Does Hedging Affect Commodity Prices? The Role of Producer Default Risk

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November 18, 2008

Abstract

Do hedging and speculative activity in commodity futures affect spot prices? Yes, when commodity producers have hedging needs. We build a model in which producers are risk-averse to future cash flow variability and hedge using futures contracts. Increases in speculative demand for futures reduces the cost of hedging, allowing producers to hedge more and hold larger inventories. This pushes spot prices higher. Reductions in speculative demand for futures have the opposite effects. The data provide support for the hedging channel we identify – oil and gas producers' hedging demands (proxied by their default risk), forecast spot prices, futures prices and producers' inventories.

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1 Introduction

Merton H. Miller in a conversation with the treasurer of a medium-sized oil company in Chicago who bemoaned his company's losses when the Gulf war's end brought down the price of oil: "It serves you right for speculating and gambling," Miller told him. "Oh, no, we didn't speculate. We didn't use the futures market at all," insisted the treasurer. "That's exactly the point," Miller replied. "When you hold inventory, non-hedging is gambling. You gambled that the price of oil would not drop and you lost."

– From the book *Merton Miller on Derivatives* (John Wiley & Sons, 1997).

Commodity futures have been amongst the most successful hedging instruments available in modern financial markets. The relatively large volume of trading in these futures is generally considered a manifestation of the significant hedging demand in the economy from commodity producers and consumers.[1] However, in the recent past, the behavior of commodity prices has raised several questions concerning the role of speculative and hedging activities in commodity markets. Between 2003 and June 2008, energy, base metals, and precious metals experienced price rises in excess of 100%, and agricultural and livestock commodities experienced much higher price rises than would be implied by inflation. Over the same period, there was a huge increase in the amount of capital committed to long positions in commodity futures contracts – in July 2008, pension funds and other large institutions were reportedly holding over $250 billion in commodities (mostly invested through indices such as the S&P GSCI) compared to their $10 billion holding in 2000 (Financial Times, July 8 2008).

Some market practitioners and economists have vehemently argued that the speculative investments of financial players in the futures market are not direct determinants of the real (or “spot") price of commodities, rather, spot prices are set by those agents in the economy who are buying and selling the underlying commodities. According to this view, the spectacular recent increase in commodity spot prices is a manifestation of increases in global demand arising from high growth rates in countries such as China and India. Other commentators (most notably, Michael Masters, a hedge-fund manager, and George Soros, who both testified to the US Congress) have blamed speculative activity for these

[1] In contrast, the usage of derivatives to hedge in other industrial firms has as of yet been limited (Guay and Kothari, 2003).

recent commodity price rises. A third group (one that includes former Federal Reserve Chairman Alan Greenspan) has taken an intermediate view – that commodity spot prices are fundamentally driven by physical demand, but that financial speculation has played some role in recent price rises. This last set of commentators has also argued that financial speculation is in fact stabilizing: the long positions taken by financial investors have enabled producers to take short hedging positions, hold larger inventories, and simultaneously pursue new acquisitions of commodities, which should stabilize prices going forward.[2]

This recent debate raises several important questions. Through what channels, if any, might speculative and hedging activity in commodity futures affect spot prices? Is there any direct evidence supportive of these channels? Can the variation in speculative and hedging demands explain both spot and futures price behavior in commodity markets? Is an increase in speculative activity necessarily welfare-reducing, or might it have some stabilizing impacts on the behavior of inventory and on production decisions?

In this paper, we provide a simple model to answer some of these questions, and present empirical evidence consistent with the model's predictions. Our focus in the model is on understanding the implications of varying the degree of risk-sharing between producers and speculators. The model incorporates elements from Anderson and Danthine (1981, 1983) and Deaton and Laroque (1992) – we analyze the interaction between risk-averse producers, who optimally manage inventory and hedge future supply commitments by shorting futures,[3] and risk-averse speculators, who take long positions in futures. The model thus nests the two classical explanations for commodity spot and futures prices: The Theory of Storage (Kaldor (1936), Working (1949), and Brennan (1958)), which has optimal inventory management as a main determinant of commodity prices, and the Theory of Normal Backwardation (Keynes (1930)), which posits that hedging pressure affects commodity futures prices. We clear markets for futures and spot commodities (assuming exogenous spot demand functions) and derive implications of producer and speculator risk aversion for the relative levels of futures and spot prices.

We show that when producers' risk-aversion goes up, their hedging demand increases and futures risk-premium – the hedging pressure on futures prices – increases. Correspondingly,

[2] "Greenspan says 'good speculation' will cut the top off market peak", Financial Times, August 11 2008.

[3] The Appendix presents a version of the hedging model of Froot, Scharfstein and Stein (1993), which is based on the assumption of costly external finance when firms face cash shortfalls for financing growth options. This extension of our benchmark model provides a micro-foundation for producer "risk-aversion", and also allows us to link speculative and hedging demands to future production decisions. Early papers on hedging by firms include Stulz (1984) and Smith and Stulz (1985).

their holdings of inventory fall, causing spot prices to rise. Conversely, if speculator risk-aversion goes up, producers find it cheaper to hedge, so their equilibrium hedging rises (as do inventories), spot prices fall, and the futures risk-premium declines. These results imply that when producers are risk-averse and have hedging demands, speculative activity arising from changes in speculators' risk appetites *can* affect spot prices. This is because speculative activity directly impacts the cost to producers of hedging, and concomitantly, the willingness of producers to hold inventories rather than to sell them in the spot market.

Our results provide a consistent, if partial, explanation for the recent gyrations in commodity prices. The increased allocation to commodities in financial institutions' portfolios made it cheaper for producers to hedge, allowing them to carry larger inventories, which raised spot prices. The fallout of the sub-prime crisis in 2008, however, increased speculator risk-aversion and simultaneously raised producer default risk. This increased producer hedging demand at the same time that it became costlier to hedge, causing inventories to fall and lowering spot prices. We acknowledge that our theory, which is based on increased risk-sharing between producers and speculators, is unlikely to explain the full *magnitude* of the rise and fall in oil prices. Rather than a complete explanation, we view the mechanism we have outlined as a likely contributing factor to recent price movements. Other potential contributing factors to the observed price pattern include shifts in global demand, and the possibility of a bubble in commodity prices that collapsed in the summer of 2008.

We test the model's predictions, assuming that producers' risk-aversion and hedging demand increase in their default risk. Default risk may increase the deadweight costs of external finance, one rationale for hedging, as argued by Froot, Scharfstein and Stein (1993). An alternative channel through which default risk may drive hedging demand is managerial aversion to turnover, with turnover higher in firms with high leverage and deteriorating performance (see, for example, Coughlan and Schmidt (1985), Warner et al. (1988), Weisbach (1988) and Gilson (1989)). We find that time-series fluctuations in the default risk of commodity producers help to explain the time-series variation in hedging demand and commodity spot and futures prices. Our empirical methods stand in contrast to the extant empirical work which has employed *outcomes* - such as inventories and hedging demand - rather than the *primitive* - the default risk itself, in order to explain commodity spot and futures prices. Indeed, we show that the inventories and observed futures positions of hedgers are themselves explained by variation in the default risk of producers.

In our tests, we focus on four commodities – heating oil, crude oil, gasoline and natural gas. Our choice of these commodities is partly driven by data requirement that we have at least ten producers in each quarter to produce an average measure of default risk for a given commodity, and partly by the fact that these are the largest commodity markets. We employ both balance sheet based measures of default risk – the Zmijewski-score (Zmijewski (1984)), as well as market based measures – the past three year stock return (Gilson (1989)), and the "naive" expected default frequency (EDF) which approximates Moody KMV's EDF (Bharath and Shumway, 2008). We show that these measures of the default risk of oil and gas producers are related to spot and futures prices and inventories in a manner that is consistent with our model.

First, an increase in the default risk of producers forecasts an increase in excess returns on short-term futures of these commodities. The effect is robust to business-cycle conditions and economically significant: a one standard deviation increase in the aggregate commodity sector default risk is on average associated with a 3% increase in the respective commodity's futures' risk premium. Second, as producer default risk increases, our model implies that producers will hold more inventory, pushing up spot prices. This prediction is confirmed in the data – increases in the default risk of oil and gas producers in a quarter predicts higher spot returns in the subsequent quarter.[4] Third, default risk positively forecasts hedging demand as measured by the net short positions of market participants classified as 'hedgers' by the Commodity Futures Trading Commission (CFTC). Fourth, default risk of producers negatively forecasts inventory holdings. These findings confirms our prediction that increases in producer default risk imply increases in futures risk premia and spot returns through the mechanism we identify in our model.

We do not explicitly confirm the role of speculative activity in affecting commodity markets. This is mainly owing to the empirical limitation that significant fluctuations in speculative activity have been observed primarily in recent years – lending less statistical power to any such analysis. The results of our empirical tests that employ measures of producer risk-aversion confirm the predictions of our model, and suggest that future investigations employing measures of speculator risk aversion would yield interesting results

At a fundamental level, our model and its results can be understood in terms of the role of contingent claims when markets are incomplete. In the standard Arrow-Debreu model with complete markets (Debreu (1959)), introducing redundant securities such as contingent claims has no effect on prices of existing assets. Though this simple paradigm is still the

[4]Put together, our first and second findings imply that both futures risk premia and spot returns have a common driver – the hedging demand of producers. This suggests that the default risk of producers should *not* explain the convenience yield or basis on the commodity very well. This is verified in the data (these results are available upon request).

basis for pricing of many contingent claims, including futures and options, commodities markets do not fit naturally in this paradigm for two main reasons. First, commodity markets are segmented in the sense that producers are the only economic agents that can adjust spot inventories with relative ease. In particular, speculators wishing to express their views on commodity prices can really *only* do so in the futures markets. One implication of this restriction is that futures prices might play the information aggregation role that spot prices do in other markets – generating one channel via which futures prices may affect spot prices. Another implication is that “arbitrage" between spot and futures markets is relatively costless only for commodity producers.

Second, another (perhaps deeper) form of market incompleteness arises from the inability of commodity producers to fully hedge future demand and production shocks. In such an incomplete markets setting, the introduction (or change in supply) of a contingent claim such as futures or options can improve risk-sharing in the economy and alter spot prices (see, for example, Detemple and Selden (1991)). In the specific context of commodities, futures affect the relative ease or cost of hedging by producers and thereby also affect their inventory holdings and production schedules, which in turn affects spot prices. Litzenberger and Rabinowitz (1995) link futures markets and prices to commodity production and provide empirical support for this channel using oil data. Our paper focuses more directly on the effect of the futures market on hedging by commodity producers, and its attendant impacts on inventories and spot prices.

The organization of the paper is as follows. The remainder of the introduction relates our paper to previous literature. Section 2 introduces our model. Section 3 presents the data we employ in our empirical tests. Section 4 presents and discusses the results from our empirical estimation, and Section 5 concludes.

1.1 Related Literature

There are two classic views on the behavior of commodity forward prices. The Theory of Normal Backwardation, put forth by Keynes (1930), states that speculators, who take the long side of a commodity future position, require a risk premium for hedging the spot price exposure of producers. The risk premium on long forward positions is thus increasing in the amount of hedging pressure and should be related to observed hedger versus speculator positions in the commodity forward markets. Bessembinder (1992) and De Roon, Nijman and Veld (2000) empirically link hedging pressure to futures excess returns, basis and the convenience yield and interpret their findings as consistent with the Theory of Normal Backwardation. The Theory of Storage (e.g., Kaldor (1936), Working (1949), and Brennan (1958)), on the other hand, postulates that forward prices are driven by optimal inventory management. In particular, the Theory of Storage introduces the notion of a "convenience" yield to explain why anyone would hold inventory in periods of expected decline of spot prices. Tests of the Theory of Storage include Fama and French (1988) and Ng and Pirrong (1994).

In more recent work, Routledge, Seppi and Spatt (2000) introduce a forward market in the optimal inventory management model of Deaton and Laroque (1992) and show that time-varying convenience yields, consistent with those observed in the data, can arise even with risk-neutral agents. In this case, of course, the risk premium on the commodity forwards is zero. The convenience yield arises because the holder of the spot also implicitly holds a timing option in terms of taking advantage of temporary spikes in the spot price. The time-variation in the value of this option is reflected in the time-variation in the observed convenience yield. Thus, time-variation in the observed convenience yield need not be due to a time-varying forward risk premium. Note, however, that the two theories are not mutually exclusive. A time-varying risk premium on forwards is consistent with optimal inventory management if producers are not risk-neutral or face, e.g., bankruptcy costs and speculator capital is not unlimited: If producers have hedging demands (absent from the Routledge, Seppi and Spatt model), speculators will take the opposite long positions given they are awarded a fair risk premium on the position.

In the data, hedgers are on average net short forwards, while speculators are on average net long, which indicates that producers on average have hedging demands. Gorton and Rouwenhorst (2006) present evidence that long positions in commodity futures contracts on average have earned a risk premium. It has proved difficult to explain the unconditional risk premium on commodity futures with traditional asset pricing theory (see Jagannathan, (1985) for an earlier effort). Erb and Harvey (2006) is a critical discussion of the average returns to investing in commodity futures. Fama and French (1987) present early empirical evidence on the properties of commodity prices and their link to the Theory of Storage.

There is a large literature on reduced form, no-arbitrage modeling of commodity futures prices (e.g., Brennan, (1991) Schwartz (1997)). Most recently, Cassasus and Collin-Dufresne (2004) show in a no-arbitrage latent factor affine model that the convenience yield is positively related to the spot price under the risk-neutral measure. Further, these authors shows that the level of convenience yield is increasing in the degree to which an asset serves for production purposes.

In a recent paper, Gorton, Hayashi, and Rouwenhorst (2007) argue that time-varying futures risk premia are driven by inventory levels and not by net speculator or hedger positions. In particular, they show that various definitions of hedging pressure do not significantly forecast excess long forward returns, although the signs are consistent with Keynes' hypothesis. Inventory, on the other hand, forecasts future forward returns with a negative sign in their sample; i.e., when inventory levels are low, the forward risk premium is high. They argue that this evidence is in favor of the Theory of Storage and that hedging pressure is not an important determinant of commodity forward risk premiums. In addition, Gorton, Hayashi, and Rouwenhorst show that the inventory level is negatively related to the basis, spot commodity price and that the relation is nonlinear in that it is stronger the lower the inventory level. This evidence strongly supports the main features of the Theory of Storage. However, they do not consider default risk directly. Identifying and highlighting the role of default risk – the primary underlying risk that we argue and find drives producers to hedge using futures contracts – constitutes our most important and novel contribution.

2 The Model

In this section, we present a model of commodity spot and futures price determination that combines both the optimal inventory management model of Deaton and Laroque (1992) and the commodity speculation and hedging demand models of Anderson and Danthine (1981, 1983). There are three types of agents in this model: (1) The commodity producers, who manage profits through optimal inventory management and hedging using commodity futures; (2) the consumers, whose demand for the spot commodity along with the equilibrium supply determine the commodity spot price; (3) the speculators, whose demand for the commodity futures along with the futures hedging demand of producers determine the commodity futures price.

Hedging demand on the part of commodity producers arises since commodity producers are assumed to be averse to future earnings volatility. The literature on hedging demand provides several justifications for this modeling choice. Managers could be underdiversified, as in Stulz (1984), or better informed about the factors responsible for generating firm performance (Breeden and Viswanathan (1990), and DeMarzo and Duffie (1995)). Managers could also be averse to distress (see Gilson (1989)), or there may be costs of financial distress to the firm (Smith and Stulz (1985)). Aversion to earnings volatility can also be viewed as arising from costs of external financing as in Froot, Scharfstein, and Stein (1993). In the Appendix, we present a slightly more complicated model which employs the Froot, Scharfstein, and Stein (1993) framework to model hedging demand as arising from costly external financing.

2.1 Consumption, Production and the Spot Price

Each period c_t units of the good is consumed. The production schedule is predetermined and production each period is denoted g_t. Thus, we have in mind an economy where the time and cost required to adjust production schedules to transitory demand shocks are prohibitively large.[5] The current economy-wide inventory level of the commodity is denoted I_t and goods in inventory depreciate at a rate d. Market clearing demands that incoming inventory and current production, $g_t + (1-d)\, I_{t-1}$, equals current consumption and outgoing inventory, $c_t + I_t$. This equality can be rearranged and we get:

$$c_t = g_t - \Delta I_t \tag{1}$$

where $\Delta I_t \equiv I_t - (1-d)\, I_{t-1}$. Let the spot price of the commodity be denoted S_t. We assume the immediate use demand, $c_t\,(S_t; a_t)$, is monotone decreasing in the spot price S_t given a level of the current demand shock, a_t. We summarize the spot market as follows:

$$S_t = a_t + f\,(g_t - \Delta I_t)\,, \tag{2}$$

where the demand shock a_t has variance σ_S^2, and f is decreasing in the supply, $g_t - \Delta I_t$.[6] The demand shock represents exogenous shifts in the commodity demand that are independent of the commodity price level. A similar inverse demand function is assumed in Routledge, Seppi, and Spatt (2000). We will in the following for simplicity of exposition, but without loss of generality, assume that the per period depreciation rate, $d = 0$ and interest rate $r = 0$.

[5] We will in the empirical section consider the behavior of short-term commodity futures contracts. Arguably, short-term contracts are more influenced by inventory fluctuations than shocks to longer term supply and demand.

[6] We assume throughout the analysis that a_t and f are specified such that (a) prices are positive and (b) a market-clearing spot price exists.

2.2 Producers

Producers are assumed to have two concerns: (i) they want to maximize the value of current and future earnings, but (ii) they also want to minimize the variance of next period's earnings. The latter concern is what gives rise to a hedging demand. The timing of the managers' decisions are as follows. In period 0, the firm stores an amount I as inventory from its current supply, g_0, and so period 0 profits are simply $S_0 (g_0 - I)$. The firm also enters h_p short futures contracts for delivery in period 1. In period 1, the firm sells its current inventory and production supply, honors its futures contracts and realizes a profit of $S_1 (I + g_1) + h_p (F - S_1)$, where F is the forward price of the futures contracts. There is an infinite mass of inventory managers normalized to one. The individual inventory manager is therefore a price taker. The firms' problem is then

$$\max_{\{I,h\}} \; S_0 (g_0 - I) + E [S_1 (I + g_1) + h_p (F - S_1)] \; ... \\ - \frac{\tilde{a}_p}{2} Var [S_1 (I + g_1) + h_p (F - S_1)] \tag{3}$$

subject to

$$I \geq 0, \tag{4}$$

where $\tilde{a}_p$ governs the degree of aversion to variance in future earnings.[7]

Hedging Demand Case: $\tilde{a}_p > 0$

The first order condition of inventory holding is:

$$S_0 - E [S_1] = -\tilde{a}_p (I + g_1 - h_p) \sigma_S^2 + \lambda, \tag{5}$$

where λ is the Lagrange multiplier on the inventory constraint and σ_S^2 is the price volatility of the period 1 commodity price. If the current demand shock is sufficiently high, an inventory stock-out occurs (i.e., $\lambda > 0$), and current spot prices can rise above future expected spot prices. Firms would in this case like to have negative inventory, but cannot. This creates predictability in the spot price and thus an observed convenience yield from holding the spot in the sense that those who do hold the spot at time 0 get to sell at a high price. This is the Theory of Storage aspect of the model. In a multi-period setting, a convenience yield of holding the spot arises in these models even if there is no actual stock-out, but as long as

[7] In this model, $E [\cdot]$ denotes the expectation conditional on the information set at time 0.

there is a positive *probability* of a stock-out (see Routledge, Seppi, and Spatt, 2000).[8]

Solving for optimal investment, we have

$$I^* = \frac{E[S_1] - S_0 + \lambda}{\tilde{a}_p \sigma_S^2} - g_1 + h_p^*. \tag{6}$$

Thus, inventory is increasing in expected future price, decreasing in current price, and decreasing in the amount of extracted oil (g_1). Importantly, inventory is also increasing in the amount of oil hedged in the futures market. That is, hedging allows the producer to hold more inventory as it reduces the amount of earnings variance the producer would otherwise be exposed to.

The first order condition for the number of short futures contracts is:

$$\begin{aligned} F - E[S_1] &= -\tilde{a}_p (I + g_1 - h_p) \sigma_S^2 && (7) \\ &\Updownarrow \\ h_p^* &= I^* + g_1 - \frac{E[S_1] - F}{\tilde{a}_p \sigma_S^2}. && (8) \end{aligned}$$

The optimal number of short futures contracts held is one-for-one with the period one supply, $I^* + g_1$, but with a price adjustment: If the futures price is lower than the expected future spot price, it is optimal for the producer to increase the expected profits by entering a long *speculative* futures position after having fully hedged the period 1 supply. Since the inventory manager is naturally short future oil, this case entails shorting fewer futures contracts. In other words, since the hedge is costly it is not optimal to hedge the period 1 price exposure fully. Increasing the producer's incentive to hedge, $\tilde{a}_p$, decreases this speculative position. Note also that if $F = E[S_1]$ there are no gains or costs to hedging activity in terms of expected profits and the producer will therefore simply minimize the variance of period 1 profits by hedging fully.

The Basis

Combining the first order conditions, we have that

$$basis = S_0 - F = \lambda. \tag{9}$$

[8] In terms of intuition with respect to practical application, where a de facto stock-out very rarely occurs, one can think of "stock-outs" in our simple one-period model as an increase in the probability of a stock-out.

In words, the basis only differs from zero if there is a stock-out. Thus, a convenience yield can only arise in this model through the inventory stock-out channel, as in Routledge, Seppi, and Spatt (2000). This in turn implies that the futures risk premium and the expected change in the spot price cancel each other out in times of no stock-out. The basis is therefore not a good signal of the futures risk premium in this model, consistent with the findings of Fama and French (1986) and our empirical results to follow.

Benchmark Case: $\tilde{a}_p = 0$

When $\tilde{a}_p = 0$, there is no hedging incentive. From the producers' first order condition for the number of futures contracts, we then have

$$F = E\left[S_1\right]. \tag{10}$$

Thus, the assumption of producer hedging demand is necessary for a futures risk premium to arise in this model.

2.3 The Speculators

Speculators in the commodity market are assumed to be subject to capital constraints due to, e.g., (expand on this and references) costs of leverage such as margin requirements, VaR limits, and increased costs of capital in the risk exposure due to moral hazard, costs of bankruptcy. In particular, we assume that these costs are proportional to the variance of the speculator position. Thus, the representative speculator maximizes the gains to trading in the commodity market subject to a penalty function that is proportional in variance:

$$\max_{h_S} E\left[h_s\left(S_1 - F\right)\right] - \frac{\tilde{a}_s}{2} Var\left[h_s\left(S_1 - F\right)\right] \tag{11}$$

$$\Downarrow$$

$$h_s = \frac{E\left[S_1\right] - F}{\tilde{a}_s \sigma_S^2}. \tag{12}$$

If speculators are not subject to any frictions, $\tilde{a}_s = 0$, the market clearing futures price would be the same as the expected spot price: $F = E\left[P_1\right]$. In this case, there would not be a role for hedging demand affecting commodity prices, as explained above. Thus, the assumption of speculator variance aversion is also necessary to generate fluctuations in the futures risk premium related to hedging activity in this model.

2.4 Equilibrium

The futures contracts are in zero net supply and therefore $h_s = h_p$, in equilibrium. From equations (8) and (12) we thus have that

$$(a_s + a_p)(E[S_1] - F) = I^* + g_1, \tag{13}$$

where $a_p \equiv 1/(\tilde{a}_p \sigma_S^2)$ and $a_s \equiv 1/(\tilde{a}_s \sigma_S^2)$. Using the fact that $S_0 - F = \lambda$, we get

$$(a_s + a_p)(E[S_1(I^*)] - S_0(I^*) + \lambda) = I^* + g_1. \tag{14}$$

Since $I^* + g_1 > 0$, we have that $E[S_1] - (S_0 - \lambda) > 0$. We assume this relation holds throughout our analysis. In the case of no stock-out, this implies that $E[S_1] > S_0$. When there is a stock-out, however, current spot prices can be higher than expected future spot prices as λ in this case is greater than zero. Equation (14) gives the solution for I^*. Given I^* and the inverse demand function in equation (2), we can calculate $E[S_1(I^*)]$. Since $F = S_0(I^*) - \lambda(I^*)$, the equilibrium supply of short futures contracts can be found using equation (8).

2.5 Model Predictions

In following, we present model predictions for the commodity inventory, spot and futures prices as we vary exogenous parameters of interest. In particular, we look at producers' propensity to hedge, $\tilde{a}_p$, and the degree of speculators' variance aversion, $\tilde{a}_s$. Proofs of the following Propositions are relegated to the Appendix, and we only give the economic intuition for the results in this section.

Proposition 1 ***Producer Risk Aversion,*** $\tilde{a}_p$***:*** *The aggregate inventory level and commodity spot price are decreasing in producer risk aversion. The futures risk premium is increasing in producer risk aversion.*

[FIGURE 1 AND FIGURE 2 ABOUT HERE]

The model's predictions with respect to changes in fundamental hedging demand are summarized in Figure 1 and Figure 2. Figure 1 shows that in the case of no inventory stock-out, producers will tend to hold less inventory when their propensity to hedge is high. Inventory is risky for the firm since future spot prices are uncertain. It is never optimal for the constrained firm to fully hedge its inventory as the futures risk premium is positive in this case, and since it therefore is costly for the firm to hedge. Increased sensitivity to the risk of holding unhedged inventory, decreases the inventory holding in equilibrium. This means that more of the commodity is sold on the spot market and the current spot prices are low while future spot prices are high. Since selling the commodity in the spot market and investing the cash is an alternative to holding an extra unit of inventory and hedging with a short futures contract in terms of receiving a risk-less payment in the future, the return to both of these strategies must be equal in equilibrium. This is why a high expected spot price leads to a high futures risk premium as illustrated in Figure 1. Figure 2 shows the case of an inventory stock-out. Now, current and future expected spot prices are constant. The increased benefit of hedging with the futures contract leads to a higher demand for short futures contracts which can only be accommodated by increasing the futures risk premium.

In sum, the model predicts that the futures risk premium is increasing in producers' hedging demand. When there is not an inventory stock-out, increased hedging demand all else equal leads to lower current spot prices and higher expected future spot prices. Thus, the cost of hedging in futures markets (the futures risk premium) affects the spot markets.

The same intuition holds for variations in the speculators appetite for risk.

Proposition 2 ***Speculator Risk Tolerance,*** $\tilde{a}_s^{-1}$***:*** *The aggregate inventory level and commodity spot price are increasing in speculator risk tolerance. The futures risk premium is decreasing in speculator risk tolerance.*

Increasing speculator risk tolerance decreases the futures risk premium in equilibrium as their demand for long futures positions increases. This, in turn, makes it cheaper for the producers to hedge their inventory, which allows them to hold more inventory. A higher inventory level means that less of the commodity is sold in the spot market, and therefore the spot price increases.

Since the basis $(S_0 - F)$ is constant in the case of no inventory stock-out, the fluctuations in the futures risk premium must be common to fluctuations in the expected return to holding the spot. This makes the basis a poor predictor of expected returns, as empirically documented in Fama and French (1986). The model provides an explanation for this fact. A high expected future spot price relative to the current spot price encourages the producer to hold more inventory. With increased inventory holding comes increased hedging demand.

The resulting increased demand for short futures contracts increases the futures risk premium needed to induce speculators to take the opposite side of these contracts. Thus, the futures risk premium and expected change in the spot price tend to move together. The basis can be written

$$S_0 - F = (S_0 - E[S_1]) - (F - E[S_1]), \tag{15}$$

which highlights the fact that the basis will not capture such a common component and therefore is not a good signal of the futures risk premium.

In the following we empirically test the predictions of the model.

3 Data and Summary Statistics

We use time-series data on inventory holdings of commodities, commodity futures prices, commodity spot prices, and hedger demand for futures contracts. In addition, we use measures of default risk obtained from balance sheet data from Compustat. We focus our analysis on the energy sector – in particular, we look at Heating Oil, Crude Oil, Gasoline and Natural Gas.

3.1 Proxies for Fundamental Hedging Demand

In Froot, Scharfstein and Stein (1993), agency costs are motivated as monitoring costs that outside investors must incur to curb the agency problems affecting firms' managers and owners. In a large body of finance literature, such costs are larger in an expected sense when firms are closer to defaulting on debt of the firm since the debtholder-equityholder conflicts become more severe in such states. The agency problems that kick in could either be the underinvestment problem, as in Myers (1977), or asset-substitution problem, as in Jensen and Meckling (1976). Indeed, costly state verification has been one of the economic rationales for debt being the optimal financing contract (Townsend (1979) and Gale and Hellwig (1985)), and the equilibrium of these models features costly verification of states only in the default states. Of course, in practice, we do see equity issuances by firms as well. These are also however associated with significant dilution costs, as theoretically motivated by the adverse selection argument of Myers and Majluf (1984).

Empirical evidence on costs of external finance is plenty. Direct costs of bond and equity issuance have been carefully examined by Altinkilic and Hansen (2000). They document that these costs are substantial and that over 85% of the total underwriter spread is a variable cost and that the marginal cost of external finance is rising. Importantly, lower quality offerings are at higher underwriter spreads. Choe, Masulis and Nanda (1993) and Bayless and Chaplinsky (1996) document that equity issuance patterns of firms are procyclical consistent with there being greater dilution costs from issuance during economic downturns and recessions, a finding that is consistent with an increase in agency problems and default risk in such times. There is also evidence that many distressed firms find it difficult to raise external finance, unless their leverage is restructured in some fashion (Franks and Sanzhar (2006), among others). Finally, it is well-known (though not as well academically documented) that firms find it extremely difficult to borrow short-term (generally, in the commercial paper market) unless they are investment-grade rated. That is, a deterioration in credit risk forces firms to borrow long-term and suffer a higher cost of capital.

An alternative driver of hedging demand is managerial aversion to distress and default.[9] Empirical evidence has demonstrated that managerial turnover is indeed higher in firms with higher leverage and deteriorating performance. For example, Coughlan and Schmidt (1985), Warner et al. (1988), Weisbach (1988) provide evidence that top management turnover is predicted by declining stock market performance. In an important study, Gilson (1989) refines this evidence to also examine the role of defaults and leverage. He finds that management turnover is more likely following poor stock-market performance, but importantly within the sample of firms (each year) that are in the bottom five percent of stock-market performance over a preceding three-year period (his sample being firms from NYSE and AMEX over the period 1979 to 1984), the firms that are in default on their debt experience greater top management turnover. Furthermore, higher leverage also increases the incidence of turnover. However, management turnover by itself would not lead to a hedging demand from managers if the personal costs managers face from such turnover are small. Gilson documents that following their resignation from firms in default, managers are not subsequently employed by another exchange-listed firm for at least three years, a result that is consistent with managers experiencing large personal costs when their firms default.

Given this theoretical and empirical motivation, we employ both balance-sheet and market-based measures of default risk as our empirical proxies for the cost of external finance. The balance-sheet based measure we employ is the Zmijewski (1984) score. This measure is positively related to default risk and is a variant of the Z-score of Altman (1968).

[9] Stulz (1984) proposes general aversion of managers to variance of cash flows as a driver of hedging demand, the rationale being that while shareholders can diversify across firms in capital markets, managers are significantly exposed to their firms' cash-flow risk due to incentive compensation as well as investments in firm-specific human capital.

The methodology for calculating the Zmijewski-score was developed by identifying the firm-level balance-sheet variables that help "discriminate" whether a firm is likely to default or not. The market-based measures we employ are first, the rolling three-year average stock return of commodity producers, and second, the naive expected default frequency (or naive EDF) computed by Bharath and Shumway (2008). The use of the rolling three-year average stock return is motivated by the analysis of Gilson (1989), who relates low cumulative unadjusted three-year stock returns to default and managerial turnover.

3.2 Default Risk Data

The longest sample period of our analysis runs from the first quarter of 1980 until the fourth quarter of 2006 (108 quarters). This sample period varies across commodities and measures according to data availability. To create the Zmijewski score, we require balance sheet information for commodity producers, and we obtain this information by first matching companies with commodities based on their four-digit SIC code (these SIC codes are taken from Gorton, Hayashi and Rouwenhorst (2007)). For Crude Oil, Heating Oil and Gasoline, this is all firms in SIC codes 2910 and 2911, i.e., Petroleum Refining. There are 50 such firms – note that the default risk series is identical (across all measures) for Crude Oil, Heating Oil and Natural Gas. For Natural Gas, this is all firms in SIC codes 1310 and 1311, i.e., Crude Petroleum and Gas Extraction. There are 475 such firms.

We then searched the merged CRSP-Compustat quarterly database for all companies that are classified as belonging to these four-digit SIC codes, and for each company, we compute:

$$\begin{aligned} Zmijewski\text{-}score \;=\; & -4.3 - 4.5 * NetIncome/TotalAssets + 5.7 * TotalDebt/TotalAssets \\ & -0.004 * CurrentAssets/CurrentLiabilities. \end{aligned} \tag{16}$$

For each period in which there are at least four firms in the data present, we take the average Zmijewski score, and use it as our measure. In the following, we will denote the Zmijewski score as $AVGZm$.

The first market based measure we employ is the rolling three-year average stock return, which is computed using monthly data from CRSP for each company. Writing R_{it} for the cum-dividend stock return for a firm i calculated at the end of month t, we compute:

$$ThreeYearAvg_{i,t} = \frac{1}{36}\sum_{k=0}^{35} \ln(1 + R_{i,t-k}) \tag{17}$$

We then select from this series $ThreeYearAvg_{i,q}$ at the end of each quarter q to match it with our quarterly data frequency, and then average the measure across all firms i in each commodity group to obtain the group-level average.

The second market based measure we employ is the naive EDF. The EDF from the KMV-Merton model is computed using the formula:

$$EDF = \Phi\left(-\left(\frac{\ln(V/F) + (\mu - 0.5\sigma_V^2)T}{\sigma_v\sqrt{T}}\right)\right) \tag{18}$$

where V is the total market value of the firm, F is the face value of the firm's debt, σ_v is the volatility of the firm's value, μ is an estimate of the expected annual return of the firm's assets, and T is the time period, in this case, one year. Bharath and Shumway (2008) compute a 'naive' estimate of the EDF, employing certain assumptions about the variable used as inputs into the formula above. We use their estimates in our empirical analysis.[10] Of the set of 50 firms for Crude Oil, Heating Oil and Gasoline, we have naive EDF estimates for 40 firms, and of the 475 firms in the Natural Gas group, we have naive EDF estimates for 395. We average these measures across all firms in each time period to get the commodity-group-level estimate.

[TABLE I ABOUT HERE]

Table I shows summary statistics for each of the aggregate default risk measures. The measures of default risk are persistent, with quarterly autocorrelations ranging between 0.70 to 0.97. Figure 1 shows the time-series of the normalized $AVG3Y$, $AVGZm$ and Naive EDF series for Crude Oil, Heating Oil, and Gasoline, which all have the same default measures, as the producer firms for these commodities all belong to the same SIC classification codes. Figure 2 shows the same for Natural Gas. First, the series are correlated, but not identical. As expected, the $AVGZm$-score and Naive EDF series move in the same direction, while

[10] We thank Sreedhar Bharath and Tyler Shumway for providing us with these estimates.

$AVG3Y$ moves in the opposite direction.[11] Second, there is considerable time-variation in measured default risk, which indicates there is economically significant time-variation in the fundamental hedging demand of producers in these commodity sectors.

[FIGURE 3 ABOUT HERE]

[FIGURE 4 ABOUT HERE]

3.3 Basis and Excess Returns Data

To create the basis and excess returns measures, we follow the methodology of Gorton, Hayashi and Rouwenhorst (2007), and employ data from Datastream. We constructed rolling commodity futures excess returns at the end of each month as the one-period price difference in the nearest to maturity contract that would not expire during the next month. That is, the excess return from the end of month t to the next is calculated as:

$$\frac{F_{t+1,T} - F_{t,T}}{F_{t,T}}, \tag{19}$$

where $F_{t,T}$ is the futures price at the end of month t on the nearest contract whose expiration date T is after the end of month $t+1$, and $F_{t+1,T}$ is the price of the same contract at the end of month $t+1$. The quarterly return is constructed as the product of the three monthly returns in the quarter.

We also employ measures of the spot returns on each commodity, which we take from the Reuters-CRB dataset, employed by Gorton, Hayashi and Rouwenhorst (2007). The 'spot return' is actually the return on the nearest-to-expiration futures contract, rolled into the next futures contract upon expiration.

The futures basis is calculated for each commodity as $(F1/F2 - 1)$, where $F1$ is the nearest futures contract and $F2$ is the next nearest futures contract. We account for the seasonality in the basis by including four quarterly dummy variables in all specifications employed to explain the basis. The statistical properties of our data match up very closely to those employed by Gorton, Hayashi and Rouwenhorst (2007), summary statistics about these quarterly measures are presented in Table I. Note that the means and medians of the

[11] Note that $AVG3Y$ predicts default with a *negative* sign, while $AVGZm$ and the naive EDF predict default with a *positive* sign.

basis in the table are computed using the raw data, while the standard deviation and first-order autocorrelation coefficient are computed using the deseasonalized basis. The basis does display some persistence once seasonality has been accounted for. Furthermore, the average basis is positive for Crude Oil, Heating Oil and Gasoline, while Natural Gas has a negative basis on average over the sample period. This indicates that the convenience yield is on average positive for the three first commodities. Note the relatively high standard deviation of the basis, which indicates that the basis for each of the commodities at times changes sign. Thus, time-varying convenience yields are an important feature of the data.

The excess returns are on average positive for all three commodities, ranging from 2.5% to 6.7%, with relatively large standard deviations (overall in excess of 20%). As expected, the sample autocorrelations of excess returns on the futures are close to zero.

3.4 Hedger Positions Data

The Hedger Net Positions data are obtained from Pinnacle Inc., which sources data directly from the Commodity Futures Trading Commission (CFTC). Classification into Hedgers, Speculators and Small traders is done by the CFTC, and the reported data are the total open positions, both short and long, of each of these trader types across all maturities of futures contracts. We measure the net position of all hedgers in each period as:

$$HedgersNetPosition_t = \frac{(HedgersShortPosition_t - HedgersLongPosition_t)}{(HedgersShortPosition_{t-1} + HedgersLongPosition_{t-1})} \tag{20}$$

This normalization means that the net positions are measured relative to the aggregate open interest of hedgers in the previous quarter. Summary statistics on these data are shown in Table I. First, the hedger positions are on average positive, which means investors classified as hedgers are on average short the commodity forwards. However, the standard deviations are relatively large, indicating that there are times when hedgers actually are net long whereas speculators are net short. This is a feature of the data we do not capture in our model. The autocorrelation of the hedger positions is mostly positive, but not as persistent as the autocorrelation of the measures of default risk. Thus, the hedging demand, as measured by the *number* of forward contracts hedgers hold, does not appear one for one with the aggregate default risk in the commodity sector. There are several reasons for this. Empirically, the variable that classifies investors as hedgers or speculators is quite noisy. For instance, the relative positions are given per commodity, not per contract. Thus, common strategies, for instance the "calendar spread" where one goes long (short) the long term forward and short (long) the short term forward on the same commodity, cannot be identified. In addition, the classification of who is a hedger and who is a speculator can sometimes be difficult. As an example, many production firms run trading desks as a part of their business. The line between a hedge trade or a speculator trade is therefore blurred. It is important to note these empirical differences as they help explain why hedger demand does not significantly forecast forward risk premiums (see Gorton, Hayashi and Rouwenhorst, 2007), while measures of default risk do.

3.5 Inventory Data

Aggregate inventories are created as per the specifications in Gorton, Hayashi and Rouwenhorst (2007). For all four energy commodities, these are obtained from the Department of Energy's Monthly Energy Review. For Crude Oil, we use the item: "U.S. crude oil ending stocks non-SPR, thousands of barrels." For Heating Oil, we use the item: "U.S. total distillate stocks". For Gasoline, we use: "U.S. total motor gasoline ending stocks, thousands of barrels." Finally, for Natural Gas, we use: "U.S. total natural gas in underground storage (working gas), millions of cubic feet." Following Gorton, Hayashi and Rouwenhorst (2007), we compute a measure of the discretionary level of aggregate inventory by subtracting fitted trend inventory from the quarterly realized inventory. Quarterly trend inventory is created using a Hodrick-Prescott filter with the recommended smoothing parameter. In all specifications employing inventories, we employ quarterly dummy variables. We do so in order to control for the strong seasonality present in inventories. The final panel in Table II shows summary statistics of the resulting aggregate inventory measure, i.e., the cyclical component of inventory stocks, for the commodities. Once the seasonality in inventories is accounted for, the autocorrelation is high and positive.

4 Empirical Results

This section presents our empirical results. The novel predictions of our model are the following. Aggregate commodity sector fundamental hedging demand should be positively related to the respective commodity's futures risk premium. We have argued that fundamental drivers of hedging demand is linked to measures of default risk. In particular, high default risk on average leads to higher hedging demand. Further, there should be a common component in the expected change in the spot price and the futures risk premium except in times of low inventory (inventory stock-out in the model). This common component is why the basis, as shown in previous research (e.g., Fama and French (1986)), is not a strong forecaster of the time-series of commodity futures risk premiums, but instead is more tightly linked to fluctuations in inventory. Finally, we investigate whether two outcomes are as predicted by the model: hedger short futures positions should be higher and inventories lower when the producers' average default risk is high.

4.1 The Futures Risk Premium and Default Risk

To evaluate whether the measures of commodity sector default risk are important for explaining futures risk premiums, we run standard forecasting regressions. In particular, we regress quarterly (excess) futures returns on one quarter lagged measures of default risk ($DefRisk$):

$$ExcessReturns_{i,t+1} = QtrDummies_{t+1} + \beta_i DefRisk_{i,t} + u_{i,t+1}, \tag{21}$$

where i denotes the commodity and t denotes time measured in quarters. All regressions include quarterly dummy variables to control for the strong seasonal variation in inventory, basis and returns.

We then re-run the same regression, but add in controls:

$$ExcessReturns_{i,t+1} = QtrDummies_{t+1} + \beta_i DefRisk_{i,t} + ControlVariables_t + u_{i,t+1}, \tag{22}$$

In a standard asset pricing setting, time-varying aggregate risk aversion and/or aggregate risk can give rise to time-variation in excess returns. We therefore include business cycle variables that have been shown to forecast excess asset returns in previous research. We include the Default Spread, the yield spread between Baa and Aaa rated corporate bond yields, which proxies for aggregate default risk in the economy and has been shown to forecast excess returns to stocks and bonds (see, e.g., Fama and French (1989)). We also include the Payout Ratio, which is defined as ln(1+ Net payout / Market Value). Here Net Payout is the aggregate equity market cash dividends plus repurchases minus equity issuance, while Market Value is the aggregate market value of outstanding equity. In a recent paper, Boudoukh, Michaely, Richardson, and Roberts (2007), show that this measure of the aggregate dividend yield dominates the cash dividend only aggregate dividend yield commonly used in terms of forecasting aggregate equity market returns. Finally, we include cay, Lettau and Ludvigson's (2001) proxy for the aggregate consumption-wealth ratio.

In addition to these controls, we include the lagged level of aggregate inventory and the lagged basis to control for other possible determinants of the futures risk premium. Table II shows the results of the univariate regression as well as the regression with controls, across the four commodities considered.

[TABLE II ABOUT HERE]

First, we note that in all cases, the regression coefficients have the predicted sign; an increase in default risk forecasts higher futures returns over the next quarter. For $AVGZm$, the regression coefficients are significant at the 10% level or more, using Newey-West t-statistics with 3 lags, in 5 out of 8 regressions. The strongest evidence is for Crude Oil and Heating Oil, which are the two commodities which have the longest return series available (91 and 108 quarters, respectively). This result is reinforced with the use of the market-based $AVG3Y$ and Naive EDF measures, for which the patterns detected with the balance sheet measure are even more clear. The joint tests, which pool all commodities together (after normalizing individual LHS and RHS variables by their commodity-specific standard deviations), are also all consistent with the commodity-specific results. Thus, our measures of fundamental producer hedging demand are indeed positively related to the futures risk premium in univariate regressions, as predicted by our model.

The results with respect to the proxies for default risk are virtually unchanged once the regressions incorporate controls. The individual coefficients are significant in 9 of the 12 regressions and all of the right sign, with the exception of the EDF and Natural Gas, which has a negative but insignificant coefficient. The significance level of the joint tests has increased and are they now all significant at the 5% level or better. From this we conclude that default risk is an important determinant of commodity futures risk premiums above and beyond previously documented business cycle variation in some combination of aggregate risk and risk tolerance. This results lends support to the model's implicit assumption of some degree of market segmentation between the stock market and the energy commodity markets considered here.

The R^2's range between 6.3% and 11.5% in the univariate regressions with significant coefficients, with an overall average around 9%. A one standard deviation increase in default risk is on average associated with approximately a 3% increase in expected futures returns, using the joint test estimates. Thus, we uncover both economically and statistically significant variation in the commodity futures risk premiums using our measures of default risk.

In sum, the evidence in Table II supports the hypothesis that a fundamental driver of hedging demand, default risk, is an important determinant for commodity futures risk premiums. The relation between producers' hedging demand and the futures risk premium is positive, consistent with the model.

4.2 Default Risk and Spot Commodity Returns

Next, we consider the relation between spot commodity returns and the measures of default risk. The model predicts a common component in the expected return to holding the spot and the futures risk premium that is driven by fundamental hedging demand. Table III reports the results of the following regression:

$$SpotReturns_{i,t+1} = QtrDummies_{t+1} + \beta_i DefRisk_{i,t} + u_{i,t+1}, \tag{23}$$

where i denotes the commodity and t denotes time measured in quarters.

We then re-run the same regression, but add in the same set of controls as for the futures excess return regressions:

$$SpotReturns_{i,t+1} = QtrDummies_{t+1} + \beta_i DefRisk_{i,t} + ControlVariables_t + u_{i,t+1}, \tag{24}$$

[TABLE III ABOUT HERE]

Table III shows that there is a clear relation between default risk and spot returns on commodities. This is especially true when the regressions incorporate the control variables. The controls related to the lagged inventory level and basis are particularly important for the spot price. Seasonality and lower frequency fluctuations in inventory leads to spot price predictability through the Theory of Storage aspect of these markets, also in the case where producers do not have a hedging demand.

In the regressions, high producer hedging demand leads to high expected returns to holding the spot (ignoring storage costs) - all the statistically significant regression coefficients (9 out 12) have the predicted sign. Further, the joint tests all have the right sign and are significant at the 5% level or better. Notably, the magnitude of the coefficients are similar to the ones obtained in the regressions forecasting the futures returns. This implies that the common component in the expected futures returns and spot price appreciation are of a similar size. This is as predicted by the model and key to explaining why these fluctuations in the futures risk premium are not uncovered by the basis. The futures thus inherits the risk of the spot as the producer trades off holding spot and hedging with future contracts. In equilibrium, the cost of hedging with the futures must equal the marginal benefit of holding an additional unit of the spot.

This result also highlights the empirical relevance of another important feature of the model. In the model, a decrease in the futures risk premium leads to an increase in the spot price as producers are willing to hold more inventory when the cost of hedging is lower. The spot regressions are consistent with this result, as an increase in the spot price all else equal leads to a lower spot premium. To the extent the massive increase in speculator demand for long commodity futures positions over the recent years led to a decrease in the futures risk premium, we should expect to have seen an increase in the spot price. This effect is due to the increased risk-sharing between producers and speculators enabled on account of a lower futures risk premium. Note that an increase in spot prices can occur through this channel even if there are no changes in current and expected future demand for the commodity.

Robustness: Persistence of Default Risk Measures The observed persistence of the default risk measures suggests that there may be problems in incorporating these measures into forecasting regressions for commodity futures returns (see Stambaugh (1999) and Lewellen (2004) for the biases inherent in predicting returns with persistent financial ratios). To check the robustness of our test results to such problems, we detrended the time series of the most persistent forecasting variables ($AVGZm$ and $AVG3Y$).[12] We find that all of our results are qualitatively unchanged when this is done.

4.3 Hedger Positions and Default Risk

The above results lead to the natural question: Are hedging positions then correlated with default risk in the manner predicted by the theory? We now address this question using the available data on net hedger positions from the CFTC. As explained in Section 3, the

[12] To do so, we used the Hodrick-Prescott filter, and the recommended quarterly smoothing parameter of 1600, and made sure to detrend each series using information only up to and including period t. This was to ensure that the forecasting regressions are not contaminated by the use of future information.

aggregate data on hedger positions is noisy and other studies (e.g., Gorton, Hayashi and Rouwenhorst, 2007) have shown that these measures of hedger positions do not significantly forecast excess futures returns as predicted by the hedging demand channel, although the sign is right. This result can be ascribed to an errors-in-variables problem. However, a noisy measure of hedger positions should still contain information about the true hedger positions. Therefore, we regress the hedger positions on the measures of default risk to uncover this component. Since hedger positions is the dependent variable in these regressions, the errors-in-variables problem described is alleviated.

The variables are constructed as the net *short* position, so we should expect high default risk to predict next period's hedger positions with a *positive* sign in the regressions. Furthermore, rather than a contemporaneous regression, we run a forecasting regression for hedger positions, in the event there is some delay before hedgers put their positions in place and to establish causality:

$$HedgerNetPosition_{i,t+1} = QtrDummies_{t+1} + \beta_i DefRisk_{i,t} + u_{i,t+1}. \tag{25}$$

We then re-run the same regression, but add in the same set of controls as we did for the futures excess return regressions:

$$HedgerNetPosition_{i,t+1} = QtrDummies_{t+1} + \beta_i DefRisk_{i,t} + ControlVariables_t + u_{i,t+1}, \tag{26}$$

[TABLE IV ABOUT HERE]

Table IV shows that the signs are as predicted in all but two of the univariate regressions, and that 10 of 15 of the coefficients are statistically significant. When controls are added, this increases to 11 of 15 regressions. The results in this table confirm that hedger's short positions are indeed determined by the level of default risk of producing firms. Together with the evidence presented earlier connecting the futures risk premium to default risk, this evidence further strengthen the conclusion that the fundamental, primitive measures of hedging demand used in this paper capture a component of realized hedging demand that is important for futures risk premiums. The R^2's in these regressions are on average about 20%. While some of unexplained variation in the hedger position variable can be attributed to the variable being a noisy measure of the truth, it also likely indicates, perhaps unsurprisingly, that a substantial amount of the trading in the futures market is not accounted for by our simple model.

4.4 Inventory and Default Risk

Finally, we check whether the specific mechanism predicted by the theory operates correctly, i.e., whether changes in default risk translate into changes in discretionary holdings of inventory. Again, rather than a contemporaneous regression, we run a forecasting regression for changes in aggregate inventory, in the event there is some friction preventing hedgers from immediately implementing their strategies and to establish causality:

$$ChangeInventory_{i,t+1} = QtrDummies_{t+1} + \beta_i DefRisk_{i,t} + u_{i,t+1}. \tag{27}$$

We then re-run the same regression, but add in the same set of controls as we did for the futures excess return regressions. We augment these controls in two ways: first, with measures of forecasted GDP and Industrial Production growth over the following quarter, as measured by the average growth forecast in the Philadelphia Fed's survey of professional forecasters. This is to pick up any variation in inventory arising from intertemporal variations in demand that would naturally lead to time-variation in the inventory holdings. Second, we augment the set of controls with four lagged values of changes in inventory, in case there are seasonalities in changes in inventory that are not captured by the quarterly dummy variables. We run:

$$\begin{aligned} ChangeInventory_{i,t+1} &= QtrDummies_{t+1} + \beta_i DefRisk_{i,t} \\ &\quad + \sum_{k=1}^{4} \gamma_i ChangeInventory_{i,t-k} + ControlVariables_t + u_{i,t+1}, \end{aligned} \tag{28}$$

[TABLE V ABOUT HERE]

Table V shows that while the univariate regressions do not generate clean support for our theory, once controls are added, the regressions reveal that the signs are as predicted in all but three of the regressions. Moreover, the joint test results all have the predicted sign and they are statistically significant for $AVG3Y$ and Naive EDF. For $AVGZm$, the t-statistic for the joint test results is 1.52. This evidence suggests that the mechanism we identify in the paper connecting discretionary changes in inventory with measures of default risk is a reasonable one.

As in the model, the empirical results presented in this paper indicate that the primitive driving force is the producers' fundamental hedging demand: An increase in default risk leads to a subsequent decrease in the optimal inventory holding, which in turn lowers the current spot price and increases future expected spot prices. The increase in default risk also increases the producers' demand for hedging in the futures market, which in turn increases the futures risk premium.

5 Conclusion

In this paper, we have demonstrated theoretically as well as empirically that the default risk of commodity producers is a significant determinant of their hedging demand in futures markets, and, in turn, of futures prices and risk premia. It is through the channel of the hedging demand of producers that commodity futures markets activity, measured for example as the increase in speculative activity, can affect spot prices by allowing production schedules (Litzenberger and Rabinowitz (1995)) and inventory holdings (our paper) to adjust better to current and future demand shocks.

The model allows us to shed light on an important recent debate – whether speculative activity in the oil futures market has been responsible for the gyrations in oil spot prices. We show that this is theoretically possible, when producers have hedging demands, as changes in speculative positions change the costs of hedging for producers, in turn changing inventory holdings and thus spot prices. Empirically we verify that the default risk of oil and gas producers (a proxy for their risk aversion) is a significant determinant of producers' hedging demand in oil and gas futures markets, and in turn, of spot and futures prices and futures risk premia.

Much work remains to be done in order to understand these relationships fully, especially from an empirical standpoint. First, it would be interesting to isolate the innovations in the default risk of producers and relate these to futures prices in a VAR framework. Second, though default risk proxies are hard to come by for other commodities due to relatively few producers, it would be interesting to see if our results are verified for a broader set of commodities than oil and gas. Third, in recent times, demand shocks to commodity markets have largely arisen from increased demand for commodities from fast developing countries like India and China. An interesting avenue for further research would be to investigate the role of such global demand shifts on commodity inventories and spot and futures prices. Exploring the role of such demand shocks in a model such as ours would open the possibility of understanding their contribution to the recent volatility in commodity prices, relative to the contribution of increased speculative activity in futures markets – activity which could indeed have been price-stabilizing.

References

[1] Altinkilic, Oya and Robert S Hansen (2000), Are There Economies of Scale in Underwriting Fees? Evidence of Rising External Financing Costs, *Review of Financial Studies*, vol. 13, issue 1, pages 191-218.

[2] Altman, Edward I. (1968), "Financial Ratios, Discriminant Analysis and the Prediction of Corporate Bankruptcy," *Journal of Finance*, Sep, 589-609.

[3] Bayless, M. and S. Chaplinksy (1996), "Are There Windows of Opportunity for Seasoned Equity Issuance?" *Journal of Finance*, 51, no. 1, 253-278.

[4] Bessembinder, Hendrik (1992), "Systematic Risk, Hedging Pressure, and Risk Premiums in Futures Markets," *Review of Financial Studies* 5: 637-667.

[5] Boudoukh, Jacob, Roni Michaely, Matthew Richardson, and Michael Roberts (2007), "On the Importance of Measuring the Payout Yield: Implications for Empirical Asset Pricing", *Journal of Finance*, 62, 877-915.

[6] Breeden, Douglas and S. Viswanathan (1990) "Why do firms hedge? An asymmetric information model", Working Paper, Fuqua School of Business, Duke University.

[7] Brennan, Michael (1958), "The Supply of Storage," *American Economic Review* 48: 50-72.

[8] Brennan, Michael (1991), "The Price of Convenience and the Valuation of Commodity Contingent Claims", in Diderik Lund, and Bernt Øksendal, eds.: Stochastic Models and Option Values (North-Holland, Amsterdam).

[9] Campbell, John Y. and Motohiro Yogo (2006), "Efficient Tests of Stock Return Predictability", *Journal of Financial Economics*, 81(1), pp. 27-60.

[10] Cassasus, Jaime and Pierre Collin-Dufresne (2005), "Stochastic Convenience Yields Implied from Commodity Futures and Interest Rates", *Journal of Finance*, 60(5), pp. 2283-2332.

[11] Choe, Hyuk, Masulis, Ronald W. and Nanda, Vikram K. (1993), "Common Stock Offerings Across the Business Cycle: Theory and Evidence," *Journal of Empirical Finance*, Vol. 1, No. 1, pp. 3-31.

[12] Coughlan, Anne and Ronald Schmidt (1985) "Executive compensation, management turnover, and firm performance: An empirical investigation", *Journal of Accounting and Economics*, 7, 43-66.

[13] Deaton, Angus and Guy Laroque (1992), "On the Behavior of Commodity Prices," *Review of Economic Studies* 59: 1-23.

[14] Debreu, G. (1959). Theory of Value, New York: Wiley.

[15] DeMarzo, Peter and Darrell Duffie (1995) "Corporate incentives for hedging and hedge accounting", *The Review of Financial Studies*, 8(3), 743-771.

[16] De Roon, Frans, Theo Nijman, and Chris Veld (2000), "Hedging Pressure Effects in Futures Markets," *Journal of Finance* 55: 1437-1456.

[17] Detemple, J. and L. Selden (1991). "A General Equilibrium Analysis of Option and Stock Market Interactions", *International Economic Review*, 32(2), 279–303.

[18] Erb, Claude B. and Harvey, Campbell R., "The Strategic and Tactical Value of Commodity Futures", *Financial Analysts Journal*, 62:2, March/April, 69-97.

[19] Fama, Eugene and Kenneth French (1987), "Commodity Futures Prices: Some Evidence on Forecast Power, Premiums, and the Theory of Storage," *Journal of Business* 60: 55-73.

[20] Fama, Eugene and Kenneth French (1988), "Business Cycles and the Behavior of Metals Prices," *Journal of Finance* 43: 1075-1093.

[21] Fama, Eugene and Kenneth French (1989), "Business Conditions and Expected Returns on Stocks and Bonds", *Journal of Financial Economics* 25, 23 - 49.

[22] Franks, Julian R. and Sanzhar, Sergey V. (2006), "Evidence on Debt Overhang from Distressed Equity Issues," EFA 2005 Moscow Meetings Paper.

[23] Froot, Kenneth A., David S. Scharfstein, and Jeremy C. Stein (1993), "Risk Management: Coordinating Corporate Investment and Financing Policies", *Journal of Finance*, 58(5), pp. 1629-1658.

[24] Gale, Douglas and Hellwig, Martin (1985), "Incentive-Compatible Debt Contracts: The One-Period Problem," *Review of Economic Studies*, Blackwell Publishing, vol. 52(4), pages 647-63.

[25] Gilson, Stuart C. (1989) "Management turnover and financial distress", *Journal of Financial Economics*, 25(2), 241-262.

[26] Gorton, Gary and K. Geert Rouwenhorst (2006), "Facts and Fantasies about Commodity Futures," *Financial Analysts Journal* 62: 47-68.

[27] Gorton, Gary, Fumio Hayashi, and K. Geert Rouwenhorst (2007), "The Fundamentals of Commodity Futures Returns," Yale ICF Working Paper No. 07-08.

[28] Guay, W. and S.P. Kothari (2003), "How Much Do Firms Hedge with Derivatives?," *Journal of Financial Economics* 70, (2003) 423-461.

[29] Jagannathan, Ravi (1985), "An Investigation of Commodity Futures Prices Using the Consumption-Based Intertemporal Capital Asset Pricing Model," *Journal of Finance*, vol. 40: 175-191.

[30] Jagannathan, Ravi and Zhenyu Wang (1996), "The Conditional CAPM and the Cross-section of Expected Returns," *Journal of Finance* 51: 3-53.

[31] Jensen, M.C., and W.H. Meckling (1976), "Theory of the firm: managerial behavior, agency costs and ownership structure", Journal of Financial Economics 3:305-360

[32] Kaldor, Nicholas (1939), "Speculation and Economic Stability," *Review of Economic Studies* 7: 1-27.

[33] Keynes, John M. (1930), A Treatise on Money, vol. 2 (London: Macmillan).

[34] Litzenberger, R. and N. Rabinowitz (1995), "Backwardation in Oil Futures Markets: Theory and Empirical Evidence", *Journal of Finance*, 50(5), 1517-1545.

[35] MacKie-Mason, Jeffrey K. (1990), “Do Taxes Affect Corporate Financing Decisions?,” *Journal of Finance*, 45(5), 1471-1493.

[36] Myers, Stewart (1977), “Determinants of corporate borrowing", *Journal of Financial Economics*, 5, 147-175.

[37] Myers, Stewart and Nicholas Majluf (1984), "Corporate financing and investment decisions when firms have information that investors do not have," *Journal of Financial Economics*, 13, 187-221.

[38] Ng, Victor and Stephen C. Pirrong (1994), “Fundamentals and Volatility: Storage, Spreads, and the Dynamics of Metals Prices,” *Journal of Business*, vol. 67, no. 2 (April): 203-230.

[39] Routledge, Bryan, Duane Seppi, and Chester Spatt (2000), “Equilibrium Forward Curves for Commodities,” *Journal of Finance* 55: 1297-1338.

[40] Schwartz, Eduardo S. (1997), "The Stochastic Behavior of Commodity Prices: Implications for Valuation and Hedging", *Journal of Finance* 52, 923–973.

[41] Smith, C., and Rene Stulz, 1985, "The determinants of firm’s hedging policies", *Journal of Financial and Quantitative Analysis* 20, 391-405.

[42] Stulz, R., 1984, "Optimal hedging policies", *Journal of Financial and Quantitative Analysis* 19, 127-140.

[43] Townsend, Robert M. (1979), “Optimal contracts and competitive markets with costly state verification," *Journal of Economic Theory*, Elsevier, vol. 21(2), pages 265-293.

[44] Warner, Jerold, Ross Watts, and Karen Wruck (1988) "Stock prices and top management changes", *Journal of Financial Economics*, 20, 461-492.

[45] Weisbach. Michael (1988) "Outside directors and CEO turnover", *Journal of Financial Economics*, 20, 431-460.

[46] Working, Holbrook (1949), “The Theory of the Price of Storage,” *American Economic Review* 39: 1254-62.

[47] Zmijewski, Mark E. (1984), “Methodological Issues Related to the Estimation of Financial Distress Prediction Models,” *Journal of Accounting Research*, Supplement, 59-82.

6 Appendix

6.1 Proofs of results given in the main body of paper

Proof of Proposition 1.

Here we consider the effect of speculator risk aversion. We focus on $a_s = 1/\left(\tilde{a}_s \sigma_S^2\right)$ as it simplifies the exposition.[13] First, note that the market clearing level of aggregate inventory is increasing in speculator risk tolerance unless there is an inventory stock-out, for which case it remains at zero.

Proof. First, consider the case of no stock-out, $\lambda = 0$. In this case,

$$(a_s + a_p)\left(E\left[S_1(I)\right] - S_0(I)\right) = I^* + g_1. \tag{29}$$

The implicit function theorem yields

$$E\left[S_1(I)\right] - S_0(I) + (a_s + a_p)\frac{dI}{da_s}\left(E\left[\frac{dS_1}{dI}\right] - \frac{dS_0}{dI}\right) = \frac{dI}{da_s}. \tag{30}$$

$$\Updownarrow$$

$$\left(E\left[S_1(I)\right] - S_0(I)\right)\left(1 - (a_s + a_p)\left(E\left[\frac{dS_1}{dI}\right] - \frac{dS_0}{dI}\right)\right)^{-1} = \frac{dI}{da_s} \tag{31}$$

(Remember, $S_0 = a_0 + f(g_0 - I)$ and $S_1 = a_1 + f(g_1 + I)$. Thus, since $f' < 0$, $\frac{dS_0}{dI} > 0$, and $\frac{dS_1}{dI} < 0$.) Since $\left(E\left[S_1(I)\right] - S_0(I)\right) > 0$ and $E\left[\frac{dS_1}{dI}\right] - \frac{dS_0}{dI} < 0$, it follows that $\frac{dI}{da_s} > 0$. In the case of an inventory stock-out, we have trivially that $\frac{dI}{da_s} = 0$. ■

This implies trivially that the spot price is increasing in speculator risk tolerance, since $S_0 = a_0 + f(g_0 - I)$, since $f' < 0$.

Finally, the futures risk premium is decreasing in speculator risk tolerance.

Proof. First, consider the partial impact on the futures risk premium of a change in inventory in the case of no stock-out, so $S_0 = F$.

$$\frac{\partial}{\partial I}\left(\frac{E\left[S_1\right] - S_0}{S_0}\right) = \frac{\frac{\partial\left(E[S_1] - S_0\right)}{\partial I}S_0 - \left(E\left[S_1\right] - S_0\right)\frac{\partial S_0}{\partial I}}{S_0^2} < 0. \tag{32}$$

Since, $E\left[\frac{\partial S_1}{\partial I}\right] - \frac{\partial S_0}{\partial I} < 0$, $E\left[S_1(I)\right] - S_0(I) > 0$, and $\frac{\partial S_0}{\partial I} > 0$, we have that the sign on the change in the risk premium relative to the aggregate inventory level is negative.

[13] This transformation of variables does not affect the sign of the derivatives other than in the obvious way (tolerance versus aversion means it is flipped) as the price volatility is constant in this model.

Next, consider the case of a stock-out. Now, price in period 0 and expected price in period 1 stay constant. The futures risk premium is given by

$$\frac{E\left[S_1\right]-F}{F}=\frac{E\left[S_1\right]-S_0+\lambda}{S_0-\lambda}. \tag{33}$$

$$\left(a_s+a_p\right)\left(E\left[S_1\left(I^*\right)\right]-S_0\left(I^*\right)+\lambda\right)=I^*+g_1.$$

First consider the derivative of λ with respect to a_s:

$$\left(E\left[S_1\left(I\right)\right]-S_0\left(I\right)+\lambda\right)+\left(a_s+a_p\right)\left(\frac{\partial E\left[S_1\left(I\right)\right]}{\partial I}\frac{dI}{da_s}-\frac{\partial S_0\left(I\right)}{\partial I}\frac{dI}{da_s}+\frac{d\lambda}{da_s}\right)=\frac{dI}{da_s}. \tag{34}$$

Since in a stock-out $\frac{dI}{da_s}=0$, we have that

$$\frac{d\lambda}{da_s}=-\left(E\left[S_1\right]-F\right)/\left(a_s+a_p\right). \tag{35}$$

Since we only achieve market clearing in the futures market if $E\left[S_1\right]-F>0$, it must be that $\frac{d\lambda}{da_s}<0$. Given this, the derivative of the futures risk premium in the case of a stock-out is

$$\frac{\frac{d\lambda}{da_s}\left(S_0-\lambda\right)+\left(E\left[S_1\right]-S_0+\lambda\right)\frac{d\lambda}{da_s}}{\left(S_0-\lambda\right)^2}<0, \tag{36}$$

since $E\left[S_1\right]-S_0+\lambda>0$, $S_0-\lambda>0$, and $\lambda>0$. ■

Proof of Proposition 2

First, we consider the effect on inventory of an increase in producer risk tolerance, a_p.

Proof. First, consider the case of no stock-out, $\lambda=0$. In this case,

$$\left(a_s+a_p\right)\left(E\left[S_1\left(I\right)\right]-S_0\left(I\right)\right)=I^*+g_1. \tag{37}$$

Then

$$\left(E\left[S_1\left(I\right)\right]-S_0\left(I\right)\right)+\left(a_s+a_p\right)\frac{dI}{da_H}\left(E\left[\frac{dS_1}{dI}\right]-\frac{dS_0}{dI}\right)=\frac{dI}{da_p}. \tag{38}$$

$$\Updownarrow$$

$$\left(E\left[S_1\left(I\right)\right]-S_0\left(I\right)\right)\left(1-\left(a_s+a_p\right)\left(E\left[\frac{dS_1}{dI}\right]-\frac{dS_0}{dI}\right)\right)^{-1}=\frac{dI}{da_p} \tag{39}$$

(Remember, $S_0 = a_0 + f(g_0 - I)$ and $S_1 = a_1 + f(g_1 + I)$. Thus, since $f' < 0$, $\frac{dS_0}{dI} > 0$, and $\frac{dS_1}{dI} < 0$.) Since $(E[S_1(I)] - S_0(I)) > 0$ and $E\left[\frac{dS_1}{dI}\right] - \frac{dS_0}{dI} < 0$, it follows that $\frac{dI}{da_p} > 0$. In the case of an inventory stock-out, we have trivially that $\frac{dI}{da_p} = 0$. ■

Given this and results already shown above it also follows that the futures risk premium is decreasing in hedger risk tolerance. Finally, a decrease in inventory leads to a decrease in the spot price from the inverse demand function.

Proof of Proposition 3

The basis result is derived in the main text.

Proof of Proposition 4

Here we derive the effects of an increase in future expected consumer demand, $\bar{a} \equiv E[a_1]$. First, we show that an increase in expected future consumer demand leads to an increase in the optimal equilibrium inventory holding.

Proof. The intuition is simple - if prices are expected to be higher tomorrow, it pays off to hold inventory and wait to sell until then. This must happen until equilibrium is restored or there is a stock-out. First, consider the case of no stock-out, $\lambda = 0$. In this case,

$$(a_s + a_p)\left(E\left[\frac{\partial S_1(\overline{a_1}, I)}{\partial I}\frac{dI}{d\overline{a_1}} + \frac{\partial S_1(\overline{a_1}, I)}{\partial \overline{a_1}}\right] - \frac{\partial S_0(I)}{\partial I}\frac{dI}{d\overline{a_1}}\right) = \frac{dI}{d\overline{a_1}} \quad (40)$$

$$\Updownarrow$$

$$(a_s + a_p) E\left[\frac{\partial S_1(\overline{a_1}, I)}{\partial \overline{a_1}}\right]\left(1 - (a_s + a_p)\left(E\left[\frac{\partial S_1(\overline{a_1}, I)}{\partial I}\right] - \frac{\partial S_0(I)}{\partial I}\right)\right)^{-1} = \frac{dI}{d\overline{a_1}}. \quad (41)$$

Since $E\left[\frac{\partial S_1(\overline{a_1}, I)}{\partial \overline{a_1}}\right] > 0$ and $E\left[\frac{\partial S_1}{\partial I}\right] - \frac{\partial S_0}{\partial I} < 0$, it follows that $\frac{dI}{d\overline{a_1}} > 0$. In the case of an inventory stock-out, we have trivially that $\frac{dI}{d\overline{a_1}} = 0$. ■

An increase in inventory leads to a higher current spot price. Since the spot demand has increased, spot prices are also higher in expectation in the future.

Next, we show that we cannot in general determine the effect on the futures risk premium on an increase in expected future consumer demand.

Proof. In the case of no stock out ($\lambda = 0$), the futures risk premium (frp) wrt $\bar{a}$ is

$$\frac{dfrp}{d\bar{a}} = \frac{\partial frp}{\partial \bar{a}} + \frac{\partial frp}{\partial I}\frac{dI}{d\bar{a}}. \quad (42)$$

Since, $\frac{\partial frp}{\partial \bar{a}} = \frac{1}{P_0} > 0$, $\frac{\partial frp}{\partial I} < 0$, $\frac{dI}{d\bar{a}} > 0$, the sign depends on the relative magnitudes of these terms. Substituting into the above, we have

$$\frac{dfrp}{d\bar{a}}S_0 = 1+\frac{\left(\frac{\partial E[S_1]}{\partial I}S_0 - E\left[S_1\right]\frac{\partial S_0}{\partial I}\right)\left(a_s+a_p\right)E\left[\frac{\partial S_1(\overline{a_1},I)}{\partial \overline{a_1}}\right]}{S_0 - S_0\left(a_s+a_p\right)\left(E\left[\frac{\partial S_1(\overline{a_1},I)}{\partial I}\right]-\frac{\partial S_0(I)}{\partial I}\right)} \tag{43}$$

$$= 1+\frac{\left(\frac{\partial E[S_1]}{\partial I}S_0 - E\left[S_1\right]\frac{\partial S_0}{\partial I}\right)\left(a_s+a_p\right)E\left[\frac{\partial S_1}{\partial \overline{a_1}}\right]}{S_0 - S_0\left(a_s+a_p\right)\left(E\left[\frac{\partial S_1}{\partial I}\right]-\frac{\partial S_0}{\partial I}\right)} \tag{44}$$

Note that $\frac{\partial S_1}{\partial \overline{a_1}} = 1$, and so

$$\frac{dfrp}{d\bar{a}}S_0 = 1+\frac{\frac{\partial E[S_1]}{\partial I}-\frac{E[S_1]}{S_0}\frac{\partial S_0}{\partial I}}{\frac{1}{a_s+a_p}-\left(E\left[\frac{\partial S_1}{\partial I}\right]-\frac{\partial S_0}{\partial I}\right)} \tag{45}$$

Thus, the sign of the derivative is positive if

$$\frac{\frac{\partial E[S_1]}{\partial I}-\frac{E[S_1]}{S_0}\frac{\partial S_0}{\partial I}}{\frac{1}{a_s+a_p}-\left(E\left[\frac{\partial S_1}{\partial I}\right]-\frac{\partial S_0}{\partial I}\right)} > -1 \tag{46}$$

$$\Updownarrow$$

$$\frac{\partial E\left[S_1\right]}{\partial I}-\frac{E\left[S_1\right]}{S_0}\frac{\partial S_0}{\partial I} > -\frac{1}{a_s+a_p}+E\left[\frac{\partial S_1}{\partial I}\right]-\frac{\partial S_0}{\partial I} \tag{47}$$

$$\Updownarrow$$

$$\left(\frac{E\left[S_1\right]}{S_0}-1\right)\frac{\partial S_0}{\partial I} < \frac{1}{a_s+a_p}. \tag{48}$$

In the case of no stock out, we cannot in general sign this derivative in the case. Next, we consider the case of a stock-out. ■

Next, we consider the case of a stock-out ($I^* = 0$, $\lambda > 0$):

Proof. In the case of a stock-out ($\lambda > 0$), the futures risk premium (frp) wrt $\bar{a}$ is

$$\frac{dfrp}{d\bar{a}} = \frac{\partial frp}{\partial \bar{a}} + \frac{\partial frp}{\partial \lambda}\frac{d\lambda}{d\bar{a}}. \tag{49}$$

We have that

$$frp = \frac{E\left[S_1\right]-S_0+\lambda}{S_0-\lambda}. \tag{50}$$

Then

$$\frac{\partial frp}{\partial \bar{a}} = \frac{1}{S_0} > 0, \tag{51}$$

$$\frac{\partial frp}{\partial \lambda} = \frac{E[S_1]}{(S_0-\lambda)^2} > 0, \tag{52}$$

$$\frac{d\lambda}{d\bar{a}} = -1 < 0. \tag{53}$$

The last derivative can be found by applying the Implicit Function Theorem on the equilibrium equation used earlier. Thus,

$$(a_s + a_p)\left(E\left[\frac{\partial S_1}{\partial I}\frac{dI}{d\bar{a}} + \frac{\partial S_1}{\partial \bar{a}}\right] - \frac{\partial S_0}{\partial I}\frac{dI}{d\bar{a}} + \frac{d\lambda}{d\bar{a}}\right) = \frac{dI}{d\bar{a}}. \tag{54}$$

Since in a stock-out, $\frac{dI}{d\bar{a}} = 0$, we have that $\frac{d\lambda}{d\bar{a}} = -1 < 0$. Thus,

$$\begin{aligned} \frac{dfrp}{d\bar{a}} &= \frac{\partial frp}{\partial \bar{a}} - \frac{\partial frp}{\partial \lambda} && (55)\\ &= \frac{1}{S_0} - \frac{E[S_1]}{(S_0-\lambda)^2} && (56)\\ &= \frac{(S_0-\lambda)^2}{S_0(S_0-\lambda)^2} - \frac{S_0(S_0-\lambda+k)}{S_0(S_0-\lambda)^2} && (57)\\ sign &: \\ &= \lambda^2 - S_0\lambda - S_0 k < -S_0 k < 0, && (58) \end{aligned}$$

where we use the equilibrium expression for $E[S_1] : E[S_1] - (S_0 - \lambda) = \frac{I^* + g_1}{a_s + a_p} = k > 0$. Thus, the futures risk premium is decreasing in the expected future consumer demand in the case of an inventory stock-out. ■

Conjecture 3 *Aggregate hedger demand for short futures contracts is increasing in aggregate inventory.*

Proof. *The conjecture implicitly assumes no stock-out, so here $\lambda = 0$. Aggregate hedger demand is given by*

$$h_p^* = I^* + g_1 + \frac{F - E[S_1]}{a_p \sigma_S^2}. \tag{59}$$

Thus,

$$\frac{dh_p}{dI} = 1 + \frac{d}{dI}\left(\frac{S_0 - E[S_1]}{a_p\sigma_S^2}\right) \tag{60}$$

$$= 1 + \frac{\frac{d(S_0 - E[S_1])}{dI} a_p\sigma_S^2 - (S_0 - E[S_1])\frac{d\left(a_p\sigma_S^2\right)}{dI}}{a_p^2\sigma_S^4}. \tag{61}$$

Since $\frac{dS_0}{dI} - E\left[\frac{dS_1}{dI}\right] > 0$*, and* $S_0 - E[S_1] < 0$*, and* $\frac{d\left(a_p\sigma_S^2\right)}{dI} = 0$*, the sign of the change in aggregate hedging demand is increasing in inventory.* ■

7 Model with Costly External Finance

The main focus of the model is on commodity producers as these agents have the inventory storage technology in place to take advantage of differences in the spot and the futures prices: They can either sell a unit of the commodity now and put the proceeds of the sale in a risk-free savings instrument or enter a short futures contract and store the commodity for delivery. Both strategies result in known cash-flows in the future and therefore yield a no-arbitrage restriction.[14] The U.S. Energy Information Administration notes the existence of these players in both the oil and gas markets and their importance for futures price efficiency (see REF). The partial equilibrium framework we employ exploits the no-arbitrage restrictions these agents impose on the market to derive implications for futures prices.

Producers are assumed to have a hedging demand which we model as arising from costs of external financing as in Froot, Scharfstein, and Stein (1993). Otherwise, the model is a two-period version of the Deaton and Laroque (1992) model of commodity prices and optimal inventory management. While we use costly external finance needed to meet firm's growth options as the rationale for a hedging demand, the model is also consistent with the other channels for hedging as emphasized by Froot, Scharfstein and Stein (1993). Indeed, our empirical proxies will partly rely on these alternative interpretations, the two relevant interpretations being hedging driven by managerial risk-aversion (Stulz, 1984, due to lack of diversification for managers, and Breeden and Viswanathan, 1990, and DeMarzo and Duffie (1995), for better performance assessment), managerial aversion to distress (Gilson (1989)), and costs of financial distress to the firm (Smith and Stulz (1985)).[15]

[14] This argument assumes that there is no credit risk in the futures market, which is a reasonable assumption for exchange traded futures.

[15] In the Appendix, we present a model where managers of commodity producing firms are risk averse and

7.1 Consumption, Production and the Spot Price

Each period c_t units of the good is consumed. The production schedule is predetermined and production each period is denoted g_t. Thus, we have in mind an economy where the time and cost required to adjust production schedules to transitory demand shocks are prohibitively large.[16] The current economy-wide inventory level of the commodity is denoted I_t and goods in inventory depreciate at a rate d. Storage costs are assumed to be included in the depreciation rate. Market clearing demands that incoming inventory and current production, $g_t + (1-d)\, I_{t-1}$, equals current consumption and outgoing inventory, $c_t + I_t$. This equality can be rearranged and we get:

$$c_t = g_t - \Delta I_t \tag{62}$$

where $\Delta I_t \equiv I_t - (1-d)\, I_{t-1}$. Let the spot price of the commodity be denoted S_t. We assume the immediate use demand, $c_t\,(a_t, S_t)$, is monotone decreasing in the spot price S_t given a level of the current demand shock, a_t. We summarize the spot market as follows:

$$S_t = f\,(a_t, g_t - \Delta I_t)\,, \tag{63}$$

where f is decreasing in the supply, $g_t - \Delta I_t$, and the demand shock, a_t.[17] The demand shock represents exogenous shifts in the commodity demand. The same inverse demand function is assumed in Routledge, Seppi, and Spatt (2000). It is useful to define the variable $\theta \equiv \frac{1-d}{1+r}$, where r is the simple net risk-free rate. This variable measures the financial loss incurred of holding a unit of the commodity in inventory due to depreciation and the time-value of money. For ease of exposition and without loss of generality, we assume that $r = 0$.

7.2 Producers

Producers are risk-neutral price takers who maximize expected profits through optimal inventory management, hedging in futures, and investment. In period 0, the firm stores an amount

show that the implications arising from this alternative channel of hedging demand yields the same predictions for the relation between producer hedging demand and the futures risk premium. This alternative model is more closely related to the speculation and hedging demand models of Anderson and Danthine (1981, 1983)..

[16] We will in the empirical section consider the behavior of short-term commodity futures contracts. Arguably, short-term contracts are more influenced by inventory fluctuations than shocks to longer term supply and demand.

[17] We assume throughout the analysis that a_t and f are specified such that (a) prices are positive and (b) a market-clearing spot price exists. For instance, a convenient assumption is that $\lim_{y\to 0} f\,(x, y) = \infty$ for all x, which ensures an interior maximum solution to the optimal inventory problem (there could still be inventory stock-outs).

I as inventory from its current supply, g_0, and so period 0 profits are simply $S_0(g_0 - I)$. The firm also enters h short futures contracts for delivery in period 1. In period 1, the firm sells its current inventory and production supply, honors its futures contracts and realizes a profit of $S_1((1-d)I + g_1) + h(F - S_1)$, where F is the forward price of the futures contracts.

At the end of period 1, producers can in addition exercise growth options of the firm. In particular, the net present value at time 1 of the output of an investment of size X is $g(X) - X$, where $g(X)$ is a concave increasing function ($g' > 0$, $g'' < 0$). Thus, the net present value of investment exhibits decreasing marginal returns to scale.[18] One can think of $g(X)$ as the ex-dividend value of the firm at time 1. After the demand shock is observed at time 1, the producers solve

$$\max g(X) - X - \delta C(e) \tag{64}$$

subject to

$$X \leq w + e, \tag{65}$$

where

$$w = S_0(g_0 - I) + S_1((1-d)I + g_1) + h(F - S_1) \tag{66}$$

is the internal funds of the producer. Notice that we allow the producer to invest the cash proceeds from time 0 sales at the risk-free rate at the risk-free rate. The function $C(e)$ is a cost function that is increasing in the amount of external financing e the firm requires: $e = X - w$. If the firm faces costs of external finance, $\delta > 0$, and the severity of the costs is increasing in δ. The maximization can then be written

$$\max_X \; g(X) - X - \delta C(X - w), \tag{67}$$

and the first order condition gives

$$g'(X) - 1 = \delta C'(e). \tag{68}$$

For the constrained firm (i.e., equation (65) binds), the invested amount is increasing in the amount of internal funds, $0 < \frac{dX}{dw} < 1$.[19] Thus, future commodity production is increasing in the amount of internal funds, and so the externality due to $\delta C(\cdot)$ is detrimental to the

[18] This will be the case if, for instance, there are technological decreasing returns to scale.

[19] In particular, from the first order condition, we have that $\frac{dX^*}{dw} = \frac{-\delta C''}{g'' - \delta C''}$.

economy assuming that higher production of the commodity is beneficial. Since marginal returns to investment are decreasing and since costs of external financing are convex, the firm has a demand for hedging period 1 profits (see Froot, Scharfstein, and Stein (1993)). The firm can, in principle, use both short futures positions and increased inventory to alleviate the financing constraint.

The firms' problem is then

$$\max_{\{I,h\}} S_0 \left(g_0 - I\right) + E\left[S_1\left(\left(1-d\right)I + g_1\right) + h\left(F - S_1\right)\right] + E\left[g\left(X^*\right) - X^* - \delta C\left(X^* - w\right)\right] \quad (69)$$

subject to

$$I \geq 0, \quad (70)$$

where X^* denotes the optimal period 1 investment. Note that $\frac{dX}{dI} = \frac{dX}{dw}\frac{dw}{dI} = \frac{dX}{dw}\left(1-d\right)S_1 > 0$ and that $\frac{dX}{dh} = \frac{dX}{dw}\frac{dw}{dh} = \frac{dX}{dw}\left(F - S_1\right) > 0$ if $F > S_1$ but $\frac{dX}{dh} < 0$ if $F < S_1$. Thus, short futures contracts is a direct way to transfer money from high S_1 states to low S_1 states, while inventory yields internal funds that are proportional to the period 1 spot price.

It will be useful to define

$$\tilde{g}\left(X, \delta\right) = g'\left(X^*\right) - 1 = \delta C'\left(X^* - w\right), \quad (71)$$

which is the marginal benefit of an additional unit of internal funds, w.[20] If the firm is financially constrained, this term is positive. If the firm is not financially constrained, this term is zero.

[20] I.e., $\tilde{g} \equiv \frac{d}{dw}\left(g\left(X^*\right) - X^* - \delta C\left(X^* - w\right)\right) = \left(g' - 1 - \delta C'\right)\frac{dX^*}{dw} + \delta C'$. From, the first order condition, we have that $g' - 1 - \delta C' = 0$, so $\tilde{g} = \delta C'$.

7.2.1 Optimal Inventory and Hedging Demand

The first order condition with respect to inventory is:

$$
\begin{aligned}
S_0 &= \theta E\left[S_1\right] + E\left[\left(g'\left(X^*\right) - 1 - \delta C'\left(e\right)\right)\frac{dX^*}{dI} + \delta C'\left(e\right)\frac{de}{dw}\frac{dw}{dI}\right] + \lambda \quad (72)\\
&\Updownarrow\\
S_0 - \theta E\left[S_1\right] &= E\left[\left(\theta S_1 - S_0\right)\tilde{g}\left(X,\delta\right)\right] + \lambda \quad (73)\\
&\Updownarrow\\
S_0 - \theta E\left[S_1\right] &= \frac{\theta Cov\left[S_1,\tilde{g}\left(X,\delta\right)\right]}{1+E\left[\tilde{g}\left(X,\delta\right)\right]} + \frac{\lambda}{1+E\left[\tilde{g}\left(X,\delta\right)\right]}, \quad (74)
\end{aligned}
$$

where λ is the Lagrange multiplier on the slack inventory constraint.[21] Note that when the firm has not fully hedged its period 1 price exposure, the covariance between period 1 spot price and the marginal benefit of internal funds ($Cov\left[S_1,\tilde{g}\left(X,\delta\right)\right]$) is negative, and therefore we have that $S_0 < \theta E\left[S_1\right]$ when $\lambda = 0$. I.e., there is a *positive* expected return to holding spot even in the case when there are no storage costs ($\theta = 1$) as holding inventory is risky for the firm relative to selling it and holding cash. If the inventory constraint binds, the convenience yield of holding the spot will increase since in this case $\lambda > 0$. In this case, the spot price can rise above the expected future spot prices.

7.2.2 The Futures Risk Premium and the Hedging Demand for Futures

The firm can also use short futures contracts to hedge against low period 1 internal funds. The futures contract is a direct hedge of fluctuations in period 1 spot price, as opposed to inventory which generates additional funds in all states of the world and more so if the spot price is high (when it is less needed). The first order condition with respect to the number

[21] We go from the first to the second equation by noting that $\frac{de}{dw} = -1$ and $\frac{dw}{dI} = \left(1-d\right)S_1 - S_0$. Also, the period 1 optimization of the firm implies that $g'\left(X^*\right) - 1 - \delta C'\left(e\right) = 0$.

of short futures positions, h, is:

$$E\left[F - S_1 + \left(g'(X^*) - 1 - \delta C'(e)\right)\frac{dX^*}{dh} + \delta C'(e)\frac{dw}{dh}\right] = 0 \quad (75)$$

$$\Updownarrow$$

$$E[S_1] - F = E\left[(F - S_1)\,\tilde{g}(X,\delta)\right] \quad (76)$$

$$\Updownarrow$$

$$E[S_1] - F = -\frac{Cov\left(S_1, \tilde{g}(X,\delta)\right)}{1 + E\left[\tilde{g}(X,\delta)\right]}. \quad (77)$$

The cost of hedging a period 1 spot sale with a short futures position is $E[S_1] - F$. Thus, if the futures price is below the expected period 1 spot price, hedging with the futures contract is costly for the firm and the firm chooses not to hedge its period 1 supply fully (i.e., $Cov(S_1, \tilde{g}) < 0$). The equation above shows that in equilibrium the marginal cost equals the marginal benefit, where the benefit of hedging with the futures contract is given by $E[(F - S_1)\,\tilde{g}(X,\delta)]$: The payoff of the futures position $(F - S_1)$ times the marginal benefit of additional internal funds.

Note that if the futures risk premium is zero, the firm will hedge fully the price exposure of its period 1 supply of the commodity. In this case, the return to holding the spot in inventory is also zero. Further, if the producers do not have a hedging demand ($\delta = 0$), the futures risk premium will be driven to zero by the producers. We will in the following be interested in the cases where the futures risk premium is *positive*, which means that hedging using futures is costly for the firm. In this case, changes in hedging demand or the cost of hedging (the futures risk premium) will affect the producers optimal inventory and futures positions.

7.2.3 The Futures Basis

The futures *basis* is defined as the difference between the spot price and the futures price, $S_0 - F$. If the futures price is below the spot price, the market is said to be in "backwardation", while if the futures price is above the spot price, the market is in "contango".[22] The basis is sometimes used as a proxy for the futures risk premium by appealing to the decomposition $S_0 - F = (E[S_1] - F) - (E[S_1] - S_0)$, where the first component is the futures risk premium.

[22] This is today the usual definition of contango and backwardation. We note that in the Theory of Normal Backwardation, Keynes instead defined backwardation as when the futures price is below the expected future spot price.

However, empirically, the basis is not a good forecaster of time-variation in commodity futures returns (see Fama and French (1986)). Our model shows how a common component in the spot and futures risk premium, which explains this empirical fact, arises due to the equilibrium behavior of competitive inventory managers.

Consistent with the empirical literature, we normalize the basis with the current level of the spot price. Using the first order conditions over inventory and futures hedging, we obtain:

$$\frac{S_0 - F}{S_0} = 1 - \frac{1}{\theta} + \frac{1}{\theta} \frac{\lambda / S_0}{1 + E\left[\tilde{g}\left(X, \delta\right)\right]}, \tag{78}$$

where the derivation is given in the Appendix.

From this expression we can see that the basis in general is a function of whether there is an inventory stock-out ($\lambda > 0$), the costs of storage ($\theta < 1$), and hedging demand $\tilde{g}$. However, unless there is an inventory stock-out, the *basis is constant and less than zero.* Thus, the inventory stock-out channel, which is central to the Theory of Storage, is the main determinant of the commodity basis in our model. This link between inventory levels and the commodity basis has been empirically documented in many studies, most recently in Gorton, Hayashi, and Rouwenhorst (2007). The value of $\theta < 1$ shows up in the basis as a higher required futures price to compensate for the costs of storage.

The fact that the basis is constant in the case of no stock-out implies that variation in the futures risk premium must be offset by variation in the spot risk premium. This common component arises from the producers arbitrage technology (i.e, their ability to store the commodity, hold cash and invest in futures). Since holding cash earns a zero return, the benefit of selling inventory at a higher future price must exactly cancel out with the cost of hedging with a short futures contract. Thus, it is the producers' arbitrage technology that forces there to be a common component in the spot and futures risk premium, which is why the basis is not a good proxy for the futures risk premium (see Fama and French (1986)). This contradicts a central tenet of the Theory of Normal Backwardation (Keynes (1936)), as the forward curve is not downward sloping in the model even though there is a positive risk premium required for holding long futures positions. We empirically verify the existence of a common component in the spot and futures risk premiums later in the paper.

Derivation of the basis. Add θ times the FOC over futures to the FOC over inventory:

$$
\begin{aligned}
S_0 - \theta E[S_1] + \theta(E[S_1] - F) &= E[(\theta S_1 - S_0)\tilde{g}(X,\delta)] + \lambda + E[\theta(F - S_1)\tilde{g}(X,\delta)] \\
&= (\theta F - S_0) E[\tilde{g}(X,\delta)] + \lambda \\
&\Downarrow \\
S_0 - \theta F &= \frac{\lambda}{1 + E[\tilde{g}(X,\delta)]} \\
&\Downarrow \\
F &= \frac{1}{\theta} S_0 - \frac{1}{\theta} \frac{\lambda}{1 + E[\tilde{g}(X,\delta)]} \\
&\Downarrow \\
S_0 - F &= \left(1 - \frac{1}{\theta}\right) S_0 + \frac{1}{\theta} \frac{\lambda}{1 + E[\tilde{g}(X,\delta)]} \qquad (79)
\end{aligned}
$$

Finally, the basis normalized by the current spot price is then

$$
\frac{S_0 - F}{S_0} = 1 - \frac{1}{\theta} + \frac{1}{\theta} \frac{\lambda / S_0}{1 + E[\tilde{g}(X,\delta)]}. \qquad (80)
$$

as given in the text.■

Finally we show that the variable δ indeed can be thought of as measuring the fundamental hedging demand. In particular, the marginal benefit of an additional unit of internal funds is increasing in δ,i.e. $\frac{d\tilde{g}(X,\delta)}{d\delta} > 0$, as shown below.
Proof. First, $\tilde{g}(X,\delta) = g'(X^*) - 1$. Then

$$
\frac{d\tilde{g}(X,\delta)}{d\delta} = g''(X^*) \frac{dX^*}{d\delta}. \qquad (81)
$$

Let $u(X(\delta),\delta) = g(X) - X - \delta C(X - w)$, which for each state w is concave in X by assumption. This function is optimized for each δ and therefore the derivative with respect to δ of its first derivative with respect to X, must be zero: $\frac{\partial^2 u}{\partial X^2}\frac{dX}{d\delta} + \frac{\partial^2 u}{\partial X \partial \delta} = 0$. Since $\frac{\partial^2 u}{\partial X^2} < 0$, $sign\left(\frac{dX}{d\delta}\right) = sign\left(\frac{\partial^2 u}{\partial X \partial \delta}\right)$. $\frac{\partial u}{\partial X} = g'(X) - 1 - \delta C'(e)$, so $\frac{\partial^2 u}{\partial X \partial \delta} = -C'(e)$. Since $C'(e) > 0$, we have that $\frac{dX}{d\delta} < 0$. Since $g'' < 0$ by assumption, we have that $\frac{d\tilde{g}(X,\delta)}{d\delta} = g''(X^*)\frac{dX^*}{d\delta} > 0$.
■ ■

7.2.4 Assumptions on Market Incompleteness

This model assumes that producers are risk-neutral. An alternative specification would have producers maximizing the value of the firm given a general stochastic discount factor which also is a valid stochastic discount factor for the futures payoff. Hedging would in this case not be costly in terms of decreasing firm value *even if the futures risk premium is positive.* This is because hedging of cash flow risk would decrease firm risk proportionately, since firm cash flows are priced by the same stochastic discount factor as the futures cash flow. Therefore, the optimal solution is to simply minimize the cost associated with $\delta C(\cdot)$ by hedging fully in the sense that $Cov(S_1, \tilde{g}(X^*, \delta)) = 0$. Time-variation in hedging demand would then *not* affect inventory decisions as complete hedging makes the inventory first order condition orthogonal to variations in the marginal benefit of internal funds.

In other words, we are implicitly assuming that there is a degree of market separation between commodity markets and the markets valuing the firm. A key assumption for time-varying hedging demand to affect production decisions is that hedging is costly to the firm, or at least to the manager. Time-variation in the marginal benefit of hedging will then be mirrored in the marginal cost of hedging in equilibrium, which is the channel through which producers' hedging demand affects the futures risk premium.

Table I
Summary Statistics

This table reports summary statistics (mean, standard deviation, and the first autocorrelation coefficient AR(1)) of the variables AVGZm (cross-sectional average quarterly Zmijewski-score); AVG3Y (cross-sectional average of the time-series average stock return per producer-firm over the past three years, each quarter); cross-sectional average naïve EDF (expected default frequency) from Bharath and Shumway (2008); basis (standard deviation and AR(1) computed for the deseasonalized series); spot returns; futures excess returns; net change in hedger's short positions and the change in aggregate inventory (standard deviation and AR(1) computed for the deseasonalized series), all measured quarterly as specified in the Data section. These statistics are computed for each of Crude Oil, Heating Oil, Gasoline and Natural Gas.

	Crude Oil	**Heating Oil**	**Gasoline**	**Natural Gas**
AVGZm				
Mean	-2.689	-2.727	-2.692	-2.587
StdDev	0.318	0.323	0.329	0.417
AR(1)	0.951	0.939	0.969	0.702
AVG3Y				
Mean	0.009	0.009	0.009	0.004
StdDev	0.010	0.010	0.010	0.013
AR(1)	0.930	0.930	0.953	0.923
Naïve EDF				
Mean	0.037	0.040	0.036	0.099
StdDev	0.030	0.032	0.029	0.073
AR(1)	0.726	0.743	0.719	0.829
Basis				
Mean	0.018	0.026	0.040	-0.039
StdDev	0.059	0.131	0.081	0.136
AR(1)	0.462	0.146	0.390	0.342
Spot Return				
Mean	0.031	0.033	0.039	0.042
StdDev	0.170	0.179	0.175	0.226
AR(1)	-0.132	-0.143	-0.137	-0.194
Futures Excess Return				
Mean	0.043	0.044	0.067	0.025
StdDev	0.206	0.200	0.210	0.298
AR(1)	-0.123	-0.078	-0.183	0.035
Hedgers Net Position				
Mean	0.003	0.080	0.069	0.067
StdDev	0.072	0.114	0.099	0.068
AR(1)	0.135	-0.010	0.256	0.206
Change in Inventory				
Mean	-0.001	0.002	0.001	-0.004
StdDev	0.044	0.088	0.035	0.156
AR(1)	0.551	0.506	0.138	0.415

Table II
Futures Excess Returns and Producer Default Risk

This table presents results from univariate and multivariate forecasting regressions for futures excess returns for Crude Oil, Heating Oil, Gasoline and Natural Gas, as well as a 'Joint Test', i.e., a pooled regression of all four commodities. Panel A shows the results when the forecasting regressions have only the (lagged) default risk measures on the right-hand side (as well as four quarterly dummy variables), and Panel B shows the results when the forecasting regressions incorporate controls in addition to the default risk measures. These controls (all lagged one quarter) are: the spread of BAA over AAA rated corporate bonds; the equity market payout ratio; cay, a proxy for the aggregate consumption-wealth ratio (Lettau and Ludvigson (2001)); the change in aggregate inventory; and the basis. All standard errors are given below coefficients. For the commodity-specific regressions, these are computed employing the Newey-West (1983) correction for heteroskedasticity and autocorrelation of up to 3 quarterly lags. For the joint tests, we use Rogers (1983, 1993) robust standard errors, which correct for heteroskedasticity, and all autocorrelations and cross-correlations of up to 3 quarterly lags. Coefficients significant at the 10% level are reported in bold.

Panel A: Forecasting Regressions, Univariate

Excess Returns	Crude Oil	Heating Oil	Gasoline	Natural Gas	Joint Test
AVG3Y(-1)	**-2.960**	**-3.645**	-3.369	**-5.801**	**-0.150**
	1.352	1.300	2.066	3.137	0.070
R-squared	0.087	0.086	0.072	0.079	0.068
N(Observations)	91	108	84	64	347
AVGZM(-1)	**0.106**	**0.108**	0.076	0.132	0.053
	0.044	0.039	0.058	0.100	0.042
R-squared	0.094	0.081	0.062	0.050	0.049
N(Observations)	91	108	84	64	347
Naïve EDF(-1)	**1.294**	**0.870**	**1.909**	0.223	**0.164**
	0.569	0.460	0.506	0.440	0.055
R-squared	0.101	0.063	0.115	0.020	0.062
N(Observations)	77	93	70	50	290
Controls?	**No**	**No**	**No**	**No**	**No**
Quarterly Dummies?	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

Panel B: Forecasting Regressions, With Controls

Excess Returns	Crude Oil	Heating Oil	Gasoline	Natural Gas	Joint Test
AVG3Y(-1)	**-5.597**	**-4.410**	**-4.263**	**-7.227**	**-0.207**
	1.905	1.292	1.953	2.888	0.064
R-squared	0.145	0.129	0.162	0.121	0.104
N(Observations)	91	108	84	64	347
AVGZM(-1)	**0.188**	**0.156**	**0.123**	0.114	**0.113**
	0.052	0.038	0.059	0.103	0.045
R-squared	0.152	0.134	0.158	0.069	0.084
N(Observations)	91	108	84	64	347
Naïve EDF(-1)	**1.407**	0.749	**1.985**	-0.426	**0.144**
	0.656	0.517	0.480	0.520	0.063
R-squared	0.136	0.098	0.209	0.080	0.074
N(Observations)	77	93	70	50	290
Controls?	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Quarterly Dummies?	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

Table III
Spot Returns and Producer Default Risk

This table presents results from univariate and multivariate forecasting regressions for spot returns for Crude Oil, Heating Oil, Gasoline and Natural Gas, as well as a 'Joint Test', i.e., a pooled regression of all four commodities. Panel A shows the results when the forecasting regressions have only the (lagged) default risk measures on the right-hand side (as well as four quarterly dummy variables), and Panel B shows the results when the forecasting regressions incorporate controls in addition to the default risk measures. These controls (all lagged one quarter) are: the spread of BAA over AAA rated corporate bonds; the equity market payout ratio; cay, a proxy for the aggregate consumption-wealth ratio (Lettau and Ludvigson (2001)); the change in aggregate inventory; and the basis. All standard errors are given below coefficients. For the commodity-specific regressions, these are computed employing the Newey-West (1983) correction for heteroskedasticity and autocorrelation of up to 3 quarterly lags. For the joint tests, we use Rogers (1983, 1993) robust standard errors, which correct for heteroskedasticity, and all autocorrelations and cross-correlations of up to 3 quarterly lags. Coefficients significant at the 10% level are reported in bold.

Panel A: Forecasting Regressions, Univariate

Spot Returns	Crude Oil	Heating Oil	Gasoline	Natural Gas	Joint Test
AVG3Y(-1)	-1.038	-0.678	-1.024	-3.680	-0.070
	1.384	1.167	1.614	2.636	0.066
R-squared	0.073	0.111	0.163	0.082	0.054
N(Observations)	91	108	88	64	351
AVGZM(-1)	0.048	0.037	0.041	0.098	0.051
	0.046	0.039	0.052	0.070	0.053
R-squared	0.075	0.114	0.165	0.074	0.042
N(Observations)	91	108	88	64	351
Naïve EDF(-1)	**0.954**	0.659	**1.508**	0.385	**0.148**
	0.560	0.468	0.498	0.355	0.055
R-squared	0.090	0.136	0.196	0.049	0.066
N(Observations)	77	93	74	50	294
Controls?	**No**	**No**	**No**	**No**	**No**
Quarterly Dummies?	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

Panel B: Forecasting Regressions, With Controls

Spot Returns	Crude Oil	Heating Oil	Gasoline	Natural Gas	Joint Test
AVG3Y(-1)	**-4.879**	**-2.501**	**-3.012**	**-6.120**	**-0.164**
	1.915	1.196	1.625	2.566	0.060
R-squared	0.219	0.198	0.233	0.158	0.148
N(Observations)	91	108	88	64	351
AVGZM(-1)	**0.160**	**0.101**	**0.118**	0.082	**0.107**
	0.047	0.040	0.047	0.088	0.034
R-squared	0.223	0.204	0.243	0.114	0.140
N(Observations)	91	108	88	64	351
Naïve EDF(-1)	**1.202**	0.597	**1.465**	-0.356	**0.120**
	0.592	0.454	0.477	0.440	0.062
R-squared	0.217	0.208	0.219	0.141	0.138
N(Observations)	77	93	74	50	294
Controls?	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Quarterly Dummies?	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

Table IV
Hedger Net Short Positions and Producer Default Risk

This table presents results from univariate and multivariate forecasting regressions for Hedger Net Short Positions (HedgerShort(t)-HedgerLong(t)/(HedgerShort(t-1)+HedgerLong(t-1)), data from CFTC) for Crude Oil, Heating Oil, Gasoline and Natural Gas, as well as a 'Joint Test', i.e., a pooled regression of all four commodities. Panel A shows the results when the forecasting regressions have only the (lagged) default risk measures on the right-hand side (as well as four quarterly dummy variables), and Panel B shows the results when the forecasting regressions incorporate controls in addition to the default risk measures. These controls (all lagged one quarter) are: the spread of BAA over AAA rated corporate bonds; the equity market payout ratio; cay, a proxy for the aggregate consumption-wealth ratio (Lettau and Ludvigson (2001)); the change in aggregate inventory; and the basis. All standard errors are given below coefficients. For the commodity-specific regressions, these are computed employing the Newey-West (1983) correction for heteroskedasticity and autocorrelation of up to 3 quarterly lags. For the joint tests, we use Rogers (1983, 1993) robust standard errors, which correct for heteroskedasticity, and all autocorrelations and cross-correlations of up to 3 quarterly lags. Coefficients significant at the 10% level are reported in bold.

Panel A: Forecasting Regressions, Univariate

Hedger Net Short Positions	**Crude Oil**	**Heating Oil**	**Gasoline**	**Natural Gas**	**Joint Test**
AVG3Y(-1)	-0.211	**-0.590**	0.283	**-0.278**	**-0.118**
	0.200	0.243	0.236	0.164	0.070
R-squared	0.078	0.237	0.238	0.137	0.074
N(Observations)	79	91	82	52	304
AVGZM(-1)	**0.016**	**0.030**	-0.006	0.011	**0.091**
	0.008	0.008	0.008	0.008	0.036
R-squared	0.120	0.286	0.233	0.149	0.089
N(Observations)	79	91	82	52	304
Naïve EDF(-1)	**0.148**	**0.153**	**0.174**	-0.001	**0.192**
	0.065	0.060	0.056	0.027	0.051
R-squared	0.143	0.286	0.281	0.081	0.100
N(Observations)	69	81	72	42	264
Controls?	**No**	**No**	**No**	**No**	**No**
Quarterly Dummies?	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

Panel B: Forecasting Regressions, With Controls

Hedger Net Short Positions	**Crude Oil**	**Heating Oil**	**Gasoline**	**Natural Gas**	**Joint Test**
AVG3Y(-1)	-0.315	**-0.744**	-0.062	**-0.521**	**-0.164**
	0.245	0.251	0.239	0.163	0.070
R-squared	0.120	0.290	0.347	0.313	0.151
N(Observations)	79	91	82	52	304
AVGZM(-1)	**0.025**	**0.040**	0.005	**0.017**	**0.161**
	0.010	0.008	0.007	0.009	0.041
R-squared	0.197	0.353	0.349	0.310	0.184
N(Observations)	79	91	82	52	304
Naïve EDF(-1)	**0.130**	**0.167**	**0.141**	-0.001	**0.141**
	0.069	0.063	0.059	0.024	0.033
R-squared	0.153	0.333	0.333	0.279	0.147
N(Observations)	69	81	72	42	264
Controls?	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Quarterly Dummies?	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

Table V
Changes in Inventory and Producer Default Risk

This table presents results from univariate and multivariate regressions to explain the change in Inventory (Inventory – Trend(Inventory)) for Crude Oil, Heating Oil, Gasoline and Natural Gas, as well as a 'Joint Test', i.e., a pooled regression of all four commodities. Panel A shows the results when the regressions have only the (lagged) default risk measures on the right-hand side (as well as four quarterly dummy variables), and Panel B shows the results when the regressions incorporate controls in addition to the default risk measures. These controls (all lagged one quarter) are: the spread of BAA over AAA rated corporate bonds; the equity market payout ratio; cay, a proxy for the aggregate consumption-wealth ratio (Lettau and Ludvigson (2001)); four lags of the change in aggregate inventory; the mean GDP and Industrial Production growth forecasts (for the current quarter) from the survey of professional forecasters at the Philadelphia Fed; and the basis. All standard errors are given below coefficients. For the commodity-specific regressions, these are computed employing the Newey-West (1983) correction for heteroskedasticity and autocorrelation of up to 3 quarterly lags. For the joint tests, we use Rogers (1983, 1993) robust standard errors, which correct for heteroskedasticity, and all autocorrelations and cross-correlations of up to 3 quarterly lags. Coefficients significant at the 10% level are reported in bold.

Panel A: Regressions, Univariate

Change in Inventory	**Crude Oil**	**Heating Oil**	**Gasoline**	**Natural Gas**	**Joint Test**
AVG3Y(-1)	**1.538**	**2.051**	0.330	0.163	**0.128**
	0.351	1.063	0.387	1.271	0.046
R-squared	0.303	0.648	0.064	0.850	0.090
N(Observations)	91	108	88	64	351
AVGZM(-1)	-0.027	-0.025	0.003	**0.095**	-0.025
	0.017	0.035	0.010	0.045	0.026
R-squared	0.247	0.630	0.057	0.860	0.074
N(Observations)	91	108	88	64	351
Naïve EDF(-1)	-0.333	**-0.698**	-0.113	**0.721**	-0.103
	0.273	0.412	0.175	0.185	0.118
R-squared	0.227	0.661	0.045	0.852	0.082
N(Observations)	77	93	74	50	294
Controls?	**No**	**No**	**No**	**No**	**No**
Quarterly Dummies?	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

Panel B: Regressions, With Controls

Change in Inventory	**Crude Oil**	**Heating Oil**	**Gasoline**	**Natural Gas**	**Joint Test**
AVG3Y(-1)	**0.898**	0.830	0.131	-1.190	**0.124**
	0.403	0.762	0.389	1.371	0.058
R-squared	0.544	0.748	0.211	0.916	0.368
N(Observations)	91	108	88	64	351
AVGZM(-1)	-0.011	0.007	0.003	**0.125**	-0.044
	0.013	0.028	0.012	0.036	0.029
R-squared	0.526	0.746	0.210	0.924	0.358
N(Observations)	91	108	88	64	351
Naïve EDF(-1)	-0.225	**-0.683**	**-0.425**	**0.456**	**-0.203**
	0.138	0.346	0.151	0.186	0.102
R-squared	0.528	0.765	0.268	0.930	0.377
N(Observations)	77	93	74	50	294
Controls?	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Quarterly Dummies?	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

Figure 1

Figure 1: This figure shows how futures and spot prices change in response to an increase in fundamental hedging demand ($\widetilde{a_p}$) in the case of no inventory stock-out. The solid lines denote equilibrium values before the change. Here the basis before the change is noted on the vertical axis: Basis = S_0 – F. The dashed lines denote equilibrium values with higher hedging demand.

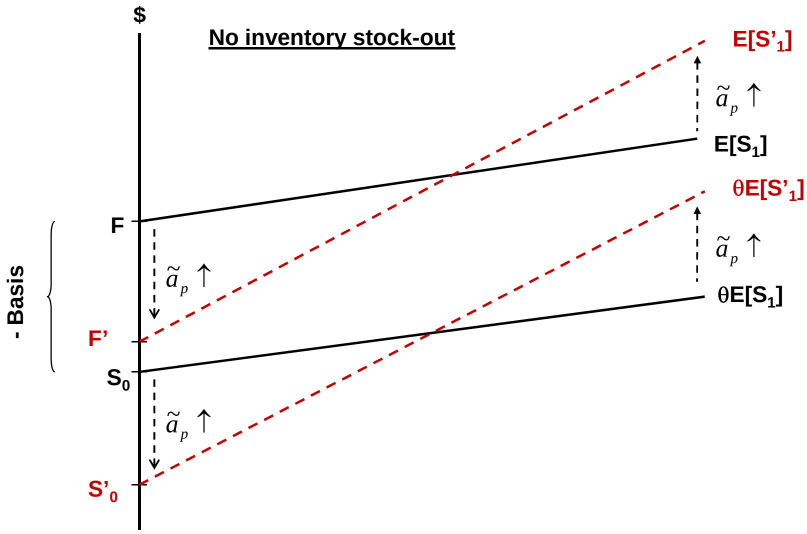

Figure 2

Figure 2: This figure shows how futures and spot prices change in response to an increase in fundamental hedging demand ($\widetilde{a_p}$) in the case of an inventory stock-out. The solid lines denote equilibrium values before the change. Here the basis before the change is noted on the vertical axis: Basis = S_0 – F. The dashed lines denote equilibrium values with higher hedging demand.

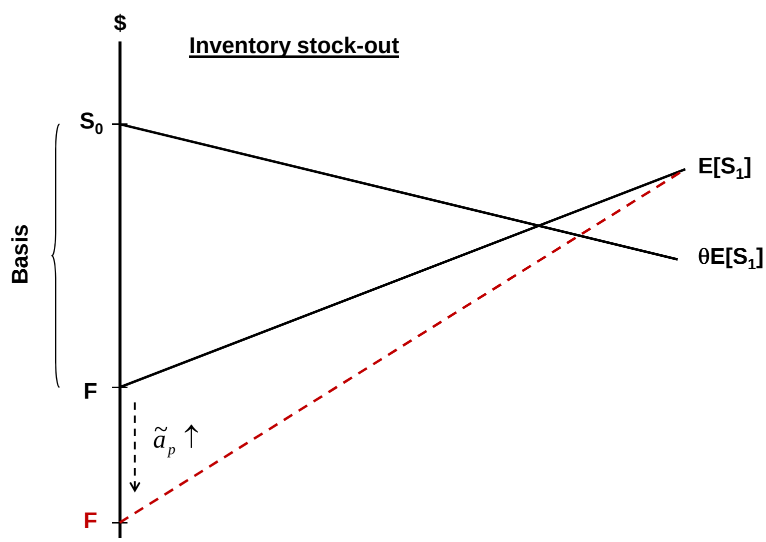

Figure 3

Figure 3: The figure plots the default risk measures (AVG3Y, AVGZm and Naïve EDF) for Crude Oil, Heating Oil and Gasoline (the series used for all three commodities are the same, since the producer firms are in the same SIC classification codes). The series are normalized by subtracting their means and dividing by their standard deviations for ease of plotting.

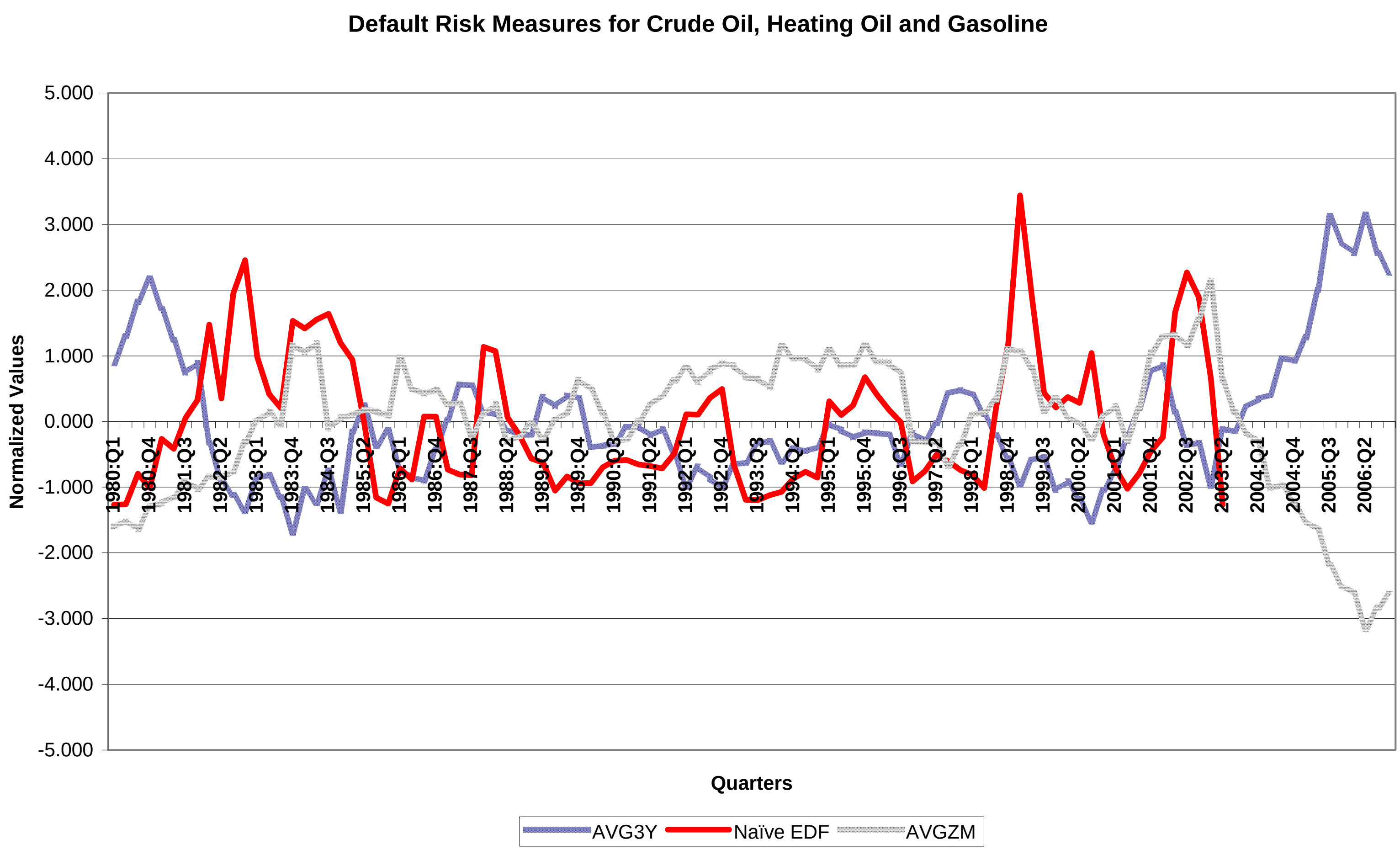

Figure 4

Figure 4: The figure plots the default risk measures (AVG3Y, AVGZm and Naïve EDF) for Natural Gas producers. The series are normalized by subtracting their means and dividing by their standard deviations for ease of plotting.