Commodity convenience yield and risk premium determination: The case of the U.S. natural gas market

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Abstract

This paper contributes to the understanding of commodity pricing issues by measuring and modeling two of the most important concepts in the storable commodity markets: the convenience yield and risk premium. An emphasis is placed on the empirical determination of these factors in the U.S. natural gas market. We find that the convenience yield and risk premium are measurable and economically significant. While we find that the determination of the convenience yield is largely consistent with economic theories, the evidence regarding the determination of the risk premium is mixed.

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1. Introduction

Commodity price determination has long been an important aspect of investigation by academic researchers as well as industry practitioners. At the center of the rationality of commodity pricing lays the concept of convenience yield, which was initially put forth by Kaldor (1939). Working (1949) provided some first evidence of the existence of convenience yield from the U.S. wheat market – stocks were held even when the inter-temporal spread within Chicago prices was “inverted.” It is now conventional wisdom that the convenience yield drives a wedge between commodity futures and spot prices (Gibson and Schwartz, 1990; Schwartz, 1997; Chambers and Bailey, 1996, to mention a few). Even though some theories of storage do not rely on convenience yield (Khoury and Martel, 1989; Brennan et al., 1997), the convenience yield is found to be economically significant and it explains the futures and spot price relationships, especially when commodity prices are in backwardation (e.g., Considine and Larson, 2001a,b; Milonas and Henker, 2001).

We contribute to the understanding of the commodity markets, in particular, the U.S. natural gas market, by focusing on two related issues in this study. The first issue is the empirical definition, measurement, and determination of the convenience yield. The second is the definition, measurement, and determination of the risk premium. Despite various theoretical discussions of convenience yield and risk premium, the empirical evidence regarding the theories is scant. A study of these topics provides further and direct empirical evidence regarding the theory of commodity price determination (for example, Pindyck (2001), Considine and Larson (2001b), Schwartz (1997), and Pilipovic (1998)). In addition, in this research we choose to use forward prices instead of futures prices since in addition to a very active natural gas futures market, there is a very active forward market for natural gas. To our knowledge, there is no study of the U.S. natural gas forward market.

The paper is organized as follows. The next section briefly introduces the U.S. natural gas forward market and explains various theoretical relationships among the forward price, spot price, and the marginal convenience yields. We review the relationship between the spot price, forward price, and risk premium as suggested by various recent theories. We also explain the theoretical determination of the convenience yield and risk premium. The Third section explains data and empirical methods that are used to estimate the convenience yield and risk premium and the determination of the variables. The Fourth section provides empirical evidence regarding the theories. The Final section concludes.

2. Forward price, spot price, and convenience yield

2.1. The natural gas forward market

There is a very active forward market for natural gas in the U.S. The forward market we investigate is the so-called First-Of-Month (FOM) market. The FOM contract specifies the price and quantity of natural gas for delivery throughout the next whole month at different delivery points (hubs). Since there are many gas hubs in the U.S., the FOM prices are different depending on the locations. We choose the most liquid hub, Henry Hub (HH) in Louisiana, for our study. HH is the hub on which the New York Mercantile Exchange (NYMEX) natural gas futures contracts are based.

The FOM prices are determined during the bid week – the last five working days of a month – during which the FOM contracts are actively negotiated. The FOM index prices remain fixed
during the whole next month. The FOM contracts are a very active tool by which companies price their natural gas supplies in the long term, mid-term, as well as short term. In addition, the FOM contracts are used as a tool by companies to hedge gas price risks.⁴

Even though there are many differences between the forward and futures prices, most in the financial literature treat the forward price the same as the futures price. In the natural gas industry the FOM price can be viewed as a form of futures price as well. Due to the fact that the NYMEX’s front month futures contract expires on the third last working day of the month prior to the delivery and the FOM price is a weighted average of prices prevailing in the last five working days of the month, the FOM price contains similar information to that contained in the NYMEX futures prices.

2.2. Marginal convenience yield

If the market is efficient, then there should be no arbitrage profit. Holding a unit of natural gas for one period has the return of \((P_{t+1} - P_t) + CY_t\), where \(P_t\) is the price of gas for the current month, and \(CY_t\) is the marginal convenience yield net of storage cost. At the same time, assuming that one also takes a short position using the FOM contract, the return is then the difference between the FOM price and the next month’s spot price, \(F_{t+1} - P_{t+1} = F_t - P_{t+1}\), where \(F_t\) is the FOM forward price. The total return therefore is

\[
P_{t+1} - P_t + CY_t + F_t - P_{t+1} = F_t - P_t + CY_t. \tag{1}
\]

Since the positions are covered, there is no risk involved in the transaction and the total return is non-stochastic. The returns should be the same as the return of a risk-free investment with price \(P_t\). Assuming the risk-free rate of return is \(r\), then the no arbitrage condition would give us the relationship:

\[
F_t - P_t + CY_t = rP_t. \tag{2}
\]

This equation defines the net marginal convenience yield as the difference between the adjusted spot price and the forward price:

\[
CY_t = (1 + r)P_t - F_t. \tag{3}
\]

The convenience yield is the benefit of holding the storage commodity. Theoretically, it depends on several factors. For example, after deriving such a relationship, Pindyck (2001) argues, based on his structural model, that the convenience yield depends on the current price level, the price volatility, and the level of storage. A high spot price (relative to the equilibrium price) reflects the imbalance between supply and demand. As the shortage of supply increases, the demand for storage will increase, driving up the value of storage. When market volatility is higher, the demand for storage is higher as well due to the greater need to buffer fluctuations in production and consumption. The amount of storage is also important in determining the marginal value of storage. The lower the storage level is, the higher the value will be for the marginal storage. A variant of the last argument is that the lower the level is of storage relative to the average storage level, the higher the marginal convenience yield will be.

⁴ See, for example, Energy Analysis, 2002-02, American Gas Association, July 1, 2002.
2.3. The forward and spot prices

The forward and spot prices of a storable commodity are expected to be different, as the forward prices are not usually equal to the expected spot prices. In general, the future or forward price should be less than the expected future spot price. The intuition is that holders of the commodity bear risks by purchasing the commodity at time \( t \). As a reward for bearing risks, investors expect to see the spot prices rise above the current futures or forward prices over the commodity-holding period. Therefore, we can formulate the idea in the following equation:

\[
F_t = E_t P_{t+1} - RP_t,
\]

where \( E \) is the expectation operator conditional on information available at time \( t \) and \( RP \) is the risk premium factor.

The theories of commodity price determination suggest that the risk premium depends on several factors. Pindyck (2001) ties the risk premium to the current spot price of the commodity. Considine and Larson (2001b) suggest the risk premium to be positively related to price volatility. Schwartz (1997) and Pilipovic (1998), in their two/three-factor models, offer that the risk premium should be negatively related to the risk-free rate and positively to the convenience yield. In addition, Schwartz (1997) also recommends that the risk premium should be positively related to the variability in the convenience yield as well as the time-varying interest rate, and the co-variances between the convenience yield and interest rate.

3. Data and empirical methodology

3.1. Data

Data on FOM prices are Platt’s Gas Daily FOM price index for delivery at Henry Hub. As indicated before, these forward prices are set in the last five working days of the previous month. To be consistent with the forward price, spot prices are obtained as the average spot price from the last five working days of the month for delivery at Henry Hub as well. The spot price data are obtained from the Gas Daily. The risk-free rate of interest is obtained from the Federal Reserve Bank of St. Louis’ FRED database. Since there is no consistent one-month t-bill rate available, monthly one-year t-bill rates are used instead. The monthly storage data are obtained from the Energy Information Administration (EIA) of the U.S. Department of Energy. The EIA collects natural gas underground storage data and issues a monthly report on the level of storage. All data cover the period of 1991:1 to 2003:8.

3.2. Empirical methods

To test the commodity price models, we examine the empirical determination of the convenience yield and risk premium separately. According to the discussions in the previous section, our empirical convenience yield can be specified as follows:

\[
CY_t = \alpha_0 + \alpha_1 \hat{P}_t + \alpha_2 \hat{\sigma}_t^2 + \alpha_3 S \hat{D}_t + \varepsilon_t,
\]

where \( CY \) is the marginal convenience yield as defined in Eq. (3), \( \hat{P}_t \) is the spot price shock modeled as the residual from an ARMA(1,1) model of log spot prices, \( \hat{\sigma}_t^2 \) is the residual from the ARMA(1,1) model of price volatility which is modeled as \( \sqrt{2 \pi} \log P_t - \log P_{t-1} \), and \( \hat{S}D_t \) is the gas storage shock modeled as the residual from an ARMA(1,1) model of the storage difference from the five-year averages. If the theories are correct, then we should expect both \( \alpha_1 \)
other explanatory variables can be at best described as mixed, with some evidence pointing to the opposite of what the theories have postulated.

Depending on the sample period, the simple empirical model is able to explain a small portion of the variation in the estimated risk premium. The adjusted $R^2$ squares range from $-0.075$ to $0.493$. This is consistent with risk premium regressions for other financial and commodity markets (e.g., the foreign exchange market (Zhu, 2002, among others)).

5. Conclusions

In this paper we have investigated the empirical relationships between a commodity’s forward price and spot price. We have considered herein the U.S. natural gas market. We first defined and measured the marginal convenience yield and examined the properties of the convenience yield, and then modeled the relationship between the forward and spot prices based on conventional theories. To explain the basic connection between the forward and spot prices, we also modeled and estimated the time-varying risk premium by using a state-space model. Finally, we have examined the determination of the risk premium with specifications suggested by several commodity pricing models in the literature.

We find that our empirical evidence is partially consistent with the prevailing theories regarding commodity price, convenience yield, and the risk premium. Specifically, we find that the convenience yields are economically significant, about 3–5% of the spot price on average. However, the convenience yields are highly variable and the variability is associated with its own lagged variability, spot price level, and the spot price variability. We also find that the forward price is not an unbiased predictor of future spot prices. The forward price is in general discounted due to the risk of holding the gas commodity (risk premium associated with the commodity). The risk premium is statistically, significantly related to the spot price, spot price volatility, and to a certain degree the convenience yield. However, we find that the variance and co-variance of the convenience yield and interest rate fail to explain significantly the variations in the risk premium.

Our findings suggest that the convenience yield behaves largely as economic theories suggest, however, the empirical evidence on the risk premium component in natural gas prices does not seem to square well with conventional commodity price theories. Further investigation of the determination of the risk premium is warranted.

References