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How does the U.S. natural gas market react to demand and supply shocks in the crude oil market?☆

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ABSTRACT

In this paper we use monthly data (over the period from January 1976 to December 2012) and a structural VAR model to disentangle demand and supply shocks in the global crude oil market and investigate their effects on the real price of natural gas in the United States. We identify the model by assuming that innovations to the real price of crude oil are predetermined with respect to the natural gas market and show that close to 45% of the variation in the real price of natural gas can be attributed to structural supply and demand shocks in the global crude oil market.

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1. Introduction

We answer two questions in this paper. Do natural gas prices in the United States react to crude oil price shocks? Does the response depend on the source of the shock in the crude oil market? Economic theory suggests that crude oil prices and natural gas prices are linked through both demand and supply. With regard to demand, crude oil is not consumed directly, but is used as a factor of production in the refining industry in the production of gasoline, diesel, heating oil, and jet fuel. However, there are interactions between the crude oil market and the natural gas market, because natural gas competes with heating oil in the residential and commercial heating markets and is also used interchangeably with residual and distillate fuels in the industrial and electricity generation sectors. For example, Hartley et al. (2008) attribute the increased demand for natural gas to the installation of advanced combined cycle gas turbine power plants. With regard to supply, the relationship between the crude oil and natural gas markets is more complicated, because natural gas is found in two basic forms — associated natural gas and non-associated natural gas. The former is a coproduct of crude as it occurs in crude oil reservoirs whereas the latter is not in contact with crude oil. Although associated natural gas accounts for a small fraction of natural gas production in the United States, the liquefaction of natural gas makes possible the storage and delivery of natural gas from remote producing areas, with oil-indexed prices and long-term contracts, to large consuming areas. These factors including recent technological innovations in horizontal drilling and hydraulic fracturing have increased the production of shale gas suggest that crude oil and natural gas prices are related. For example, as can be seen in Fig. 1, crude oil and natural gas prices in the United States (from the U.S. Department of Energy) in general move together over time, but they decouple episodically in response to deregulation, technological change, and major policy changes.

Over the years, a large number of studies have sought to investigate whether the price of crude oil is an important determinant of the natural gas price. See, for example, Pindyck (2003), Serletis and Rangel-Ruiz (2004), Panagiotidis and Rutledge (2007), and Brown and Yücel (2008), among others. Most of this literature employs time series models, specifically cointegration models and tests, to examine the long run equilibrium relationship between crude oil and natural gas prices. Among those, some studies such as Brown and Yücel (2008), Pindyck (2003), Yücel and Guo (1994), and Asche et al. (2006) show that the relationship between the oil price and the natural gas price is stable and asymmetric in a way that the oil price predominantly drives the natural gas price, but not the other way

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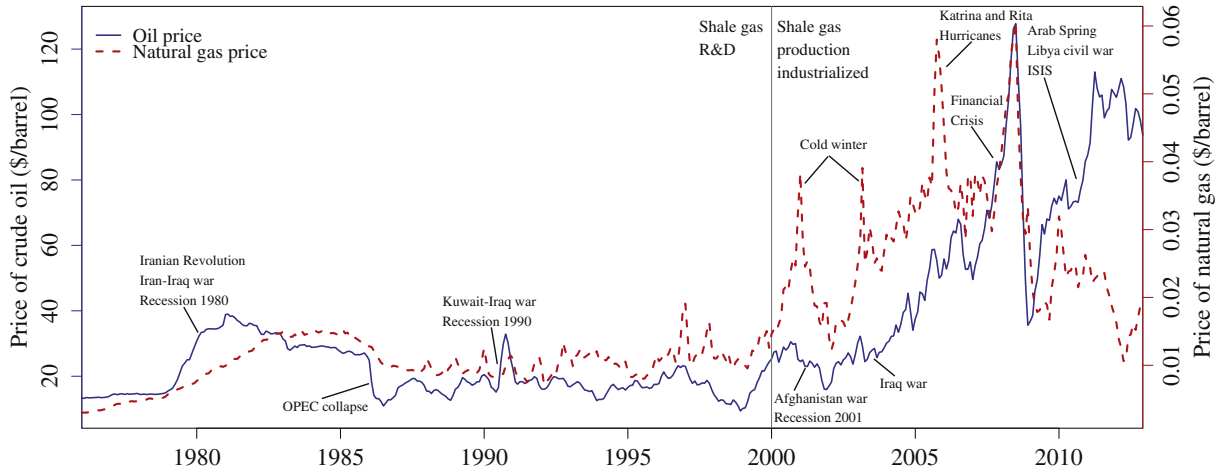

Fig. 1. Crude oil and natural gas prices, 1976:1–2012:12.

around. In contrast, other studies find that there is no relationship, or a very weak relationship between the two prices. For example Serletis and Rangel-Ruiz (2004) suggest that because of oil and gas deregulation in the United States, West Texas Intermediate (WTI) crude oil prices and Henry Hub natural gas prices do not have shared stochastic trends. Similarly, Bachmeier and Griffin (2006) conclude that, in the very long run, there is no relationship between the prices of primary energy goods, including crude oil and natural gas.

In this paper we build on Kilian (2009) and Kilian and Park (2009) and estimate the global crude oil market model of Kilian (2009), augmented with the real price of natural gas, in order to investigate the relationship between crude oil and natural gas prices. In doing so, we depart from the earlier literature that mostly treats the price of oil as exogenous and does not identify the causes underlying oil price shocks. We follow Kilian (2009) and Kilian and Park (2009) and treat the price of crude oil as endogenous and disentangle the causes underlying oil price shocks. In particular, we model changes in the real price of crude oil as arising from three different sources: shocks to the global supply of crude oil, shocks to the global demand for all industrial commodities (including crude oil) that are driven by the global business cycle, and oil-market specific demand shocks (also referred to as precautionary demand shocks). We augment Kilian's (2009) structural Vector AutoRegressive (VAR) model to include the real price of natural gas, and investigate the response of the real price of natural gas to structural shocks in the crude oil market. More specifically, we incorporate the price of natural gas into Kilian's (2009) structural VAR model. Kilian (2009) shows how we can decompose the price of oil into structural shocks, and in this study we investigate the impact of those shocks on natural gas prices.

We show (using monthly data over the period from 1976:1 to 2012:12) that in the long run, an average of 45% of the variability of the real natural gas price in the United States can be attributed to structural shocks that drive the global crude oil market, suggesting that crude oil market fundamentals are an important determinant of natural gas prices. In particular, we show that oil supply shocks, shocks to the global demand for all industrial commodities that are driven by the global business cycle, and oil-market specific demand shocks (also referred to as precautionary demand shocks) have made big contributions to the real price of natural gas in the United States, as they account for about 45% of the long run variability of the real price of natural gas. We show that the responses of the real price of natural gas vary depending on the cause of the oil price shock, with aggregate demand shocks and precautionary demand shock accounting for most of the variation. We also show that shocks in the natural gas market (such as supply disruptions, weather conditions, deregulation, and major policy changes) account for about 55% of the long run variability of the real price of natural gas, thus causing episodic decoupling of the real price of natural gas from the real price of crude oil.

The paper is organized as follows. Section 2 discusses the data and provides some graphical representations. Sections 3 and 4 describe the empirical method and present the results. Section 5 addresses robustness issues, and the final section concludes the paper.

2. Data

We consider a structural VAR model based on monthly time series data for the United States, over the period from 1976:1 to 2012:12 (a total of 444 observations), for $z_t = (\Delta prod_t, rea_t, rpo_t, rpg_t)'$, where $\Delta prod_t$ is the percent change in global crude oil production, rea_t is a measure of real economic activity, rpo_t is the real price of oil, and rpg_t is the real price of natural gas.

Regarding the percent change in global crude oil production, $\Delta prod_t$, we use the oil production data from the U.S. Department of Energy to compute the log differences of world crude oil production in millions of barrels pumped per day (and averaged by month). We use Kilian's (2009) detrended real freight rate index to measure the component of real economic activity (rea_t) that drives demand for industrial commodities in global markets. As noted by Kilian (2009), this index is constructed from dry cargo single voyage ocean freight rates and is deflated by the U.S. Consumer Price Index (CPI) to express it in real terms. The real freight rate index is linearly detrended to remove long-term trends and thus represent the global business cycle. See Kilian (2009) for more details regarding the construction of this measure of global real economic activity.[1] Finally, we divide the U.S. composite refiners' acquisition cost of crude oil (RAC), as compiled by the U.S. Department of Energy, by the U.S. CPI to obtain the real price of crude oil, rpo_t, and we divide the U.S. natural gas wellhead price, as compiled by the U.S. Department of Energy, by the U.S. CPI to obtain the real price of natural gas, rpg_t.

The fact that global oil production enters the VAR model in percent changes, $\Delta prod_t$, and the measure of real economic activity, rea_t, is expressed as percent deviations from trend, suggests that we should be using the first differences of the natural logs of the real crude oil and natural gas prices in order to have consistent variables in the VAR system of equations. We note that the logged real crude

[1] Whether the detrended freight rate index is an adequate reflection of the overall economic climate is an issue beyond the scope of this paper.

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