies in this field, for example: (Lee and Yung, 2014; Bouezmarni et al., 2012 and Taamouti et al., 2014), but none of them deals with the relations between commodity prices and stock markets.

Existing studies present different results; some find that there is no significant effect of oil price shocks on stock prices (Cong et al., 2008; Hammoudeh and Choi, 2006; Mohanty et al., 2010; Maghyereh, 2004; Sari and Soytas 2006), others find a significant positive impact of oil prices on stock prices (Narayan and Narayan, 2010; Nguyen and Bhatti, 2012; Broadstock et al., 2012; Mohanty et al., 2011), while still others find a significant negative effect (Aloui and Jammazi, 2009; Park and Ratti, 2008; Cifarelli and Paladino, 2010). Hence, the evidence from the existing literature on the significance and sign of the impact of oil price changes on stock prices is still inconclusive.

The purpose of the paper is to investigate dynamic linkages between main European stock indices and two commodity prices: crude oil and gold. There are several reasons for choosing European stock market indices. Firstly, they represent the second largest economy worldwide, with GDP of 12,715,823 million USD in 2013 (GDP in the USA in the same year equalled 16,803,000 M.$). Secondly, European countries suffer from insufficient supplies of energy sources and other raw materials. In fact, European Union counties are the largest world importer of crude oil and mining products (24% share of world import, according to the World Trade Organization). However, to the best of our knowledge, relations between European stock markets and main commodity prices have not been of interest among researches so far. Our study investigates this issue.

The analysis is based on daily data from the period between January 2, 1998 and June 30, 2014, which contains 4210 observations. Stock markets are represented by the main indexes of the largest European stock market: DAX from Frankfurt Stock Exchange and FTSE100 from London Stock Exchange. Commodity prices are represented by crude oil closing spot prices of Europe Brent and spot gold fixing prices in London. To analyse Granger causality, a nonparametric test based on an empirical copula was used, following the suggestion of Genest and Rémillard (2004). In order to capture autocorrelation, fat tails, leverage effects and heteroscedasticity of returns, we use (following Lee and Wang (2014) or Zhu et al. (2014)) ARMA-GARCH model, although in our study innovation processes are assumed to be skewed t-student, which seems to be a more general model. Next, for standardized residuals obtained earlier, an empirical copula is found, which is then compared with the independence copula. Granger causality is analysed with the assumption that one of the series (residuals) is lagged relative to the other. Using a test for empirical copula has two basic advantages: firstly, the test results obtained refer to causality in distributions, which means that causality here is treated in more general terms than in traditional cases, when causality is analysed for the first two moments, that is the mean and the variance or some quantiles. The lack of causality in moments does not have to indicate the lack of causality in distributions (including quantiles), thus can give wrong signals to investors. Secondly, the test used is nonparametric, which allows us to avoid the risk of incorrectly specified distribution (of copula function), possibly leading to wrong conclusions regarding certain null hypothesis.

Bearing in mind that the period of analysis covers several episodes of wide instabilities and crises, the analysis is conducted recursively in overlapping rolling windows. The first sub-sample starts on January 2, 1998 and ends on December 31, 2002. The second window is moved towards the first one by one year, so the second sub-sample starts on January 2, 1999 and ends on December 31, 2003. The final (13th) sub-sample starts on January 2, 2010 and ends on June 30, 2014.

The rest of the paper is organized as follows. Section 2 describes the concept of Granger causality in distribution and methods of testing for Granger non causality in copula contexts. Our data are presented in Section 3, while empirical results for two European stock markets and two commodity prices are reported in Section 4. Conclusions are stated in the last section.

2. Methodology

In this section, we will briefly describe Granger causality in distribution (GCD) and present the method of its testing used in our study. To explore causality between two time series we use $\{X_t\}$ to denote the preceding variable and $\{Y_t\}$ as the trailing variable. Consequently, we will assume that market *X* closes before market *Y* closes. The information set before market X closes will be denoted as G_t, and the information set after market X closes but before market Y closes will be denoted as F_t ($\mathrm{F}_t = \mathrm{G}_t \cup \{x_t\}$).

It is said that $\{X_t\}$ does not Granger-cause $\{Y_t\}$ in distribution (in short $\{X_t\}$ NGCD $\{Y_t\}$) if and only if $F_Y(y|\mathrm{F}_t) = F_Y(y|\mathrm{G}_t)$, where $F_Y(y|\mathrm{F}_t) = P(Y_t < y|\mathrm{F}_t)$ and $F_Y(y|\mathrm{G}_t) = P(Y_t < y|\mathrm{G}_t)$. Of course, it means that $\{X_t\}$ Granger-causes $\{Y_t\}$ in distribution (in short $\{X_t\}$ GCD $\{Y_t\}$), if $F_Y(y|\mathrm{F}_t) \neq F_Y(y|\mathrm{G}_t)$ for some *y*.

The above implies that testing NGCD can be based on the following null hypothesis:

$$H_0^1 : f_Y(y|\mathrm{F}_t) = f_Y(y|\mathrm{G}_t), \tag{1}$$

where $f_Y(y|\mathrm{F}_t)$, $f_Y(y|\mathrm{G}_t)$ denote densities of conditional distributions respectively $F_Y(y|\mathrm{F}_t)$, and $F_Y(y|\mathrm{G}_t)$. Using the fact that joint density function is the product of the conditional density and the marginal density (see Lee and Yang, 2014):

$$f_{XY}(x, y|\mathrm{G}_t) = f_Y(y|\mathrm{F}_t) \cdot f_X(x|\mathrm{G}_t), \tag{2}$$

and with the assumption that

$$f_{XY}(x, y|\mathrm{G}_t) = f_X(x|\mathrm{G}_t) \cdot f_Y(y|\mathrm{G}_t), \tag{3}$$

that is with the independence of marginal densities, we obtain the equation from the null hypothesis (1). Hence, the null hypothesis of NGCD, in (1), can be stated as the null hypothesis that conditional marginal distributions are independent:

$$H_0^2 : F_{XY}(x, y|\mathrm{G}_t) = F_X(x|\mathrm{G}_t) \cdot F_Y(y|\mathrm{G}_t). \tag{4}$$

Conditional distributions $F_Y(y|\mathrm{F}_t)$ and $F_Y(y|\mathrm{G}_t)$ are modelled using two univariate processes ARMA(1,1)-GARCH(1,1) and the null hypothesis in eq. (4) is verified using multivariate independence test based on the empirical copula process, following the suggestion of Genest and Rémillard (2004) and Genest et al. (2006, 2007) for standardized residuals of these processes.

It is a rank test based on combinations of asymptotically independent Cramér–von Mises statistics derived from a Möbius decomposition of the empirical copula process[1]:

$$\zeta_n(u) = \sqrt{n}\left(C_n(u) - \prod_{j=1}^{d} u_j \right), \tag{5}$$

where the empirical copula (Deheuvels, 1979), defined by

$$C_n(u_1,...,u_d) = \frac{1}{n}\sum_{i=1}^{n}\prod_{j=1}^{d} 1(R_{ij} \le nu_j), \tag{6}$$

is an estimate of the unique copula C, describing joint distribution H of the multivariate vector with continuous marginals $F_1,...,F_d$

$$H(x_1,...,x_d) = C\big(F_1(x_1),...,F_d(x_d)\big). \tag{7}$$

Symbol R_{ij} from the formula (6) stands for ranks which are used to replace original observations X_{ij}:

$$R_{ij} = \sum_{k=}^{n} 1\big(X_{kj} \le X_{ij}\big),\ 1 \le i \le n,\ 1 \le j \le d. \tag{8}$$

Process (5) measures the difference between the empirical copula C_n and the independent copula $C_\perp = u_1 \cdot ... \cdot u_d$.

In practice, this test is applied in two steps:

- a simulation step, which consists of simulating the distribution of the test statistics under independence for the sample size under consideration,
- the test itself, which consists of computing the value of the global Cramér-von Mises statistic derived directly from the independence empirical copula process (see Genest et al. (2007) p.175) and corresponding p - value).

3. Data

For the empirical analysis, we use daily data from the period January 2, 1998 to June 30, 2014, which contains 4210 observations. The analysis is based on two closing value indexes: FTSE100 (London Stock Exchange) and DAX (Frankfurt Stock Exchange), and

[1] The description of the test below covers testing independence of *d* random variables. In the paper we use its two-dimentional version.

crude oil closing spot prices of Europe Brent (BRENT) (London Spot Market), based in U.S. dollars per barrel and spot gold fixing prices (GOLD) (3:00 P.M., London time, London Bullion Market), based in U.S. dollars per troy ounce. Both indices are denominated in USD, and data are obtained from the Yahoo Finance database (http://finance.yahoo.com). The data for crude oil spot prices and gold prices are taken from the CEIC Data database. Indexes DAX and FTSE100 represent two European stock exchanges with the highest capitalization (London SE Group domestic market capitalization amounted to approximately $4,428,975 million in 2013 and Deutsche Börse domestic market capitalization amounted to approximately $1,936,106 million in 2013 (source: World Federation of Exchanges)). The Brent index actually serves as pricing benchmark for two thirds of the world's internationally traded crude oil supplies.

Basic descriptive statistics can be found in Table 1. The data analyzed are the logarithmic returns. The returns of daily value indexes, crude oil prices and gold prices are calculated on a continuous compound basis, defined as $r_{i,t} = \ln(P_{i,t} / P_{i,t-1})$, where $P_{i,t}$ and $P_{i,t-1}$ are the closing value index or crude oil price or gold price (i) for days t and $t - 1$, respectively. Daily prices or indexes and daily returns of each four variables are given in Fig. 1 and Fig. 2, respectively. The plots of prices and returns in their respective markets clearly move in a similar manner. The descriptive statistics for crude oil returns, gold returns and set index returns are reported in Table 2.

Table 1. Descriptive statistics for levels.

	DAX	FTSE100	BRENT	GOLD
Mean	7221.96	9195.28	60.46	750.31
Median	6769.74	9238.77	57.17	580.63
Max	13625.45	13963.45	145.41	1895.00
Min	2429.42	4872.93	9.21	252.80
Std. Dev.	2525.31	1727.56	35.91	488.41
C.V.	0.35	0.19	0.59	0.65
Skewness	0.46	0.16	0.33	0.70
Kurtosis	2.42	2.85	1.73	2.06

C.V. is the coefficient of variation.

Table 2. Descriptive statistics for returns

	DAX	FTSE100	BRENT	GOLD
Mean	0.00025	0.00007	0.00046	0.00036
Median	0.00095	0.00053	0.00040	0.00050
Max	0.11238	0.12172	0.14337	0.07006
Min	-0.09796	-0.10537	-0.16536	-0.11184
Std. Dev.	0.01706	0.01409	0.02341	0.01155
Skewness	-0.14184	-0.10649	-0.19095	-0.51747
Kurtosis	6.62482	10.87260	6.61714	11.29558

The study period runs from January 2, 1998 to June 30, 2014 and covers several episodes of wide instabilities and crises (e.g., the Gulf War, the Libyan revolution, the global financial crisis (the sub-prime crisis (July 26, 2007 to September 14, 2008), the great recession (September 15, 2008 to December 31, 2009)) and the European debt crisis (January 1, 2010 to January 31, 2013) (Fry-McKibbin et al., 2014). During this period the number of transactions in the commodity market increased rapidly. In order to check stability of relations between indexes, we divide the period of analysis into 13 sub-samples, each lasting 5 years and use the rolling procedure. The first sub-sample starts on January 2, 1998 and ends on December 31, 2002. The second sub-sample starts on January 2, 1999 and ends on December 31, 2003. The final (13th) sub-sample starts on January 2, 2010 and ends on June 30, 2014. A detailed description of all sub-samples can be found in Table 3.

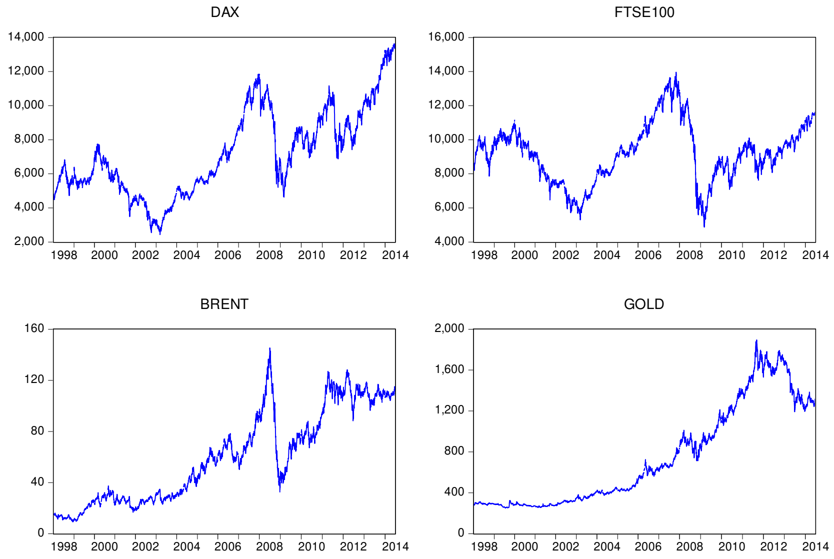

Fig. 1. Brent spot oil and gold prices, DAX and FTSE100 indexes between January, 2 1998 and June 30, 2014.

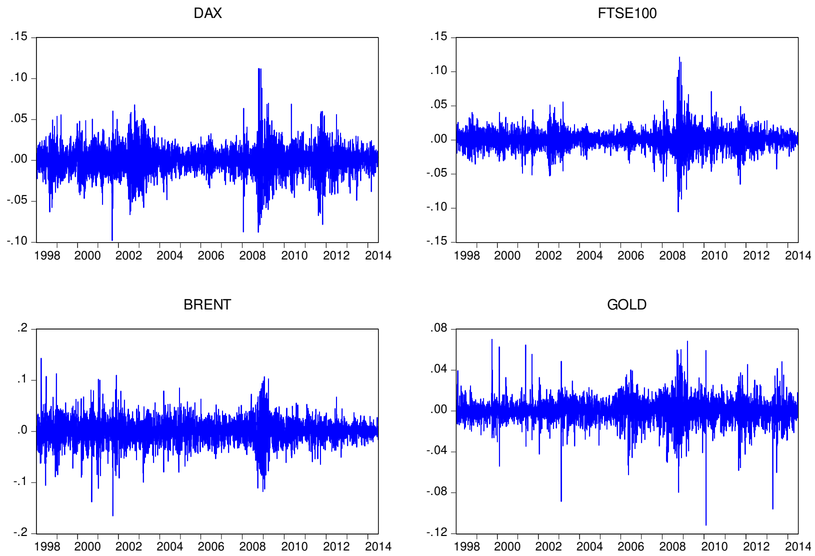

Fig. 2. Returns of series Brent spot oil and gold prices, DAX and FTSE100 indexes between January, 2 1998 and June 30, 2014.

Table 3. Sub-samples in each date set

Sub-sample	Period	Obs.	Sub-sample	Period	Obs.
1	Jan 2, 1998 – Dec 31, 2002	1262	8	Jan 4, 2005 – Dec 31, 2009	1279
2	Jan 4, 1999 – Dec 31, 2003	1265	9	Jan 3, 2006 – Dec 30, 2010	1285
3	Jan 4, 2000 – Dec 31, 2004	1268	10	Jan 2, 2007 – Dec 30, 2011	1290
4	Jan 2, 2001 – Dec 30, 2005	1268	11	Jan 2, 2008 – Dec 31, 2012	1290
5	Jan 2, 2002 – Dec 29, 2006	1269	12	Jan 2, 2009 – Dec 31, 2013	1290
6	Jan 2, 2003 – Dec 31, 2007	1272	13	Jan 4, 2010 – June 30, 2014	1159
7	Jan 2, 2004 – Dec 31, 2008	1276			

4. Empirical results

We investigate causality between the European stock market and commodity prices using methodology described in Section 2. The analysis of contemporaneous causality and Granger causality in distribution between European stock markets and commodity prices is conducted for the following pairs: the German stock index and crude oil prices (DAX – BRENT); the German stock index and gold (DAX-GOLD); the UK stock market and crude oil (FTSE100-BRENT); and the UK stock market and gold (FTSE100-GOLD).

The aim of the analysis is to investigate both the direction of relations between stock markets and commodity prices, and stability of these relations, which is of vital importance for financial investors.

The analysis is conducted for each sub-sample from Table 3, assuming that a preceding variable is a logarithmic rate of return lagged by 1 (Granger causality in distribution) or not lagged (contemporarous causality). We are not interested in causality in a longer horizon, because, as Dufour and Renault (1998) and Dufour et. al. (2006) show, in the financial market, if there is no causality between $\{X_t\}$ and $\{Y_t\}$, it will be difficult to explore Granger causality in a longer horizon. As a consequence of the development of information technology, the impact of information in one market has the most significant effects in a short run.

For each pair, each sub-sample and each conditional lag, distribution was modelled with the use of univariate processes ARMA-GARCH, in which standardized residuals follow skewed Student's t-distribution[2]. The order of ARMA terms and the lag orders of the GARCH model are all specified to be 1, as (Brooks, 2002) stated that a GARCH-family model with lag order of 1 can sufficiently describe volatility clustering in asset returns, and higher-order models are rarely used in financial literature. Skewed Student's t- distribution was chosen because it is a desirable extension of both normal and Student ‐ t density. According to

[2] The parameters of the model are assessed using R package "rugarch" (version 1.2-9), developed by Alexios Ghalanos. The results can be obtained from the author upon request

(Bastianin, 2009), two of the most common deviations from normality are fat tails and asymmetry. Although Student ‑ t density can capture fat tails, skewed-t density can capture both skewness and fat tails.

Independence of standardized residuals is tested using a multivariate independence test based on the empirical copula process. Obtained values of Cramér-von Mises statistic and corresponding p-values are presented in Tables 4, 5 and 6[3] for all analysed sub-periods.

a) Are distributions of the European stock market and commodity prices independent on the same day?

Table 4 show result of the evaluation of dynamic interactions between the European stock market and commodity prices on the same day. The value of the Cramér-von Mises statistic may be interpreted as contemporaneous causality between the European stock market and commodity prices. At the 5% significance level we conclude that contemporaneous causality between the UK stock market index (FTSE100) and Brent spot prices exists starting from the fourth sub-period. Similarly, at the 5% significance level, we find contemporaneous causality between the German stock index (DAX) and Brent spot prices beginning from the seventh sub-period.

Table 4. Testing for contemporaneous causality (delay 0)

	DAX - GOLD		DAX - BRENT		FTES100 - GOLD		FTSE100 - BRENT	
Subsample	CM	p-value	CM	p-value	CM	p-value	CM	p-value
1	0.038	0.163	0.011	0.989	0.023	0.532	0.021	0.574
2	0.028	0.383	0.016	0.820	0.019	0.653	0.022	0.525
3	0.028	0.388	0.053	0.070	0.031	0.323	0.029	0.361
4	0.051	0.071	0.046	0.118	0.132	**0.000**	0.074	**0.018**
5	0.081	**0.019**	0.037	0.171	0.336	**0.000**	0.104	**0.004**
6	0.512	**0.000**	0.029	0.323	0.967	**0.000**	0.122	**0.001**
7	0.502	**0.000**	0.072	**0.022**	0.994	**0.000**	0.334	**0.000**
8	0.524	**0.000**	0.416	**0.000**	0.817	**0.000**	0.863	**0.000**
9	0.559	**0.000**	0.970	**0.000**	0.835	**0.000**	1.518	**0.000**
10	0.616	**0.000**	1.445	**0.000**	0.639	**0.000**	1.874	**0.000**
11	0.616	**0.000**	1.930	**0.000**	0.656	**0.000**	2.408	**0.000**
12	0.743	**0.000**	1.980	**0.000**	0.846	**0.000**	2.521	**0.000**
13	0.447	**0.000**	1.478	**0.000**	0.607	**0.000**	1.938	**0.000**

CM is the Cramér-von Mises statistic

Similar results of the Cramér-von Mises statistic test presented in Table 4 indicate that at the 5% level of statistical significance there are simultaneous links between the European stock market and gold prices. Contemporaneous causality between the German stock index

[3] These values were obtained by using R package ”copula” (version 0.999-10), developed by Marius Hofert, Ivan Kojadinovic, Martin Maechler and Jun Yan.

(DAX) and gold prices is observed from the fifth sub-period (statistically significant at the 5 % level). Similarly, the interaction between the UK stock index (FTSE100) and gold prices on the same day is observed from the fourth sub-period till the last sub-period. This means that contemporaneous causality between FTSE100 and gold prices lasts from January 2001 to June 2014.

b) Is there an impact of the European stock market on crude oil and gold prices?

The results of Granger causality in distribution obtained with the use of the Cramér-von Mises test presented in Table 5 show that in all sub-periods the German stock index (DAX) does not Granger cause the prices of crude oil. Similarly, it can be observed that the UK stock market index (FTSE100) does not Granger cause crude oil prices in all sub-periods except for the fourth sub-period from January 2, 2001 to December 31, 2005 (the p-value of the Cramér-von Mises statistic is below the 5% significance level). These results indicate that past information from the European stock market index does not improve forecasts of Brent spot prices.

Table 5. Impact of the European stock market on crude oil and gold prices

	DAX → GOLD		DAX→BRENT		FTSE100 →GOLD		FTSE100 → BRENT	
Subsample	CM	p-value	CM	p-value	CM	p-value	CM	p-value
1	0.040	0.151	0.062	0.043	0.047	0.100	0.053	0.075
2	0.036	0.193	0.039	0.160	0.058	**0.050**	0.048	0.097
3	0.054	0.055	0.023	0.515	0.097	**0.006**	0.050	0.092
4	0.040	0.150	0.022	0.557	0.123	**0.001**	0.064	**0.027**
5	0.072	**0.017**	0.027	0.372	0.141	**0.000**	0.028	0.352
6	0.049	0.067	0.014	0.908	0.143	**0.000**	0.012	0.957
7	0.080	**0.016**	0.025	0.457	0.121	**0.002**	0.016	0.789
8	0.079	**0.010**	0.029	0.361	0.097	**0.003**	0.019	0.668
9	0.055	**0.050**	0.042	0.129	0.070	**0.027**	0.017	0.729
10	0.054	**0.050**	0.031	0.282	0.070	**0.032**	0.048	0.091
11	0.060	**0.050**	0.017	0.766	0.057	**0.045**	0.033	0.278
12	0.076	**0.016**	0.019	0.691	0.073	**0.021**	0.025	0.465
13	0.090	**0.005**	0.037	0.205	0.043	0.165	0.037	0.178

CM is the Cramér-von Mises statistic

However, at the 5% statistical significance level, the German stock index (DAX) Granger causes gold prices beginning from the fifth sub-period. So, these results indicate that past information from the German stock index (DAX) improves forecast of gold prices in London from 2002 to June 2014. Similarity, the UK stock index (FTSE100) Granger causes gold prices from the second sub-period to the twelfth sub-period. It means that European stock market index influences gold prices from 1999 (in case of the UK stock index) and from 2002 (in case of the German stock index).

c) Is there an impact of crude oil and gold prices on the European stock market?

The results of the Cramér-von Mises test presented in Table 6 show that, at the 5% statistical significance level, crude oil prices do not Granger cause the German stock index (DAX). Similarly, the prices of crude oil do not influence the UK stock index (FTES100) except for the period from the third sub-period to the fifth sub-period. So, Brent spot prices significantly influence the UK stock index (FTSE100) from the third sub-period to the fifth sub-period. It means that the prices of crude oil have an impact on the UK stock index (FTSE100) from January 2000 to December 2006.

Table 6. Impact of crude oil and gold prices on the European stock market

	GOLD →DAX		GOLD → FTSE100		BRENT→DAX		BRENT→FTSE100	
Subsample	CM	p-value	CM	p-value	CM	p-value	CM	p-value
1	0.037	0.189	0.023	0.516	0.033	0.236	0.032	0.243
2	0.043	0.124	0.024	0.466	0.026	0.413	0.048	0.091
3	0.076	**0.020**	0.019	0.708	0.031	0.290	0.070	**0.027**
4	0.105	**0.005**	0.018	0.736	0.024	0.472	0.079	**0.019**
5	0.045	0.122	0.016	0.843	0.037	0.181	0.061	**0.046**
6	0.071	**0.028**	0.016	0.800	0.023	0.507	0.031	0.301
7	0.042	0.129	0.025	0.460	0.015	0.862	0.012	0.961
8	0.022	0.531	0.048	0.107	0.015	0.861	0.020	0.646
9	0.026	0.425	0.043	0.133	0.024	0.462	0.026	0.434
10	0.013	0.936	0.018	0.720	0.055	0.062	0.055	0.066
11	0.017	0.732	0.017	0.771	0.037	0.187	0.054	0.080
12	0.017	0.795	0.013	0.921	0.024	0.439	0.045	0.111
13	0.014	0.859	0.021	0.599	0.023	0.470	0.036	0.210

CM is the Cramér-von Mises statistic

However, the results indicate that, at the 5% statistical significance level, gold prices do not Granger cause the UK stock index (FTSE100). So, past information from gold prices does not improve forecasts of the UK stock index (FTSE100) in all sub-periods. Similarity, the prices of gold do not influence the German stock index (DAX) except for the third sub-period, the fourth sub-period and the sixth sub-period. So, gold prices significantly improve forecasts of the German stock index (DAX) from January 2000 to December 2007.

5. Conclusion

The objective of the study is a dynamic assessment of dependencies between European stock markets and commodity prices: crude oil and gold using daily data spanning from January 2, 1998 to June 30, 2014. The dependencies are analysed using causality in distribution with a test based on a copula. The study investigates both contemporaneous causality in distribution and Granger-causality in distribution with the rolling procedure (that is, the analysis in 5-year sub-periods).

There are three main findings of the study. First, relations between commodity prices and stock markets are not stable in time. It is especially clear when we compare contemporaneous causality between stock market indexes and commodity prices for different sub-periods. At the beginning, stock markets seem to be unrelated to the commodity market, which changes in the period starting in 2003, where dependencies between them are observed. This phenomenon, on the one hand, can be explained by a fast flow of information between financial and commodity markets, and, on the other hand, indicates that both markets respond to global factors.

Second, when we focus on Granger causality, it is clear that the role of stock market indexes and commodity prices is not symmetrical. Generally, commodity prices do not Granger cause the European stock market indexes. Only in several sub-periods, that is for data covering years 2000-2006, significant causal relations are observed from gold to DAX and from Brent to FTSE.

Third, dissimilar behaviours of commodity prices in response to past values of stock market indexes. The price of gold depends on past values of both stock market indexes for almost all sub-periods. A different trend is observed for crude oil prices, which in most sub-periods do not depend on past values of stock market indexes.

Such linkages between European stock market indexes and gold prices can indicate that indeed gold is perceived by investors as "save heaven", which confirm the results obtained by Baur and McDermott (2010).

Understanding the type of relationship between commodity prices and stock prices is beneficial to portfolio managers, investors, financial market regulators, and energy analysts and policy makers. The findings can be utilized to build profitable portfolio strategies for traders, who operate on both financial and commodity markets. Showing the connections between markets and particular processes indicates the directions of diversification.

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