行政院國家科學委員會專題研究計畫　成果報告

天然氣市場期貨與現貨價格之探討及其對天然氣沖銷之意涵

計畫類別：個別型計畫
計畫編號：NSC93-2415-H-343-001-
執行期間：93 年 08 月 01 日至 94 年 07 月 31 日
執行單位：南華大學經濟學研究所

計畫主持人：邱魏頌正

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主持人：邱魏頌正　南華大學經濟學研究所
計畫參與人員：吳文正、潘嘉玲 南華大學經濟學研究所

一、中文摘要

本研究提供了一個商品價格測量的模式，探討商品市場中兩個重要概念：便利收益與風險溢酬。 我們以美國天然氣市場為大宗，探討這兩種概念之決定要素。結果發現便利收益與風險溢酬是可以實證測量且經濟意涵顯著。便利收益之決定要素與經濟理論大致相符，但，風險溢酬之要素檢定則是不一致。

關鍵詞：便利收益、風險溢酬、能源商品、效率市場

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 the determination of the convenience yield is largely consistent with economic theories, the evidence regarding the determination of the risk premium is mixed.

Keywords: Convenience yield, risk premium, energy commodity, efficient market

二、緣由與目的

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 the commodity futures and spot prices (Gibson and Schwartz [1990], Schwartz [1997], Chambers [1996], to mention a few). Even though some theories of storage do not rely on convenience yield (Khoury and Martel [1989], Brennan, Williams and Wright [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, 2001b], Milonas and Henker [2001]).

We contribute to the understanding of the commodity market, 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 the 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 project 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. In addition, 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.

三、結果與討論

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 whole next 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 price remains 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.[1]

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 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 those contained in the NYMEX futures prices.

Data

The FOM prices are the *Gas Daily* FOM price index for delivery at Henry Hub. As indicated before, these forward prices were 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. Louise 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.

The results of the convenience yield variability regression are provided. The volatility of the convenience yield as modeled by $\sqrt{\pi/2}\,|(CY_t - CY_{t-1})/CY_t|$ is regressed on its own lag, the spot price, the lagged spot price, and the volatilities of the spot price and storage variables. The

[1] See, for example, Energy Analysis, 2002-02, American Gas Association, July 1, 2002.

convenience yield volatility can be explained by mainly three variables: the own lagged volatility, the lagged spot price, and the price volatility, especially for the sample period of 2000 to 2003 during which the spot price volatility was the highest of all sample periods. However, most of the volatilities are not explainable by the above variables as the adjusted R squares are fairly small.

We use the Kalman filter technique to estimate the state-space model of the risk premium. Several results stand out. First, the estimate of α_1 (0.861) suggests that the forward rate is a biased predictor of the future spot rate. Second, the risk premium explains future spot price movement statistically significantly as well. Third, even though the risk premium is assumed to follow an AR(1) process, the estimation suggests that the AR(1) model fits the data well. The first order autoregressive coefficient is estimated to be 0.912 and is highly statistically significant. This indicates that the risk premium is highly persistent.

As we hypothesized before, the risk premium should be positively related to the spot price level, the spot price volatility, the convenience yield, and the variances and covariance of convenience yield and interest rate, while negatively correlated to the interest rate variable. The spot price volatility seems to be positively correlated with the risk premium; however, the relationships are not statistically significant. We have a limited evidence of a positive relationship between the risk premium and convenience yield since all of the estimated signs of the coefficients are positive and one of the signs is statistically significant. Spot price level appears to be statistically positively related to the risk premium in the whole sample period and one of the three sub-sample periods. However, the evidence of the relationship between risk premium and 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 estimated risk premium. The adjusted R squares range from -0.075 to 0.493. This is consistent with risk premium regressions for other financial and commodity markets (e.g., foreign exchange market (Zhu [2002] and among others)).

四、計畫成果自評

In this project we investigated the empirical relationships between a commodity's forward price and spot price. The market we considered is 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 price, we also modeled and estimated the time-varying risk premium by using a state-space model. Finally, we examined the determination of the risk premium with specifications suggested by several commodity pricing models in the literature.

We have carried out this project in an efficient and smooth way as we had already planned in the earlier proposal. The project is also quickly accepted without revision by Energy Economics (a SSCI Journal), which will be appearing in January, 2006.

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行政院國家科學委員會補助專題研究計畫成果報告

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