Energy Economics 42 (2014) 325–331

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneco

Bidirectional causality in oil and gas markets

Marketa Halova Wolfe *, Robert Rosenman [1]

School of Economics Sciences, Washington State University, Pullman, WA 99164, United States

ARTICLE INFO

Article history:
Received 22 March 2013
Received in revised form 17 December 2013
Accepted 18 December 2013
Available online 7 January 2014

JEL classification:
Energy demand and supply Q41
Energy and the macroeconomy Q43
Energy forecasting Q47
Futures pricing G13

Keywords:
Crude oil
Natural gas
Commodity futures prices and volatility
Inventory
Energy

ABSTRACT

Do events in the natural gas market cause repercussions in the crude oil market? This paper studies linkages between the two markets using high-frequency, intraday oil and gas futures prices. By analyzing the effect of weekly oil and gas inventory announcements on price volatility, we show a bidirectional causal relationship. Both inventory gluts and shortages have a cross-commodity effect on price volatility not only for the next-month nearby futures contract but also for the following six months' contracts.

1. Introduction

Weekly inventory reports made by the Energy Information Administration (EIA) of the Department of Energy are the key news announcements in the oil and gas markets. As such, they are closely followed by the energy industry. This paper uses these inventory announcements and high-frequency, intraday oil and gas futures prices to study linkages between the oil and gas markets and show a bidirectional causality. Both inventory gluts and shortages have a cross-commodity effect on futures prices for both the next-month nearby futures contract and the following six months' contracts.

The relationship between the oil and gas markets has been of interest to researchers before. Several papers have shown a cointegrating relationship between oil and gas prices (see, for example, Villar and Joutz, 2006, for a review of this literature). This paper goes further by analyzing how strongly specific fundamentals-based shocks from one market are transmitted to the other market. We show that the gas market has a causal effect on the oil market in addition to the oil market affecting the gas market, a result that has not been shown before. We find that the effect of gas inventory announcements on oil price volatility is more than twice as strong as the effect of oil inventory announcements on gas price volatility. Moreover, the spillover effects from the gas market into the oil market, while small individually, amount to substantial swings in the values of futures contracts. These results add to, and sometimes differ from, studies that used lower frequency data, such as daily, weekly or monthly prices, and applied different empirical approaches, such as Granger-causality or cointegration procedures. For example, Asche et al. (2006) analyzed monthly oil, gas and electricity prices in the U.K. from 1985 to 2002 and concluded that the energy market was integrated with the oil price being the exogenous leading price. Similarly, Pindyck (2004) conducted Granger causality tests between daily oil and gas price volatility from 1990 to 2003 and concluded that the oil price affected the gas price but not the other way around.[2]

Economic theory suggests that there should be bidirectional causality between oil and gas markets for several reasons as outlined by Villar and Joutz (2006). From the demand perspective, oil and gas are substitutes because portions of both the power generation and industrial sectors have the ability to switch between gas and products refined from crude oil as the production input. An increase in the relative price of one energy source might move some firms to the other source. The situation is more complex from the supply perspective. An increasing oil

* Corresponding author. Tel.: +1 509 335 8509.
E-mail addresses: marketa.halova@wsu.edu (M. Halova Wolfe), yamaka@wsu.edu (R. Rosenman).
[1] Tel.: +1 509 335 1193.

[2] Several studies analyzed the effect of own inventory announcements on energy prices, although none focused on the cross-commodity effect between oil and gas markets. Generally, these studies find that oil inventory announcements affect the oil price and gas inventory announcements affect the gas price (Chang et al., 2009; Bjursell et al., 2009 for oil and Linn and Zhu, 2004; Ates and Wang, 2007; Mu, 2007; Gregoire and Boucher, 2008; Bjursell et al., 2009; Gay et al., 2009 for gas).

0140-9883/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.eneco.2013.12.010

Table 1
Summary statistics for oil and gas inventory surprise variables.

	Min	Max	Mean	Standard deviation
Oil inventory surprise, S_O	−2.85%	2.82%	−.02%	.94%
Gas inventory surprise, S_G	−1.55%	2.93%	.05%	.46%

price will simultaneously exert positive and negative pressures on the gas price. Oil and gas are often jointly produced from the same underground reservoirs. If the oil price increases, then potentially gas supply will also increase with new drilling for oil. As a result, this could push gas prices lower. At the same time, however, an increasing oil price may intensify competition for resources, such as drilling rigs, production facilities, and engineering and operations staff, used in exploration and production of both oil and gas, causing an increase in the cost of supplying gas, and hence having a commensurate impact on its price. Which effect is stronger is an empirical question.

Understanding the linkages between the two energy markets has increasing importance as evolving energy policies promote natural gas as a cleaner fuel and a domestic source of energy, leading to the energy mix in the U.S. changing in favor of gas. In 2003, crude oil and natural gas comprised 40% and 23% of the U.S. energy consumption, respectively. By 2010, the mix between oil and gas has changed to 37% and 25%, respectively.[3] This trend is likely to continue as North America has witnessed unprecedented discoveries of shale gas in the last several years. In addition, trading in the oil and gas futures markets has increased dramatically, ranking the oil and gas futures as the first and the second largest energy futures, and the first and the ninth largest commodity futures by volume in 2008, respectively.[4] Understanding how commodity markets relate to one another can help policy-makers, consumers and investors more efficiently incorporate risk spillovers into their decisions.

2. Methodology

To study linkages between the oil and gas markets, we use high-frequency, intraday oil and gas futures prices. Our choice of the 10-minute time interval trades off noise due to the data microstructure and loss of information. One approach, the volatility signature plot technique, graphs the scaled realized volatility (daily average of squared returns), against time intervals in multiples of 1 min (Andersen et al., 2000). We choose the 10-minute interval as the appropriate length since realized volatility stabilizes at that interval length.[5]

Oil trading ceases on the third business day prior to the twenty-fifth calendar day of the month preceding delivery. At expiration, oil has to be physically delivered to Cushing, OK. Gas trading ceases three business days prior to the first day of the delivery month. At expiration, gas has to be physically delivered to Henry Hub, LA. Very few market participants make physical delivery at contract expiration opting instead to roll over positions into a new contract. We create a continuous record of the futures contract prices by using current contracts until expiration date. Because trading may be thin during the last few days before the contract expiration date, we tested switching to the next contract as soon as its daily contract volume exceeds the current contract volume as an alternative method for creating a continuous record of prices. The results do not materially differ between the two methods, so only the results using the expiration date method are reported.

As is customary in these studies, we measure volatility as the absolute value of returns, $|R_j|$, where R_j is the difference between the log price at the end of interval j and the log price at the end of interval $j-1$: $R_j \equiv ln(P_j) - ln(P_{j-1})$ where P_j is the price at the end of period j. To validly undertake hypothesis testing about the regression parameters, we test for stationarity of the return series. The series is stationary as gauged by an augmented Dickey–Fuller test.

Following Ding et al. (1993), Ederington and Lee (1993), Gwilym et al. (1999), McKenzie (1999), Bollerslev et al. (2000), Ederington and Guan (2005), we measure the response of volatility to unexpected changes in inventories.

Using unexpected changes in inventories assumes efficient markets, implying that only the unanticipated component of news announcements matters: the anticipated component has already been built into market participants' price forecasts. The unexpected component is the difference between the actual value, A_{kj}, and the expected value, E_{kj}, where $k \in \{O,G\}$ stands for oil and gas announcements. To come up with a common metric of "surprise" for oil and gas, which are measured, respectively, in thousands of barrels and billions of cubic feet, the unexpected component is divided by the actual value and then multiplied by 100. The resulting "surprise", $S_{kj} \equiv \frac{A_{kj}-E_{kj}}{A_{kj}} \times 100$, is the percentage of actual inventory by which the expected inventory falls short of actual inventory.[6] Measuring surprise this way means that a positive surprise occurs when the analysts under-forecast inventory. We call this an inventory glut. A negative surprise, which we term an inventory "shortage", occurs when the analysts over-forecast inventories.

To allow for the possibility of asymmetric reaction of the price volatility to shortages and gluts, indicators, $I(S_{kj} > 0)$, are created that take on a value of 1 if $S_{kj} > 0$ and 0 otherwise. These indicators are then multiplied by the surprise, i.e., $S_{kj} \times I(S_{kj} > 0)$ and used as an additional explanatory variable in our equation measuring volatility response to surprises. This means that the coefficient on the surprise, S_{kj}, measures the effect of a shortage while the sum of the coefficients on S_{kj} and $S_{kj} \times I(S_{kj} > 0)$ measures the effect of a glut.[7]

The effect of the surprise is analyzed using ordinary least squares (OLS) regression. Several control variables are also included in the regressions. As suggested by Andersen et al. (2003), lags of surprise and dependent variable are added to allow for autocorrelation.

A beginning-of-day dummy is included to account for unusual price movements at the beginning of the day. This dummy takes on the value of 1 during the first interval of the day and 0 in all other intervals. An end-of-day dummy is included in the same way to account for unusual price movements at the end of the day. These time-of-the-day effects have been identified in many financial markets, for example by Becker et al. (1993), Bollerslev et al. (2000) and Linn and Zhu (2004). Alternative specifications are run where the beginning-of-day (end-of-day) dummy takes on the value of 1 for the first (last) two and three intervals. The results do not change.

A first-trading-day dummy is included that takes on the value of 1 in all intervals on the day after a non-trading day, i.e., after a weekend or a holiday, to allow for effects due to the market being closed for an extended period of time. A trader composition variable, defined as the ratio of non-commercial financial traders volume to the traditional commercial traders volume, is added to account for a change in the composition of firms' trading oil futures. As documented by Buyuksahin et al. (2008), the proportion of non-commercial financial traders has been on the rise and the proportion of traditional commercial traders has declined. The three-month Treasury bill rate is included to account for the cost of holding inventory (Pindyck, 2004). Trading

[3] EIA Annual Energy Review 2010.

[4] Futures Industry Magazine Annual Volume Survey, 2008 A Wild Ride.

[5] See Dacorogna et al. (2001) for a discussion of scaling factors. Also, note that the realized volatility is used only to choose the appropriate interval. It is not used in the regressions. The dependent variable in the volatility regressions is defined as the absolute return. As a robustness check, the regressions are repeated using 15-minute and 30-minute intervals. The results do not change materially.

[6] Balduzzi et al. (2001) implement another methodology for standardizing announcement units. They divide the difference between the actual and expected values by its sample standard deviation σ_k and interpret the coefficient as the change in oil price return for one standard deviation change in the surprise. In this paper, dividing by the actual value is preferred to allow for interpreting the surprise as a percentage deviation of the expectation from the actual value.

[7] Except for Gregoire and Boucher (2008), who analyze only the effect of gas inventory announcements on gas price using daily data, previous papers have not distinguished between inventory gluts and shortages.