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Pricing forward contracts in power markets by the certainty equivalence principle: Explaining the sign of the market risk premium ☆

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Abstract

In this paper we provide a framework that explains how the market risk premium, defined as the difference between forward prices and spot forecasts, depends on the risk preferences of market players and the interaction between buyers and sellers. In commodities markets this premium is an important indicator of the behavior of buyers and sellers and their views on the market spanning between short-term and long-term horizons. We show that under certain assumptions it is possible to derive explicit solutions that link levels of risk aversion and market power with market prices of risk and the market risk premium. We apply our model to the German electricity market and show that the market risk premium exhibits a term structure which can be explained by the combination of two factors. Firstly, the levels of risk aversion of buyers and sellers, and secondly, how the market power of producers, relative to that of buyers, affects forward prices with different delivery periods.

JEL classification: G13; G11; D81; Q40

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1. Introduction

Commodities are a very different asset class from the more traditional classes of traded assets such as equities and bonds. Commodities normally encompass physical goods such as oil, gas, electricity, metals, agriculturals and live stock. The physical nature of commodities is perhaps one of their most defining characteristics specifically because it plays an important role in the behavior of their prices in both the spot and forward markets.

Let us contrast equity forwards with commodity forwards. For example, if interest rates and dividends are assumed to be deterministic, the pricing of equity forwards is a straightforward exercise. Simple no-arbitrage arguments are employed and the pricing is principally based on the ability to borrow money to purchase the underlying equity and hold it until delivery. As a result, the arbitrage-free forward price is the cost of borrowing net of dividends yielded by the equity. With commodities one can in principle apply a similar strategy to price forward contracts. However, the physical nature of commodities makes it very difficult for two reasons. First, the cost-of-carry (interest plus 'storage' costs) is not straightforward to calculate or measure. Second, it is

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necessary to account for the convenience yield (equivalent to collection of dividends on equities), but this is also exceptionally difficult to quantify or model.

The shape of commodities' forward curves for different delivery periods has always been of utmost importance to understand market players' (producers, consumers and speculators) 'attitudes' towards bearing risk in these markets. Forwards exhibit peculiar behavior depending on the time or delivery period. A situation where forward prices are above current spot prices is labeled contango and it is normally associated with circumstances where the immediate supply of the commodity is plentiful relative to demand. Similarly, the situation where forward prices are below spot prices is known as backwardation and it is generally associated with circumstances of low current supply levels and/or low inventory levels. One can determine whether contango or backwardation exists by simple observation of the forward markets. For example, in electricity and gas markets one normally observes that, for 'long' dated forward contracts, markets are in backwardation and for 'shorter' maturities the market is in contango (Cartea and Figueroa, 2005; Cartea and Williams, 2007).

Another quantity of importance that relates forward and expected spot prices is the market risk premium or forward bias $\pi(t,T)$. This is defined as the difference, calculated at time t, between the forward price $F(t,T)$, at time t with delivery at T, and the expected spot price:

$$\pi(t,T) = F(t,T) - \mathbb{E}^P[S(T)|\mathscr{F}_t]. \tag{1}$$

Here $\mathbb{E}^P$ is the expectation operator, under the historical measure P, with information up until time t and $S(T)$ is the spot price at time T.[2]

To the best of our knowledge, recent literature on commodities has not addressed the connection between the market risk premium and market players' behavior and risk preferences. Moreover, it has not dealt with the question of why and how in some commodities markets we expect the market risk premium $\pi(t,T)$ to change signs in time T. The main contribution of this article is therefore to address these questions and propose a framework that allows us to establish explicit relationships between the market risk premium, the market price of risk and market players' risk preferences. By doing so, this allows us to explain the interesting connections between forward price formation and its deviations from spot forecasts based on the consumers' and producers' attitudes to risk.

To understand the importance of the market risk premium, it is important to point out that forward curves are not forecasts of the commodity spot price in the future. The clearing prices of forwards are the result of demand and supply, which in turn are determined by the individual characteristics of market players. Indeed the main motivation for players to engage in forward contracts is that of risk diversification. Producers have made large investments with the aim of recouping them over a long period of time as well as making a return on them. As with any other investments, there is an incentive for producers to reduce variability in their profits by trading in instruments with payoffs that covary with their profits. Similarly, consumers (which might be intermediaries and/or use the commodity in their production process) also have an incentive to hedge their positions in the market by contracting forwards that help diversify their risks.

The relative appetite of producers and consumers for risk-diversification has a temporal dimension to it. Variations in this appetite for risk diversification will be evident in the different levels of market exposure chosen by producers and consumers and in the different levels chosen by members within each of these groups. For example a producer will generally be exposed to market uncertainty for a longer period of time, perhaps determined by the remaining life of its assets, whilst consumers will tend to make decisions based on a shorter time scale. In other words, the gains in terms of risk-diversification for consumers and producers will vary across time, therefore having a first order impact on forward clearing prices.

In this article we argue that it is precisely these differences in the desire to hedge positions and diversify risk that explain the market risk premium and its sign. Intuitively, the further out one looks into the market, the less incentivized consumers are to contract commodity forwards; however the producers' desire to hedge does not diminish as quickly. We associate situations where $\pi(t,T) > 0$ (a positive market risk premium) with markets where the consumers' desire to cover their positions 'outweighs that of the producers. Conversely situations where $\pi(t,T) < 0$ (a negative market risk premium) result when the producers' desire to hedge their positions outweighs that of the consumers.

In order to explain the market risk premium and the driving forces that give rise to it we organize the rest of the article as follows. Section 2 discusses the notion of a representative producer and a representative consumer. Based on their preferences we calculate an attainable set of forward prices where the two representative agents are willing to trade forward contracts. Section 3 discusses clearing market forward prices and the relative 'market power' agents have over these prices. Section 4 examines the market price of risk and market risk premium implied by our model under different assumptions. Section 5 applies our model to German electricity data and Section 6 concludes.

2. Representative agents, price dynamics and forward price bounds

In this section we describe producers' and consumers' preferences via the utility function of two representative agents. As an example we look at the wholesale electricity markets where we model the dynamics of the spot price as a stochastic process. Agents must decide how to manage their exposure to the spot and forward markets for every

[2] Note that it is incorrect to say that when $\pi(t,T) < 0$ (resp. $\pi(t,T) > 0$) the forward curve is in contango (resp. backwardation). Moreover, $S(t)$ is not generally a martingale under P.