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The impact of downward/upward oil price movements on metal prices

Juan C. Reboredo[a,*], Andrea Ugolini[b]

[a] Department of Economics, Universidade de Santiago de Compostela, Spain
[b] Dipartimento di Statistica, Informatica, Applicazioni "G. Parenti", University of Florence, Italy

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ABSTRACT

We examine the impact of large upward/downward oil price movements on metal prices and the asymmetric response of metal prices to large oil price movements. We use copulas to characterize dependence between oil and metal price returns and we quantify spillover effects by computing the unconditional and conditional value-at-risk. Taking price data for ten metals – six industrial (aluminium, copper, lead, nickel, tin and zinc) and four precious (gold, silver, palladium and platinum) – widely traded on the London Metal Exchange for the period 2000 to 2015, our empirical evidence indicates that large downward and upward oil price movements had spillover effects on all these metals both before and after the outbreak of the global financial crisis. The fact that spillovers for upward oil price movements were larger than for downward oil price movements provides evidence of asymmetric spillover effects. Our results have implications for downside and upside risk management for investors and manufacturers.

1. Introduction

In recent years, large oil price upsurges and plunges have renewed interest in the impact of the oil market on other markets and, in particular, on metal markets. Oil and metals both play a crucial role, not only in economic activity worldwide, but also in financial markets, given that both are traded by manufacturers for industrial uses and by investors for strategic reasons, with spillover effects of extreme upward or downward oil price movements, in particular, having important implications in terms of risk management and trading and hedging strategies. The aim of this research was to study the impact of extreme upward or downward oil price movements on metal prices and the asymmetric response of metal prices to large oil price movements.

Extant empirical studies have examined the impact of oil on metal prices. Baffes (2007) provided evidence that precious metal prices – in particular for gold – were very sensitive to crude oil price movements. Soytas et al. (2009) found that oil prices had no predictive power regarding precious metal prices, while Sari et al. (2010) reported that although precious metal markets responded positively and significantly to oil prices in the short run, those effects dissipated over the long run. Likewise, Zhang and Wei (2010) reported evidence of causality from oil to gold prices but not in reverse. Reboredo (2013) provided evidence of average dependence and tail independence between oil and gold prices, indicating gold as a useful safe-haven asset against extreme oil price movements. Other studies focused on modelling the impact of oil prices on metal price volatility generally point to the sensitivity of metal prices to oil price changes (see, e.g., Hammoudeh and Yuan, 2008; Choi and Hammoudeh, 2010; Ji and Fan, 2012; Ewing and Malik, 2013; Mensi et al., 2013; Charlot and Marimoutou, 2014; Behmiri and Manera, in press). All these studies analyse the average impact of oil price changes on metal price levels or volatility, yet little is known regarding the impact on metal prices of large upward or downward oil price swings.

We attempt to add to the existing empirical literature regarding the oil-metal price nexus by studying the dependence structure of oil with a wide set of precious and non-precious metals and by quantifying the impact of extreme upward or downward oil price movements on metal prices. Specifically, we characterized the bivariate dependence structure between the oil and metal markets using copula functions, which provided information as follows: whether oil and metals were somewhat dependent or

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[*] Correspondence to: Universidade de Santiago de Compostela. Departamento de Fundamentos del Análisis Económico, Avda. Xoán XXIII, s/n, 15782 Santiago de Compostela, Spain.

E-mail address: juancarlos.reboredo@usc.es (J.C. Reboredo).

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independent; whether extreme upward or downward movements in oil prices were symmetrically or asymmetrically dependent on swings in metal prices; and whether dependence has evolved as a consequence of the impact of certain recent economic events (e.g., the global financial crisis) on the oil and metal markets. Furthermore, from the information provided by the copulas, we quantified the impact of large downward and upward oil price movements on the metals market by computing downside and upside conditional value-at-risk (CoVaR), as proposed by Adrian and Brunnermeier (2011) and generalized by Girardi and Ergün (2013). CoVaR is a systemic risk measure that, through the conditional value-at-risk, captures price spillover effects to other markets from a market experiencing large price movements. The CoVaR can thus quantify the impact of extremely high or low oil prices on metal prices, show how this impact has changed over time and indicate whether the systemic impact is symmetric or asymmetric. The statistical significance of systemic price spillovers was evaluated by testing for significant differences between the CoVaR and the value-at-risk (VaR) measures using the Kolmogorov–Smirnov (KS) bootstrapping test as proposed by Abadie (2002).

Our empirical study considered oil prices and spot prices for six industrial metals (aluminium, copper, lead, nickel, tin and zinc) and for four precious metals (gold, silver, palladium and platinum) widely traded on the London Metal Exchange during the period January 2000 to October 2015. Our evidence on the bivariate dependence structure for before the outbreak of the global financial crisis pointed to positive and low average dependence for industrial and precious metals alike and also upper and lower tail independence. However, after the onset of the crisis, we found an increase in average positive dependence but mixed evidence of tail dependence. Furthermore, our empirical results indicate that extreme downward and upward oil price movements had spillover effects on all metal markets, both before and after crisis outbreak; they also indicate that spillovers for upward oil price movements were larger than for downward oil price movements and, consequently, provide evidence of asymmetric oil price spillover effects. These results have implications for both investors and manufactures: investors need to adopt different risk management strategies when managing downside/upside risk in metal prices arising from oil prices, while manufacturers requiring metals for their production processes need to consider the asymmetric impact on financial results of oil price movements, especially when oil prices are at the high end of the market.

The remainder of this paper is laid out as follows. In Section 2, we describe the methodological approach used to account for oil price spillover effects using the CoVaR measure and its computation in terms of a copula function; in Section 3 and Section 4 we describe our data and discuss our empirical results, respectively, and in Section 5 we describe some conclusions.

2. Methodology

2.1. Price spillovers

In order to quantify price spillovers from oil to metal prices, we quantified the impact of large upward and downward movements in oil prices, measured by high and low quantiles to high and low quantiles of metal prices, respectively. As low and high price quantiles are given by the VaR, spillover effects can be captured by computing the CoVaR as proposed in the systemic risk literature (see e.g., Adrian and Brunnermeier, 2011; Billio et al., 2012; Bisias et al., 2012; Girardi and Ergün, 2013; Reboredo and Ugolini, 2015). Thus, for downward spillovers, the CoVaR for metal stock returns (r^m) is the VaR for metal price returns conditional on the fact that Brent oil price returns (r^o) experience a large downward movement. This can be formally stated as the β-quantile of the conditional distribution of r^m as:

$$\Pr(r_t^m \le CoVaR_{\beta,t}^m | r_t^o \le VaR_{\alpha,t}^o) = \beta, \tag{1}$$

where $VaR_{\alpha,t}^o$ is the VaR of the oil return that measures the maximum fall in those returns for a confidence level $1-\alpha$ and a specific time horizon, i.e., the α-quantile of the oil price return distribution: $\Pr(r_t^o \le VaR_{\alpha,t}^o) = \alpha$. Similarly, price spillovers from large upward movements in metal prices can be defined as the β-quantile of the conditional distribution of r^m as:

$$\Pr(r_t^m \ge CoVaR_{\beta,t}^m | r_t^o \ge VaR_{\alpha,t}^o) = 1-\beta, \tag{2}$$

where $VaR_{\alpha,t}^o$ is now the α-quantile that measures maximum upward movement in oil returns for a confidence level α and for a specific time horizon, $\Pr(r_t^o \ge VaR_{\alpha,t}^o) = 1-\alpha$.

We can assess the significance of oil price spillover effects (upwards and downwards) by testing for equality between the β-quantile of the conditional distribution of r^m and the unconditional β-quantile (measured by the VaR), in other words, by testing the following null hypothesis:

$$H_0\colon CoVaR_{\beta,t}^m = VaR_{\beta,t}^m. \tag{3}$$

Thus, when the null hypothesis is rejected there are spillover effects and vice versa. The null hypothesis can be tested using the KS bootstrapping test as proposed by Abadie (2002) and applied by Bernal. et al. (2014) and Reboredo et al. (2016). This test measures the difference between two cumulative quantile functions relying on the empirical distribution function and without considering any underlying distribution function. It is defined as:

$$KS_{mn} = \left(\frac{mn}{m+n}\right)^{\frac{1}{2}} \sup_x \left|F_m(x) - G_n(x)\right|, \tag{4}$$

where $F_m(x)$ and $G_n(x)$ are the cumulative CoVaR and VaR distribution functions, respectively, and n and m are the size of the two samples. For the p values, which were obtained using a bootstrap procedure (Abadie, 2002), values smaller than 0.05 indicate rejection of the null of equality between CoVaR and VaR at the 5% significance level.

We can also assess whether upside/downside oil price spillover effects may be asymmetric by testing for significant differences between the downside CoVaR normalized by the downside VaR and the upside CoVaR normalized by the upside VaR:

$$H_0\colon \frac{CoVaR_{\beta,t}^m(down)}{VaR_{\beta,t}^m(down)} = \frac{CoVaR_{\beta,t}^m(up)}{VaR_{\beta,t}^m(up)}. \tag{5}$$

We tested for significant differences between downside and upside spillovers using the KS statistic test in Eq. (4).

2.2. CoVaR and VaR computation

To compute the CoVaR from (Eqs. (1) and 2) we need information on the joint distribution of r^m and r^o and the marginal distribution of r^o. Note that Eq. (1) can be written as:

$$\frac{F_{r_t^m r_t^o}(CoVaR_{\beta,t}^m, VaR_{\alpha,t}^o)}{F_{r_t^o}(VaR_{\alpha,t}^o)} = \beta, \tag{6}$$

where $F_{r_t^m r_t^o}$ and $F_{r_t^o}$ are, respectively, the joint distribution function and the marginal distribution function of r^o. Since $F_{r_t^o}(VaR_{\alpha,t}^o) = \alpha$, and given that the joint distribution of two continuous variables can be expressed in terms of a copula function (Sklar, 1959), Eq. (6) can be rewritten as a copula function as:

$$C(F_{r_t^m}(CoVaR_{\beta,t}^m), F_{r_t^o}(VaR_{\alpha,t}^o)) = \alpha\beta, \tag{7}$$