Energy Economics 56 (2016) 229–238

Contents lists available at ScienceDirect

Energy Economics

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

Research Article

Integration of physical and futures prices in the US natural gas market

Hamed Ghoddusi

School of Business, Stevens Institute of Technology, 1 Castle Point on Hudson, Hoboken, NJ07030, USA

ARTICLE INFO

Article history:
Received 30 March 2015
Received in revised form 12 March 2016
Accepted 13 March 2016
Available online 23 March 2016

JEL classification:
Q40
Q43
N72

Keywords:
Natural gas
Spot–futures cointegration
VECM
Causality

ABSTRACT

This paper examines the integration between the prices of different types of physical (upstream/end-use) and futures contracts of natural gas in the US for the period of June 1990–Dec 2014. To examine the equilibrium relationship between physical and futures prices, several cointegration tests are applied. The study finds that (a) futures prices are cointegrated with wellhead, power, industrial, and citygate prices; (b) NG1 futures prices Granger cause all physical prices; (c) upstream physical prices Granger cause futures prices; (d) shocks to wellhead prices are the only ones among physical prices with persistent long-term effects; (e) shocks to futures prices have persistent effects on all physical prices; (f) futures contracts with a longer time-to-maturity explain a larger portion of commercial gas price variations; and (g) commercial and residential prices show different behavior compared to other physical prices in multiple tests.

1. Introduction

The US natural gas market consists of a set of production, import/export, transmission, storage, and consumption nodes, with market prices associated with different nodes. The price of gas at different end-use nodes (e.g., industrial, commercial, or residential points) follows a long-run equilibrium relationship with wholesale prices (Mohammadi, 2011). The connection between spot and futures prices have been investigated extensively in the literature (e.g. Garbade and Silber, 1983; Chinn et al., 2005; Joseph et al., 2014). Because of the forces connecting prices an integration between physical and futures markets is also expected to hold. However, the physical/futures markets integration has not been tested empirically. The goal of this paper is to address this question using 25 years of monthly data.

The U.S. natural gas market went through a series of regulatory reforms in the 80s and 90s. As a consequence of these changes implemented by the Federal Energy Regulatory Commission (FERC), the production and trading of natural gas are decoupled from gas transportation[1] . The production and trading sides of the natural gas market are competitive. However, due to a typical natural monopoly effect, transportation (mainly through pipelines) tends to be concentrated and requires supervision by a regulatory body (Cuddington and Wang, 2006; De Vany and Walls, 1993).

In the years following the physical market reforms, a liquid and well-functioning futures market has also developed and evolved. An active futures market provides opportunities for market participants (producers and consumers) to hedge their price risk. Hedging would be more effective and cost efficient if for every type/location of physical price there existed a corresponding futures contract. This is not the case in reality. For the majority of commodities (including natural gas), futures contracts are offered only for one or a very limited number of underlying spot prices. For example, in the case of refined products, futures contracts are mainly available for gasoline and heating oil. Consumers of other types of products (e.g., jet fuel) should use existing contracts as an imperfect cross-hedging[2] solution.

[1] The 1985 FERC decision allowed interstate natural gas pipelines to transport the gas owned by their customers instead of the prior practice, which forced them to own the transported gas. The new regulation set the stage for the emergence of spot prices in different locations (Walls, 1995).

[2] Cross-hedging refers to using an available futures contract as a proxy for another (usually non-existent) contract . To provide an effective hedge, the two contracts should have a reasonably high correlation and move in the same direction.

E-mail address: hghoddus@stevens.edu.
URL: http://www.ghoddusi.com (H. Ghoddusi).

http://dx.doi.org/10.1016/j.eneco.2016.03.011

Table 1
Description of natural gas prices

Price variable	Description
Wellhead	The price of unprocessed gas at the head of a gas well.
Industrial	The price of gas used for manufacturing purposes, such as production feedstock or to produce heat.
Power (electricity)	The price of gas purchased by power companies for the purpose of converting gas to electricity.
Citygate	The price paid by a natural gas retail company receiving gas from the end of a main transmission pipeline.
Commercial	The price paid by service companies such as restaurants and hotels.
Residential	The price paid by households. The gas is mainly used for heating purposes.

The mismatch between futures and physical prices also exists in the U.S. natural gas market. While natural gas is traded in many locations in the country and for different purposes (e.g., residential, industrial, and electricity generation [power]), futures contracts exist only for spot prices of the Henry Hub, Louisiana delivery node. In the absence of futures contracts written specifically on all other natural gas prices, users should rely on Henry Hub (HH) futures contracts as a cross-hedging solution. The stronger the integration of physical and Henry Hub futures prices, the more effective the hedging practice will be. Thus, understanding the degree of cointegration between different types of wholesale and end-use prices (“physical prices”) and marketed futures contracts is an important question for understanding hedging effectiveness in this market.

Moreover, the speed of response to news in the physical and futures market is different. If futures contracts are an unbiased predictor of future events, using futures contracts for hedging will be efficient. However, if they are biased in a certain direction, hedgers may end up paying an additional “error premium” . An efficient futures market will quickly reflect expectations regarding future supply and demand. Retail prices are usually less responsive but will eventually follow the path behavior of more responsive ones (Mohammadi, 2011). Knowing the direction and speed of shock transmissions between physical and futures markets will improve our understanding of the natural gas market efficiency.

The prior literature has recognized the importance of incorporating cointegration relationship in the estimation of optimal hedging ratio, tests of market efficiency, and pricing of spread options (Alexander, 1999). da Hsiang (1996) shows that failing to consider the cointegration between spot and futures prices results in underhedging.

Motivated by the above discussions, the goal of this paper is to study the relationship between futures contracts and various types of physical prices. To the best of my knowledge, there has been very little work on testing the connection between the two markets, with disaggregated physical prices, for the U.S. natural gas industry. The only exception is Walls (1995) who examines market efficiency of the U.S. futures market by testing the cointegration between futures prices and spot prices in major delivery locations. However, Walls (1995) uses only 44 observations and does not allow for structural breaks in the cointegration relationship. Moreover, the paper is not concerned with the integration between various types of natural gas end-use prices and futures prices.

The paper’s research question can be perceived as testing a triangle relationship between cointegrated prices. Futures prices are usually cointegrated with their underlying spot prices. Moreover, as Mohammadi (2011) reports, different physical price pairs are cointegrated with each other. However, we also need to test the cointegration of other physical prices with futures prices to gauge their effectiveness for hedging.

Following the open access reform, a set of papers tested the impact of changes in market regulation on the efficiency and integration of markets. De Vany and Walls (1993) was one of the first papers that applied cointegration tests to market price pairs between 20 locations, and concluded that reforms have significantly increased the level of spatial integration. King and Cuc (1996) and Serletis (1997) examine market integration for the North American (U.S. and Canada) market. King and Cuc (1996) use a Kalman Filter approach to account for time-varying parameters, and concludes that while the North American market has become more integrated following FERC reforms, there is a split between West–East markets. In contrast, Serletis (1997) uses Engle and Granger (1987) and Johansen (1988) cointegration tests and rejects the so-called West–East split. In a more recent study, Park et al. (2008) finds that two decades after the reforms, the U.S. and Canadian markets are highly integrated.

Cuddington and Wang (2006) uses daily spot prices at 76 locations to assess the market integration impact of FERC’s open access reforms. The paper concludes that the low connectivity between the U.S. West and the rest of the country causes a poor price integration between that region and prices in other locations. Mohammadi (2011) examines the integration of upstream and downstream markets. However, his analysis is limited to the physical market. Arano and Velikova (2009) concludes that the residential (end-user) and citygate prices are cointegrated in 90% of U.S. states. The literature on the market efficiency of natural gas outside of the U.S. is also abundant. For example, Asche et al. (2000) studies France’s natural gas market and finds a long-run integration between the prices of imported gas from Norway, the Netherlands, and Russia. Brown and Yücel (2009) tests the integration between the U.S. and European markets and finally, Asche et al. (2006) examine the decoupling of natural gas, oil, and electricity prices in the UK market.

A few papers have studied the integration between spot and futures prices of crude oil, such as Maslyuk and Smyth (2009), who examine the cointegration relationship between spot and futures prices of different types of crude oil (WTI and Brent). Similarly, Chen et al. (2014) considers the effect of structural breaks on the relation between spot and futures prices, and finds that the presence of structural breaks affects conclusions regarding the efficiency of the crude oil market. Compared to the crude oil market, the existence of several types of physical prices in the natural gas market makes the problem

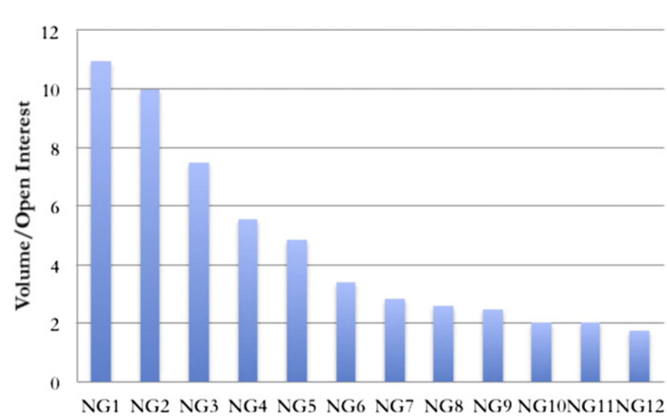

Fig. 1. Ratio of volume to open interests for NG1 to NG12, for Year 2014. The trend suggests that contracts with shorter maturity have a higher liquidity (volume) in the market.