Energy Policy 87 (2015) 270–283

Contents lists available at ScienceDirect

Energy Policy

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

Pricing the (European) option to switch between two energy sources: An application to crude oil and natural gas

Hayette Gatfaoui *

IÉSEG School of Management; Finance, Audit & Control Department, Socle de la Grande Arche, 1 Parvis de la Défense, 92044 Paris La Défense Cedex, France

HIGHLIGHTS

- We consider a firm, which chooses either crude oil or natural gas as an energy source.
- The capability to switch offers the firm a hedge against energy commodity price risk.
- A European put option prices the ability to switch from crude oil to natural gas.
- The capability to switch between two energy sources reduces the firm's energy costs.
- The discount illustrates the efficiency of the energy management policy (e.g. timing).

ARTICLE INFO

Article history:
Received 20 March 2015
Received in revised form
31 August 2015
Accepted 8 September 2015

Keywords:
Crude oil
Energy cost
European put option
Natural gas
Stochastic modeling

ABSTRACT

We consider a firm, which can choose between crude oil and natural gas to run its business. The firm selects the energy source, which minimizes its energy or production costs at a given time horizon. Assuming the energy strategy to be established over a fixed time window, the energy choice decision will be made at a given future date *T*. In this light, the firm's energy cost can be considered as a long position in a risk-free bond by an amount of the terminal oil price, and a short position in a European put option to switch from oil to gas by an amount of the terminal oil price too. As a result, the option to switch from crude oil to natural gas allows for establishing a hedging strategy with respect to energy costs. Modeling stochastically the underlying asset of the European put, we propose a valuation formula of the option to switch and calibrate the pricing formula to empirical data on a daily basis. Hence, our innovative framework handles widely the hedge against the price increase of any given energy source versus the price of another competing energy source (i.e. minimizing energy costs). Moreover, we provide a price for the cost-reducing effect of the capability to switch from one energy source to another one (i.e. hedging energy price risk).

1. Introduction

We consider the viewpoint of a firm, which has the choice between two energy sources to run its business (e.g. energy production, goods production, delivering services). The two energy sources under consideration consist of crude oil and natural gas. The trade-off between those two energy sources is straightforward since the firm buys crude oil when its price is lower than natural gas. Conversely, the firm buys natural gas when this energy source is cheaper than crude oil. Hence, it chooses the energy source, which minimizes its energy or production costs over a given forthcoming time horizon. In this light, substitution opportunities arise when energy producers and consumers perceive a durable price decrease of' one energy source relative to the other one (over a sufficient time horizon). Such substitutability patterns generate then a price competition between crude oil and natural gas through supply and demand adjustments.

We assume the energy strategy to be established over a fixed time window, and the energy choice decision to be made at a given future date *T*. In this light, the firm's energy cost can be considered as a long position in a risk free bond by an amount of the terminal oil price, and a short position in a European put option to switch from oil to gas by an amount of the terminal oil price too. As a result, the option to switch from oil to gas allows for establishing a hedging strategy with respect to energy cost(s). Under a stochastic modeling framework, we propose a well-chosen specification for the underlying asset of the European put and apply the corresponding option pricing formula. Then, we calibrate the valuation formula to empirical data on a daily basis. Thus, we are able to characterize and price the European put option to switch

* Corresponding author.
E-mail addresses: h.gatfaoui@ieseg.fr, hgatfaoui@gmail.com

http://dx.doi.org/10.1016/j.enpol.2015.09.010
0301-4215/

from oil to gas. Past history, indicates that, though the price of natural gas is often lower than the one of crude oil, there have been time periods during which such price relationship inverted. Such patterns render useful the hedge against a price increase of one energy source versus the price of the other competing energy source. Moreover, the option pricing setting can easily be inverted (i.e. switching from gas to oil) and extended to other energy sources and energy cost trade-offs. Such option computation is critical to fuel cost-driven energy producers and consumers for cost optimization prospects. For example, fossil fuel power plants (e.g. natural gas-fired and petroleum-fired units) exhibit the lowest capital costs (EIA-860, 2014) so that fuel-fired units' costs are mainly driven by fuel costs. Such pattern supports the reported price correlation between electricity, on one side, and both crude oil and natural gas, on the other side (Emery and Liu, 2002; Kilian, 2014; Moutinho et al., 2011).

Our paper is organized as follows. Section 2 introduces the innovative theoretical framework and European option setting, which is employed to value the option to switch from crude oil to natural gas. The European put's underlying corresponds to the ratio of natural gas price to crude oil price. In particular, the underlying asset's negative return follows a generalized extreme value (GEV) distribution in the risk neutral universe and the European put's price exhibits a closed form. Then, Section 3 applies naturally the theoretical framework while calibrating the valuation formula to observed daily data. Empirical results show the appropriateness of the GEV distribution with a negative shape parameter. We are therefore able to price the option to switch, which is written on a non-traded asset. Such innovative setting allows for an assessment of the firm's energy policy efficiency among others. Section 4 discusses the relevance and policy implications of previous findings. Finally, Section 5 introduces concluding remarks and possible future extensions.

1.1. Crude oil and natural gas prices

Energy commodity prices are driven by several fundamentals among which the development and delivery costs of energy producers (i.e. supply side). Moreover, the balance between the supply and demand for energy commodities also determines commodity prices. In particular, energy commodity prices depend on weather (i.e. periodic winter and summer effects).[1] Finally, energy price moves result from the energy market's globalization as well as cross-commodity correlation to some extent (i.e. connectedness of commodity markets).

As regards supply and demand, the supply of a commodity depends on its related production costs. For example, the production process of a given commodity may rely on capital-intensive investments as well as long-term investments. And, such production costs are highly sensitive to regulation changes. Moreover, supply factors such as inventories, storage, perishability and delivery/transportation costs are significant for establishing energy commodity prices. Furthermore, unpredictable fluctuations in demand engender supply and demand imbalances (Carmona, 2009) and therefore volatility in energy commodity prices. As an example, the demand for energy depends on temperature, rain and humidity among others. Exceptionally strong winters and/or hot summers trigger demand shocks due to unpredicted heating and/or air conditioning activity (i.e. seasonal consumption patterns, which generate spikes in the demand for energy).

As regards correlation, electricity generation results mainly from the conversion of fossil fuels such as natural gas (Arezki et al., 2014; Hartley et al., 2008) and crude oil (without forgetting coal as well).[2] Thus, an energy price correlation arises between electricity, on one side, and both crude oil and natural gas, on the other side (Emery and Liu, 2002; Kilian, 2014; Moutinho et al., 2011). Incidentally, price correlation or comovements also arise between crude oil and natural gas prices (Asche et al., 2006; Brigida, 2014; Brown, 2005; Kilian, 2014; Nordic Council of Ministers, 2008; Villar and Joutz, 2006). Moreover, commodities are widely considered as a diversifying asset class within portfolios (e.g. markets' globalization; Joëts, 2014, Labys, 2006). In U.S.A., futures on energy commodity are traded on the Intercontinental Exchange (ICE) in Atlanta and on the New York Mercantile Exchange (NYMEX) in New York. As a result, trading activity, and more specifically, the trading of commodity indexes strengthens the correlation between commodities. Tang and Xiong (2010) as well as Tonn et al. (2010) describe such phenomenon as the « financialization » of commodity markets.

1.2. Crude oil and natural gas as energy substitutes

Natural gas and crude oil are two competing energy sources, which also compete with other energy commodities such as coal for example. During the 1970s up to the 1990s, natural gas replaced crude oil and oil-related products (Stern, 2014). Nowadays, residential and commercial consumers use broadly natural gas as compared to oil-related products (e.g. space heating). And, industry's consumption of natural gas depends on the price spread with crude oil (Huntington, 2007). Conversely, oil-related products play a major role in transportation as compared to natural gas. However, crude oil and natural gas are prone to a high degree of substitution at least in the long term (Aloui et al., 2013; Atil et al., 2014; Ji et al., 2014; Loungani and Matsumoto, 2012). For example, a switch to natural gas generates efficiency gains in the vehicle transport industry while heavy trucks' sector has tax incentives to switch from crude oil to natural gas (World Bank, 2014). Analogously, the power sector can choose either crude oil or natural gas as an energy source to produce electricity, managing therefore arising substitution opportunities (EIA, 2008). In this light, substitution can be either rapid or, more or less, time demanding, specifically when the substitution process is investment-consuming (e.g. requiring new equipment or new technology). Any time-demanding substitution process will be undertaken when energy consumers anticipate a durable price spread between the two competing energy sources. Previous pattern explains the emergence of some limitations in the substitution opportunities of crude oil or oil-related products for natural gas after 2005. Such limitations result from the infrastructure investments, which are required to permit a large-scale substitution (e.g. price regulation due to supply and demand feedback across the two commodity markets; EIA, 2010).

The demand for natural gas has been strongly linked to the substitution between crude oil and natural gas (Hartley et al., 2008; Huntington, 2007; Villar and Joutz, 2006). In particular, the substitutability between crude oil and natural gas helps establish implicit natural gas prices (Brown, 2014), setting up therefore a price competition between the two energy sources. Conversely, the strength of substitution between crude oil and natural gas

[1] For example, the crude oil market faces a globally high demand in the fourth quarter due to cold weather and inventory building. Then, demand diminishes at winter end because of weather warming. Analogously, the increased consumption of gasoline in the U.S. during the summer generates a price increase (Source: U.S. Energy Information Administration). Moreover, Auer (2014) exhibits a daily seasonality of crude oil market while Hsu et al. (2014) exhibit seasonality in WTI oil options. Analogously, gasoline and heating oil markets exhibit seasonality (Clark, 2014).

[2] Natural gas is a good substitute for coal while generating electricity (Arezki et al., 2014).