Risk Appetite and Intermediation by Swap Dealers*

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ABSTRACT

Using novel data on WTI crude oil swaps and futures positions of individual dealers, we relate dealer liquidity provision to changes in risk appetite over the 2007–2015 period. We find evidence consistent with a theoretical model of dealers who hedge bespoke contracts with standard, liquid instruments and face basis risk. Swap dealers provide less intermediation service for customers, and hedge the existing swaps more tightly, when risk appetite decreases. We also find evidence that dealers have larger single commodity swap books if they have a larger index book, suggesting that increased commodity index activity enhances liquidity provision to hedgers.

JEL classification:

Keywords: Dealers, Hedging, Risk Appetite, Liquidity Provision, Commodity Index

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"We don't have a proprietary trading business in commodities, we have a client business that takes risk." – Bob Diamond, CEO of Barclays Capital[1]

I. Introduction

How do dealers manage a derivatives trading book? To what extent do dealers use derivatives contracts to increase their risk exposures or to hedge their business risks? Despite the fundamental nature of these questions, the existing evidence is sparse and mostly anecdotal, partly because of data limitations. Further, market participants claim that regulatory reform efforts since the financial crisis have reduced the overall intermediation capacity of dealers and altered the behavior of dealers. For example, a comment letter from the Coalition of Derivatives End-Users to the Board of Governors, OCC, FDIC, CFTC, and SEC on 17 October 2018 states that "Following the [Volcker] rule's implementation, however, we have been and are concerned by an apparent reduction in the availability of certain bespoke and less liquid derivative products." Have commercial end-users of derivatives, who often desire bespoke instruments in relatively illiquid products or tenors, faced increased difficulty in transacting post-Crisis?

Management of a dealer's commodity derivatives trading book provides a rich environment for examining risk management within the context of a financial institution. Anecdotally, dealer activity in commodity markets is often distinguished from activity in more liquid equity and fixed income markets. Whereas the archetypal market maker in equities participates in an active "flow" business, quoting two-sided markets and holding very transient positions, market making in commodities is described as much more sporadic in nature. Whereas financial market participants may have a wide latitude in

[1] Barclays Capital Investor Seminar Q&A, 17 June 2009, www.home.barclays/content/dam/barclayspublic/docs/InvestorRelations/IRNewsPresentations/2009Presentations/Barclays-Capital-Investor-Seminar-QandA.pdf

activities, commercial producers and consumers are more limited with respect to the products traded. Commercial users are beholden to the large volumes they would like to hedge over long time frames, while other participants prefer smaller volumes and shorter time frames. Dealers emphasize that their market making activities in commodities involves the warehousing of risks - holding positions for a period of time, rather than immediately laying off the risk. They also highlight the fact that their positions often involve basis risk, because they use standardized, liquid hedging instruments to hedge the customized products desired by customers. Dealers also readily engage in arbitrage activities across instruments.[2]

Dealers generally reduced their balance sheets as they re-evaluated their business models post-Crisis. Some commodity dealers are known to have exited the business during the years following the Crisis, and most are believed to have reduced their footprint in the space.[3] The regulatory environment also became more restrictive as regulatory reforms were implemented. Basel constraints limited balance sheet flexibility, the Volcker rule limited proprietary trading activity, the Federal Reserve proposed stricter rules on bank activity in physical commodities, and public reporting of swap transactions have all been cited as factors in reducing liquidity for commodity derivatives end-users. (See the discussions in Mixon (2018) and Commodity Futures Trading Commission (2018)). However, there is limited systematic evidence linking the balance sheets of individual dealers to their activities providing liquidity to commodity clients.

To address this lack of quantitative evidence in the literature, we provide an in-depth examination of swap dealing activity, pre- and post-Crisis, for a wide cross-section of

[2]See, for example, the discussion on p. 113 of Morgan Stanley's September 30, 2011 10-Q Quarterly Report.

[3]E.g., see "Deutsche Bank Quits Commodities Under Regulatory Pressure", David Sheppard and Ron Bousso, *Reuters*, 5 December 2013; "Credit Suisse to Exit Commodities Trading", Max Colchester and Sarah Kent, *Wall Street Journal*, 22 July 2014; "Barclays Exit from Energy Trading Stirs Concerns over Liquidity", Catherine Ngai and Olivia Oran, *Reuters*.

individual dealers. To our knowledge, this is the first time that such portfolio-level data has been used to gauge the provision of risk-bearing services ("liquidity") by OTC swap dealers and their related hedging activity in the listed derivatives market. We find evidence that dealer risk appetites persistently declined in the post-Crisis period, and that client-facing derivatives books declined along with risk appetite. This strong, supply-side relation holds even after controlling for demand-side shocks such as the growth in U.S. production of crude oil to be hedged.

Anecdotally, real-economy firms that use crude oil swaps to hedge prefer long-dated contracts in order to get net short exposure spread out over a period of months or years, while dealers tend to hedge with the most liquid, short-dated contracts. Dealers also face offsetting flows from index investors, who generally desire long exposure to near-dated contracts. We provide empirical evidence describing the interaction of these clienteles, as intermediated by swap dealers. We find that the majority of dealer futures hedging activity is in near-dated contracts when hedging commodity index exposures, but the hedging activity for single commodity swaps in WTI is more dispersed across the term structure. Finally, we also find evidence supporting the idea that dealers hedged a given swap exposure more tightly (i.e., took on less basis risk) during the post-Crisis part of the sample when balance sheet constraints were tighter. Overall, we find that dealers generally use futures contracts to mitigate their risks due to swap exposures, but they do not (or cannot) hedge all risks. Consistent with our theoretical model of optimizing dealers who provide swap exposure to hedgers but retain some risk (e.g., basis risk), equilibrium outcomes in the market are related to the risk appetite of dealers.

The reminder of the paper is organized as follows. Section II provides an overview of the related literature. Section III offers empirical facts motivating our modeling approach. Section IV introduces our theoretical model, while Section V gives the details of our data and summary statistics. Section VI provides the results of our empirical analysis and Section VII concludes.

II. Related Literature

Our paper is closest to the work of Naik and Yadav (2003*b*), who examine the trading behavior of individual dealers in the UK gilt market. Whereas they examine futures hedging of cash gilt positions over a one-year sample, we examine futures hedging of dealer swap positions over an eight year period encompassing major structural and regulatory changes. We also link the hedging behavior to the risk appetite of individual firms. Naik and Yadav (2003*a*) also provide insight into the internal structure of dealer portfolio behavior, providing evidence that trading desk activity within dealers is often decentralized and not coordinated. Begenau, Piazzesi and Schneider (2015) provide evidence that futures trading activity within dealers is often centralized, allowing dealers to provide more single commodity liquidity when it is offset with index activity within the same firm.

Also closely related is the literature focusing on dealer balance sheets and leverage representing a focal point of asset pricing. Adrian and Shin (2010) and Adrian, Boyarchenko and Shachar (2017) provide evidence that dealer risk appetite varies over time and can potentially rationalize movements in asset prices. Etula (2013), in particular, examines the impact of dealer leverage on commodity price changes and concludes that dealer balance sheets are important for explaining energy price changes.

Given the crude oil data used in the analysis, our work is also related to the literature specifically examining that market. Mixon, Onur and Riggs (2018) describe the aggregate positions taken by swap dealers and their counterparties in the WTI crude oil market over the 2014 – 2016 period, but they do not explore the behavior of individual dealers, nor do they test hypotheses explaining position changes over time. Irwin and

Sanders (2012) examine the aggregate, index-linked positions from the same data collection, but they do not examine the single commodity swap data or the activities of individual dealers.

Acharya, Lochstoer and Ramorai (2013) consider a model of risk averse hedgers and arbitrageurs and connect the model's implications to risk premia in the energy derivatives market. They find that the risk appetite of energy producers varies the intensity with which hedging occurs, and this is related to the risk bearing capacity of dealers. In contrast, we allow for risk averse dealers and hedgers in a world with swaps and futures markets, and we focus on the quantities traded more than the pricing implications.

Our paper is also linked to the work of Gârleanu, Pesersen and Poteshman (2009), who examine the pricing of derivatives when demand pressure matters. They focus on cases where the dealer is unable to hedge derivatives risks completely due to market frictions. In contrast, our theoretical motivation assumes that risk averse dealers optimally choose to underhedge, compared to the full hedging in the baseline, perfect markets case. Consistent with anecdotal dealer descriptions of their business, we find evidence that hedging of derivatives risk varies over time. This supports the view of Stulz (1996) that dealers should engage in selective risk taking as part of their business, but it is less in line with the view of Froot and Stein (1998) that intermediaries should hedge fully.

In the theoretical framework motivating our empirical analysis, we incorporate a two-tiered market similar to the frameworks of Vogler (1997) and Viswanathan and Wang (2004). In those papers, however, dealers interact with clients in a public market and then manage inventory risk in a second stage, dealer-only market. In our framework, we consider a dealer who first engages with a customer in the swaps market and then manages portfolio risk in a related, public futures market.

Our work differs from the aforementioned studies in that we examine portfolio-level data for individual dealers and relate their dealing and hedging activities to observable measures of risk appetite. We link balance sheet variables and trading VaR measures to dealer liquidity provision in the swaps market and liquidity taking in the futures market. The panel nature of the data, covering the pre- and post-Crisis period, provides a unique window into the business of managing a derivatives trading book in practice.

III. A First Look at the Data

In this section, we present several charts highlighting salient institutional features of the data that we will subsequently incorporate into the theoretical and empirical analysis that follows. Our focus is to use the futures and swap positions, aggregated across a broad sample of large dealers in WTI-related swaps, to illustrate broad co-movements of swap and futures positions, the relative magnitudes of commodity index-related positions and single commodity swap positions, and the change in the number of swap dealers engaged in this business over the sample period. In all cases, the positions are measured in terms of futures contract equivalents; options or swaps including optionality are delta-adjusted. Further, the futures positions include dealer holdings in the NYMEX WTI futures contracts, the ICE cash-settled WTI futures contract, and the NYMEX WTI calendar swap futures contract.

How do dealers manage the risk of a derivatives trading book? Figure 1 provides our first empirical evidence that variation in dealer futures risk appears to offset the variation in their swap risk. The solid black line shows the aggregate, net WTI-related swap position of dealers in our sample. Dealers were net short swap exposure during much of the 2008-2012 period, and they were net long during the remainder of the sample that ends in October 2015. The figure also displays the net WTI futures position of dealers. The data closely track the net futures positions reported in the CFTC's Commitments of Traders report.

The swap and futures positions have roughly the same magnitude at any given point in time, but with opposite signs. During the first three years of the sample, dealers were net short WTI exposure via swap and long a similar exposure via listed futures. For the next three years (2011–2013), the net swap position trended upward while the net futures position trended in the opposite direction. Finally, the two series trend in opposite directions during the final portion of the sample. Broadly speaking, the figure supports the idea that the dealer community used the WTI futures market to hedge their swap exposure and not to take strong directional bets on the WTI price.

Researchers have emphasized the lack of hedging activity for firms using derivatives. Chernenko and Faulkender (2011) conclude that a meaningful amount of interest rate swap activity by nonfinancial firms is not due to hedging, but to "speculation". Similarly, Begenau, Piazzesi and Schneider (2015) conclude that banks do not typically use interest rate swaps to hedge other businesses. Naik and Yadav (2003*b*) find that dealers use gilt futures to hedge cash gilt exposure locally, with cash and futures positions generally moving in opposite directions. However, they conclude that dealers were not targeting a fully hedged book but were targeting a net short duration position in both futures and cash during their sample. In contrast, the net WTI exposures described above do not appear to show a strong tendency for dealers to take, on aggregate, a net short or long position; the first impression is that dealers hedge a significant amount of swap exposure with futures.

We explore the net swap position of dealers in more detail in Figure 2. In aggregate, we find that dealers are net long WTI exposure via single commodity swaps (because hedgers are net short) and net short WTI exposure via commodity index swaps (because index investors have been net long). The aggregate swap dealer position therefore reflects the relative magnitudes of these two exposures, each of which is on the order of magnitude of hundreds of thousands of futures contracts. During the first several years of the sample, net WTI exposure due to index activity exceeded net WTI exposure to single commodity swap activity, resulting in a net short position of roughly 100,000 contracts. During the final years of the sample, commodity index activity declined in size and single commodity swap exosure increased, resulting in a dealer net long position on the order of 100,000 contracts.

Mixon, Onur and Riggs (2018) examine similar data for the final year and a half of the sample examined here and find that WTI positions due to index investing were smaller in size than the positions due to hedging activities of commercial end-users. Examination of the longer time series of data reveals that these relative sizes varied over time. Based on the evidence displayed in the chart, we conclude that a meaningful examination of dealer activity in the crude oil market must incorporate information on both the direct dealer exposure to single commodity swaps in WTI as well as the indirect exposure via commoidty index contracts. To date, the publicly available data on swaps (the CFTC's Index Investment Data report) incorporates only the index activity; therefore, the present study represents a signficant step forward in understanding the total financial activity of swap dealers in the commodity space.

The final chart in this section speaks to the comprehensiveness and variation through time in business activity. The aggregate sample includes 26 dealer firms; the CFTC initially identified dozens of entities likely to have large swap positions and requested information from them. Over time, some new firms were added, and some of the dealers left the sample because of bankruptcies or due to leaving the commodity swap business. In Figure 3, we display the three month average of the number of dealers engaging in the index swap dealing business and the number of dealers engaging in single commodity swaps dealing business for WTI. For this measure, we include dealers reporting more than a *de minimis* quantity (100 contracts) of WTI swap exposure. Examination of the chart suggests that the sample contains well over a dozen firms engaged in index swaps and a similar number engaged in single commodity swaps, with no obvious discontinuities in population coverage of dealers. Nonetheless, it is evident that the number of dealers engaged in the single commodity swaps business decreased dramatically after 2012, even as the number with an index swap book remained steady. We conclude that further analysis of this market should allow for a decline in the number of market participants, even as the size of the market increases.

In the sections that follow, we formulate a simple model that captures these initial observations, and we test the empirical predictions of the model on the data. We model swap dealers who intermediate different clienteles: index investors and hedgers. Commodity index investors are typically long and the indexes typically represent positions in liquid, nearby contracts, even though the swaps referencing the indexes might be for much longer tenors. Commercial hedgers in crude oil, such as exploration and production companies, are known to take positions over multiple maturities in order to hedge crude production or consumption over intervals that could span several years. Hence, dealers retain risk even after facing these two offsetting flows. We also allow dealers to choose an optimal hedge hedge in the futures market, based on their risk appetite.

Because the equilibrium prices and quantities depend crucially on dealer risk appetite, we carefully consider the comparative statics as dealer risk appetite varies. Such variation in risk appetite gives the static model a more dynamic flavor and could, in principle, generate a decline in dealer activity consistent with the evidence in in Figure 3. Note that we do not expliclty model the factors driving risk appetite (e.g., by modeling the effects of particular regulations), but we treat it as exogenous and use multiple proxies for it in our empirical analysis.

The observations also motivate us to split the sample into the 2007–2011 "Crisis and rule writing period" and the 2012–2015 "post-Crisis" period at several points in the analysis. As noted by Adrian, Boyarchenko and Shachar (2017), the nature of the rule implementation process led to a variety of measures occuring or being anticipated simultaneously. Given the difficulty of unraveling so many simultaneous factors, we view the splitting of the sample in this way as a transparent way to illustrate disparities across the two periods.

IV. Theory

The goal of our theoretical work is to provide a simple model that captures the key elements of a dealer's business transacting long-dated swap contracts to producers, and optimally hedging the risk in the liquid, short-dated futures market. Consider an economy with one commodity, "WTI crude oil". The producers of the commodity hedge production in the swap market by selling the commodity forward at the swap strike K. The swap dealer facilitates the swaps by going long and hedges by going short in the futures market. Mirroring actual market practice, swap dealers hedge swaps with the liquid, active futures contracts that are not perfect substitututes for these swap exposures, and hence they take on basis risk. Producers and swap dealers interact in the swaps market, while swap dealers interact with futures traders in the futures market. Futures traders do not participate in the swaps market, and producers do not enter into the futures market.

In abstract terms, we consider two correlated instruments that are traded, and for which we find the equilibrium prices and quantities traded. For our particular application, we will treat these two instruments as the short-dated futures contract and the long-dated swap contract. The prices of futures and swap markets are based on the same fundamental with different but correlated error terms. Liquidation values for the two instruments are given by $f = E[s] + \epsilon_f$ in the futures market and $k = E[s] + \epsilon_k$ in the swap market.

Error terms for the two instruments are mean zero noise ($E[\epsilon_f) = E[\epsilon_k] = 0$), have the same variance ($var(\epsilon_f) = var(\epsilon_k) = \sigma^2$), and have a correlation of ρ. All market participants have the same beliefs over these parameters and stochastic processes. Market prices for futures and swap instruments are determined endogeneously and are denoted by F and K, respectively. All market participants are mean-variance optimizers and their risk aversion parameters are denoted by γ_P for producers, γ_{SD} for swap dealers and γ_{FT} for futures traders. Finally, there is exogenous index investment in the economy, which is denoted by I. We model this index investment taking place directly in the futures market.

A. Equilibrium in the Futures Market

We begin by solving for the futures market equilibrium, conditional on the dealer's swap demand. In the futures market, swap dealers trade only with futures traders and optimally hedge their swap positions. Swap dealer demand for futures is denoted by Q^F_{SD}, and futures traders' demand for futures is denoted by Q^F_{FT}. As indicated above, the price F clears the market and comes from the equilibrium

$$Q^F_{SD} + Q^F_{FT} + I = 0 \tag{1}$$

The dealer has a portfolio of long-dated swaps and short-dates futures and maximizes

$$max\, E[Q^F_{SD}(f - F) + Q^S_{SD}(k - K)] - \frac{\gamma_{SD}}{2} var(Q^F_{SD}(f - F) + Q^S_{SD}(k - K)) \quad w.r.t. \quad Q^F_{SD} \tag{2}$$

The dealer's optimal futures demand is therefore

$$Q^F_{SD} = \frac{E[s] - F}{\gamma_{SD}\sigma^2} - \rho Q^S_{SD}, \tag{3}$$

where Q^S_{SD} is the dealer's swap demand.

The second source of demand in the futures market comes from the futures trader, who has no initial endowment and participates only in the futures market. The futures trader maximizes

$$max\, E[Q^F_{FT}(f - F)] - \frac{\gamma_{FT}}{2} var(Q^F_{FT}(f - F)) \quad w.r.t. \quad Q^F_{FT} \tag{4}$$

and her equilibrium demand is therefore given by

$$Q^F_{FT} = \frac{E[s] - F}{\gamma_{FT}\sigma^2} \tag{5}$$

Imposing the market clearing condition from Equation 1, the equilibrium futures price is

$$F^* = E[s] - (Q^S_{SD}\rho - I)\left[\frac{1}{\gamma_{SD}} + \frac{1}{\gamma_{FT}}\right]^{-1} \sigma^2 \tag{6}$$

Substituting this price into Equation 6, we find that the equilibrium futures demand by the swap dealer can be expressed as

$$Q^{F*}_{SD} = \rho Q^S_{SD}\,[R - 1] - IR, \tag{7}$$

where $R = \left[\frac{1}{\gamma_{SD}}\right]\left[\frac{1}{\gamma_{SD}} + \frac{1}{\gamma_{FT}}\right]^{-1}$. Note that for $\gamma_{FT}, \gamma_{SD} > 0$, $0 < R < 1$ and $(R-1) < 0$.

This equilibrium expression obviously comports with standard intuition. A dealer will short more futures if 1) the quantity of swaps Q^S_{SD} increases, 2) exogenous index investment I increases, or 3) if the futures provide a better hedge because ρ is larger and basis risk is lower. Further, our empirical tests also rely on intution from the partial derivative of Q^F_{SD} with respect to γ_{SD}:

$$\frac{\partial Q^F_{SD}}{\partial \gamma_{SD}} = (Q^S_{SD}\rho - I)\left[\frac{\partial R}{\partial \gamma_{SD}}\right] \tag{8}$$

where it can be shown that $\frac{\partial R}{\partial \gamma_{SD}} < 0$. As γ_{SD} increases and dealer risk appetite declines, the dealer hedge position in futures tends toward the more neutral position $-rhoQ^S_{SD}$ that obtains when $F = E[s]$. This neutral hedge would also obtain if there were no market impact ot the dealer's futures trading, or $\gamma_{FT} = 0$. In the model, $F > E[s]$ when index investment is large, increasing the market clearing price above the future, inducing dealers to "overhedge" their swap position and act as arbitrageurs. Technically, this occurs when $\rho Q^S_{SD} > I$. Similarly, dealers "underhedge" their swap position when the producer forward sales dominate and $F < E[s]$. In either case, an increase in dealer risk aversion attenuates the dealer position towards a more neutral stance. Our empirical tests on hedging behavior for dealers derive from these partial derivatives of this equation.

B. Equilibrium in the Swap Market

We also solve for the swap market equilibrium and derive empirical predictions relating the size of a dealer's single commodity swap book to risk aversion and other state variables. Only swap dealers and producers trade in the swap market. Swap dealer demand for swaps is denoted by Q^S_{SD} and producers have demand denoted by Q^S_P. The variable K is the swap strike, and we solve for the value that satisfies the market clearing equilibrium of $Q^S_{SD} + Q^S_P = 0$. Note that the market clearing solution is a function of Q^F_{SD}, which we solved for and presented in Equation 7.

Specifically, the swap dealer maximizes the following equation

$$max\, E[Q^F_{SD}(f-F)+Q^S_{SD}(k-K)]-\frac{\gamma_{SD}}{2}var(Q^S_{SD}(f-F)+Q^S_{SD}(k-K)) \quad w.r.t. \quad Q^S_{SD} \tag{9}$$

and the optimal swap market demand becomes

$$Q^S_{SD}=\frac{E[s]-K}{\gamma_{SD}\sigma^2}-\rho Q^F_{SD}* \tag{10}$$

where $Q^F_{SD}*$ is as defined in 7. Substituting this back into 10 gives us

$Q^S_{SD}=\frac{E[s]-K}{\gamma_{SD}\sigma^2}-\rho Q^S_{SD}\,[R-1]-IR$ and solving for the equilibrium swap demand by the swap dealer, we get

$$Q^{S*}_{SD}=\left[\frac{E[s]-K}{\gamma_{SD}\sigma^2}+\rho IR\right]\left[1-\rho^2(1-R)\right]^{-1} \tag{11}$$

The other player in the swap market, the producer, also optimizes his swap demand by maximizing the following equation

$$max\, E[Q_0k+Q^S_P(k-K)]-\frac{\gamma_P}{2}var(Q_0k+Q^S_P(k-K)) \quad w.r.t. \quad Q^S_P \tag{12}$$

and the producer's demand in the swap market is therefore given by

$$Q^S_P=\frac{E[s]-K}{\gamma_{SD}\sigma^2}-Q_0 \tag{13}$$

Applying the market clearing condition, we solve for K^* using the market clearing condition

$$\left[\frac{E[s]-K}{\gamma_{SD}\sigma^2}+\rho IR\right]\left[1-\rho^2(1-R)\right]^{-1}+\frac{E[s]-K}{\gamma_{SD}\sigma^2}-Q_0=0 \tag{14}$$

and find

$$K^* = E[s] - \left[\left[\frac{1}{\gamma_{SD}}\right]\left[1-\rho^2(1-R)\right]^{-1} + \left[\frac{1}{\gamma_P}\right]\right]^{-1} \sigma^2 \left[Q_0 - \rho IR\left[1-\rho^2(1-R)\right]^{-1}\right] \tag{15}$$

Using this equilibrium price, we find that the equilibrium size of the producer's swap book by combining equations 13 and 15. Our testable predictions on the swap market are derived from the equilibrium given by

$$Q_P^{S*} = \frac{-Q_0\left[\frac{1}{\gamma_{SD}}\right] - \rho IR\left[\frac{1}{\gamma_P}\right]}{\left[\frac{1}{\gamma_{SD}}\right] + \left[\frac{1}{\gamma_P}\right]\left[1-\rho^2(1-R)\right]^{-1}} \tag{16}$$

Using equation 16, we can sign the partial derivatives of the producer's swap demand. We find that $\frac{\partial Q_P^{S*}}{\partial Q_0} < 0$, indicating that producers hedge more if they are endowed with more. Additionally, we also find $\frac{\partial Q_P^{S*}}{\partial I} < 0$, meaning producers hedge more if there is more index investment. The effect of swap dealer risk aversion on the producer's demand depends on the precise parameter values. Roughly speaking, however, we find that $\frac{\partial Q_P^{S*}}{\partial \gamma_{SD}} > 0$ if Q_0 is "large" compared to I. Under these conditions, we can state that producers would hedge less if swap dealers become more risk averse. The alternative scenario is that pricing is dominated by extremely large values of I, and the futures price far exceeds $E[s]$, dealers are incentivized to go short to benefit from this extreme imbalance. If dealer risk aversion increases, they want to decrease this short position, which would mean that producers would be hedging less. We generally consider the case where Q_0 is "large" compared to I as the more realistic case.

It is worth noting that because swap demand adds up to zero, $Q_{SD}^S + Q_P^S = 0$, the partial derivatives for the swap dealer demand are opposite of those for the producer. Namely, swap dealers have a larger swap book if producer endownment increases; if there is more exogenous index investment; and if dealer risk aversion decreases (again, assuming Q_0 is large compared to I). In the empirical analysis that follows, we examine the size of the swap book from the dealer's perspective.

V. Data and Summary Statistics

A. Description of the Data

We combine three main types of data for the analysis in this paper: swap positions, futures positions, and balance sheet/risk data. The final sample is monthly and spans the period from December 2007 to October 2015.

The swap data consists of end-of-month long and short positions held by dealers who received a special call from the CFTC to provide such data. In mid-2008, the Commission contacted 16 dealers known to have significant commodity index swap businesses and 13 other dealers having large commodity futures positions. The Commission also contacted 14 entities managing commodity index funds, including funds indexed to a single commodity. Respondents were required to provide position information related to commodity index transactions, starting from December 2007. The special call continued monthly until October 2015. The number of participants contacted varied over time as firms merged or entered/left the business.

Data were reported in notional terms and in the number of futures equivalent contracts (delta-adjusted). Dealers provided information on positions, broken down into the individual commodity exposure, resulting from commodity transactions including index swaps, single commodity swaps, and other products such as commodity index-linked notes or ETFs. Aggregated data on index investments were published by the CFTC in Commodity Futures Trading Commission (2008) and in a subsequent, periodical "Index

Investment Data" (IID) report. The aggregated data summed positions resulting from dealer index swaps and notes, as well as direct transactions in the futures market. The data has been used by researchers (e.g., Irwin and Sanders (2012)) to evaluate the effect of index investment on prices and volatility of commodity prices.

In this paper, we use the raw, firm-level data compiled for the IID report and focus our attention on the trading activity of individual dealers. Our primary measure of dealer positions is constructed from the single commodity swaps on WTI crude oil, which has not been previously reported publicly. Separately, we use the dealer-level WTI positions associated with index-linked swaps to measure the size of the dealer's index book. In both cases, we refer to the data as "swap data", although it includes other dealer transactions such as index-linked notes. In addition to using the size of the individual swap dealer's index book as a state variable, we use the size of non-swap index positions. These non-swap positions include direct futures market holdings by mutual funds, ETFs, or other funds. We also construct this variable using the raw data used to construct the IID report.

The futures data used in the paper comes from the daily futures and options on futures position data collected by the U.S. Commodity Futures Trading Commission as part of their Large Trader Reporting System. Data contain end-of-day long and short positions of different expirations of each contract per large trader, where a large trader is defined as having a position greater than some threshold number of contracts. Data also include the delta-adjusted options positions for each large trader.

The futures data we examine start from the end of 2007 and go until end of October 2015. We aggregate the net value of futures and delta-adjusted options in three contracts that have WTI crude oil underlying to gauge the WTI futures exposure of each dealer on a daily basis [4]. The futures data is then combined with the swaps data on certain

[4]The three contracts used in the analysis are NYMEX WTI crude oil contract, NYMEX WTI crude

observation dates we have the swaps data for to have a comprehensive data set.

The fundamental data for each dealer was collected through public sources: quarterly, semi-annual, and annual reports (as available), and investor presentations usually associated with earnings announcements. We collected the following balance sheet variables: Assets, Equity, Repo plus Short-Term Borrowing, Repo, Tier 1 Capital Ratio, and Physical Commodity holdings. We also collected Trading Value-at-Risk (VaR) figures for the aggregate trading portfolio, and its interest rate, credit, and commodity components, as available. The universe of firms includes entities that file under U.S. accounting practices and European practices, which required us to standardize some data for analysis. We follow standardizations employed by Bloomberg Markets for the balance sheet data. Because fundamentals vary in timing and frequency, we repeat variable values until the next observation is available.

VaR presentation varied over time across and within firms. Our target VaR measure is the 99%, one-day VaR, averaged over the trailing quarter. We used that measure when it was presented and used the best available proxies when it was not available. For example, we convert 95% VaR statistics to 99% by multiplying the reported value by the normal distribution function conversion factor of 1.41432, and we convert 10-day VaR statistics to 1-day statistics by dividing the reported value by the square root of 10. We used end-of-period values when average data was not reported, and we use data from multiple periods to compute quarterly VaR when required.

B. Summary Statistics

Table I presents descriptive information on the typical levels of major variables used in the analysis. We provide average values over the entire sample as well as over two subsamples. The subsamples each comprise approximately half of the total observa-

oil calendar contract, and ICE crude oil linked contract tions. Roughly speaking, the first subsample (December 2007 to December 2011) covers the financial crisis period and the rule-writing period, whereas the second subsample (January 2012 to October 2015) covers the rule implementation period and a period of substantially increased U.S. crude oil production due to new technology ("tight oil"). We briefly note some of the most interesting observations resulting from examination of the statistics. Panel A presents information on the aggregate dealer swap positions. As previously seen in Figure 1, the net WTI swap exposure of dealers due to their commodity index business became smaller during the sample, declining in magnitude by approximately one third (from 330,000 contracts to 230,000 contracts). At the same time, the aggregate WTI exposure from WTI-specific swaps increased by a similar magnitude of 130,000 contracts (increasing from 220,000 contracts to 350,000 contracts). Gross positions, which sum the absolute values of long and short positions, fell sharply from the first subsample to the second. Panel B displays information on WTI and market variables, highlighting that the second subsample generally featured increased U.S. crude oil production, which was associated with lower prices and lower volatility for crude oil, as well as more distress for producers, as measured by the Zmijewski z-score. There was was also a modest increase in commodity index investing activity not carried out via index swaps (i.e., through direct investment vehicles such as mutual funds). Finally, Panel C presents typical levels of the balance sheet and risk fundamentals for the universe of swap dealers. Broadly speaking, the statistics suggest that dealers were less levered, had more balance sheet equity and higher Tier 1 capital ratios, and had VaR levels that were roughly half as much during the second subsample, as compared to the first subsample. Further, dealers pursued less short-term borrowing, including repurchase transactions during the second subsample.

VI. Empirical Analysis

A. Risk Appetite Dynamics

One of the main findings from section IV is that the willingness of dealers to accommodate client hedging demand in the swap market, and their subsequent demand for hedge instruments in the futures market, depends crucially on risk appetite. We begin the empirical analysis by demonstrating the strong downward trend in dealer VaR over the sample, even after controlling for important state variables such as balance sheet equity and market volatility. Our interpretation of the results in table II is that the strong, residual, downward trend in VaR is striking empirical evidence that dealers fundamentally shifted their risk appetite over the sample period.

B. How Much Liquidity Provision to Customers?

In this section, we use panel regressions with dealer fixed effects to understand whether dealers with larger risk appetites have larger WTI swap books. Further, we test whether having a larger than average index swap book yields a larger WTI swap book. To answer these questions, we regress monthly net single commodity WTI swap positions on our proxies for dealer risk appetite, on individual dealer net index position and on other control variables as described below. Table III shows the results of our swap book size regression, which strongly confirm the theoretical predictions.

Each column in the table presents the results of a panel regression of dealer single commodity swap book size (net long position) explained by demand side variables (U.S. Crude Oil Production Forecast, Sector Z-Score for Oil Producers), market control variables (lagged price of one year ahead CL13 oil futures, the TED spread, WTI 3 month at-the money implied volatility index), supply side variables (equity for each dealer, net size of the dealer's WTI-index swap book, aggregate non-swap index investment in WTI futures), a time trend, and a proxy for dealer risk appetite. All variables are the same in each regression, except for the risk appetite proxies, which vary across regressions. T-statistics are in parentheses below coefficients; coefficients with absolute t-statistics larger than 1.96 are highlighted in gray.

The model predicts that increased production demand should lead to more hedging and larger swap books, and we find strong evidence to support this prediction. The production variable is the one-year ahead baseline forecast of U.S. crude oil production from the Energy Infomration Administration. The variable is highly significant, with t-statistics well above conventional significance levels in all specifications. We also control for producer risk aversion, proxied by producer distress. This is measured by the Zmijewski z-score of large producers in SIC code 1311, following the work of Acharya, Lochstoer and Ramorai (2013). The variable is signed correctly, and it is significant in two specifications.

We also control for the price of crude oil. We use the one-year ahead WTI crude oil futures price (denoted CL13) and lag it one month, and we generally find it is quite significant. We interpret this as a mechanical relation. Producers often sell a quantity of crude oil forward using collars (short calls and long puts). The data represent delta-adjusted futures equivalents, therefore, a change in crude price (holding the actual portfolios constant) would result in a change in the delta-adjusted position. If the price increases and the call options go into the money, this would increase the delta of the futures hedge.

Further, we find that an increase in a dealer's index investment book is associated with an increase in the size of the single commodity swap book. As the index position of investors increases, the dealer position gets shorter. A larger negative value multipled by a negative coefficient leads to a larger predicted single commodity swap book. However, we do not find a significant relation between other, direct index investment and the size of a dealer's single commodity swap book. If index investors take larger positions in mutual funds or ETFs indexed to commodity products, this does not appear to have a meaningful effect on the size of an individual dealer's swap book. We intend to explore this relation further to examine if there is an industry-wide impact of index investing.

We find that the risk appetite proxies are always highly related to the size of the dealer swap books. As dealers became more risk averse in the sample - whether measured by decreased leverage, decreased VaR to equity, less repo or short-term borrowing, or a higher Tier 1 capital ratio - the dealer single commodity swap book became smaller.

Finally, we also find that a trend variable remains highly signficant in most cases, even after controlling for the factors described above. The meaning of this finding is not immediately obvious, but it might suggest a role for the changing composition of WTI production in equilibrium hedging. As described in Commodity Futures Trading Commission (2018), some industry observers suggest that the shorter lifecycle of tight oil has led producers to shift some hedging from derivatives to operational hedging. We intend to explore this explanation in subsequent work.

C. Hedging Dynamics

We begin by providing descriptive information on dealer hedge portfolios. While it is suggested anecdotally that dealers prefer to hedge positions with the most liquid, near-dated futures contracts, there is little quantitative evidence to pin down the fact. in table IV, we break out dealer positions by tenor. Table IV shows net positions in Panel A and open positions in panel B. All the data is broken into 5 tenor buckets; 0 to 3 months bucket, 3 months to 12 months bucket, 12 months to 24 months bucket, 24 months to 36 months bucket, and longer than 36 months bucket. Additionally, the table shows dealers' futures and options positions separatley and together. Finally, data are presented for the pre-2012 (period 1) and post-2012 (period 2) periods separately, capturing the 2012 switch visible in figure 2.

We observe some simple patterns in Table IV. Starting with panel B, there is an overall drop in open positions held by dealers between period 1 and period 2. Just focusing on the change column, it is obvious that this drop is bigger in magnitude at the tail end of the tenor buckets. From panel A, we observe net futures and options positions to be positive in period 1 but they drop to a large negative value in period 2. Even with this drop in period 2, net exposure in the first tenor bucket is positive and positions in the rest of the tenor buckets are negative; a pattern that does not change across periods. Additionally, Comparing these numbers to the individual futures and options positions, we see that most of the changes are driven by futures, not by options.

We next provide analysis relating dealer hedge portolios, by tenor, to the swap book. We begin with regressions at the aggregate level, covering all 26 dealers in the sample. We regress change in dealers' futures, options and both futures and options positions on changes in index swap positions and changes in single commodity swaps. Motivated by our findings in table IV, we also run our regressions separately for the five different tenor buckets. More formally, we estimate Table V corraborates our earlier observations that hedging is mainly done with futures, not options. Additionally, when broken out into tenor buckets, hedging ratio coefficients are negative and significant for the shortest bucket, but either not significant or negative for longer tenor buckets for index swap position changes. For changes in single commodity swaps, hedging at the longer end of the tenor buckets seems to be statistically significant but coefficients are quite small.

Finally, we provide evidence on how individual dealers hedge their particular swap book. We find substantial variation across dealers, as do Naik and Yadav (2003*b*). Results are shown in VI. Panel A summarizes the coefficients of the baseline time series regression for each dealer $i = 1, ..., 26$:

$$\Delta F_{it} = \alpha_i + \beta \Delta S^{I}_{it} + \gamma \Delta S^{SCS}_{it} + \varepsilon_{it}, \tag{17}$$

where ΔS^{I}_{it} is the change in dealer i's net WTI swap exposure due to commodity index swaps, and Δ^{SCS}_{it} is the change in dealer i's net WTI swap exposure due to single commodity swaps on WTI. We present summary statistics for each coefficient. Overall, the hedging coefficients have the correct sign, and the magnitude of the coefficient is larger for index swaps (which have tenors more closely matching the futures hedge tenors) than for single commodity swaps (which have tenors much longer than the futures hedge). Coefficents are generally quite significant.

The results in Panel B allow the coefficents to change between the first and second subperiods. If dealer risk appetite declined during the second period and caused dealers to hedge the positions more tightly, as the model predicts, we would expect to see the coefficients cluster more tightly near a neutral hedge coefficient. The evidence is consistent with this prediction. Index hedge coefficients cluster much more tightly near a value of unity, and single commodity swaps also appear consistent with the prediction. Panel B summarizes the coefficients of the regression allowing the slopes to change for each of the 26 dealers:

$$\Delta F_{it} = \alpha_i + \beta_{i,1} \Delta S^{I}_{it} D_1 + \beta_{i,2} \Delta S^{I}_{it} D_2 + \gamma^{I}_{i,1} \Delta^{SCS}_{it} D_1 + \gamma^{SCS}_{i,2} \Delta^{SCS}_{it} D_2 + \varepsilon_{it},$$

where D_1 is a dummy variable taking the value 1 up to December 2011 and 0 afterwards and D_2 is a dummy variable taking the value 0 up to December 2011 and 1 afterwards.

Panel C reports the results of the cross-sectional regression of the change in dealer i's estimated slope coefficient between periods 1 and 2 on the estimated value for period

1. This regression provides a simple description of how an individual dealer's hedge coefficients varied over the subsamples. For dealers with index coefficients that were greater than approimately 0.90 in the first subsample, the regression predicts that the coefficient in the second subsample is lower and closer to 0.9. Similarly, dealers with low index hedge coefficients in the first subsample are predicted to have an index coefficient closer to 0.9 in the second subsample. For single commodity swap coefficients, dealer coefficients similarly present a story of reversion. Dealers with low values of the hedge coefficent are predicted to have increased values for the second subsample, and vice versa. We view these results as quite consistent with the model predictions of hedge ratios.

VII. Conclusion

Despite the size and importance of swap markets, relatively little systematic evidence is available on them. Dealers participate in the swap market and in listed derivatives markets and provide intermediation services to customers. However, the changes in the regulatory environment since the crisis have led to substantial changes in the business activities of dealers. End-users of derivatives have complained that competition in swap markets has declined, along with liquidity. We provide evidence that links the risk appetite of individual dealers to their intermediation business for customers. We use observable balance sheet measures to control for changes in risk appetite, and we use dealer-level data on their provision of swaps to clients and the futures hedges against those swaps. We find strong evidence that the decline in dealer risk appetite occurred alongside a decline in the provision of liquidity to customers. This link persists even after controlling for shifts in user demand for swaps. Further, consistent with a theoretical model of dealer activity, we find that dealers hedged these swaps more tightly as their risk appetite declined. That is, dealers were less willing to take on basis risk on behalf of customers when risk appetite declined. Dealers provided fewer swaps to clients and provided worse pricing on those swaps.

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Table I: Summary Statistics - Average Levels

Aggregate Dealer swap positions are displayed in Panel A; values are in thousands of delta-adjusted futures equivalents. Panel B contains WTI average prices, the 3 month at-the-money implied volatility, EIA baseline forecast for 1 year ahead U.S. crude production (millions of barrels per year), the sector average Zmijewski (1984) default score for SIC code 1311, and aggregate non-swap commodity index investing for WTI (contracts). Panel C presents average values for dealer fundamental variables; VaR levels, Equity, Short-Term Borrowing, and Repo values are in millions of US dollars. Data are monthly from December 2007 to October 2015.

Panel A: Aggregate Dealer Swap Positions (Thousands of Contracts)							
Sample Period	**Net Index**	**Net WTI**	**Net Swap**	**Gross Index**	**Gross WTI**	**Gross Swap**	
2007/12 - 2011/12	-326.7	222.3	-104.4	622.3	5,964.9	6,587.1	
2012/1 - 2015/10	-231.8	346.5	114.7	474.6	2,040.0	2,514.7	
Full Sample	-279.8	283.7	3.9	549.2	4,023.6	4,572.8	
Panel B: WTI and Market Variables							
Sample Period	**CL13 Price**	**Implied Vol**	**Forecast Production**	**Producer Z-Score**	**Non-Swap Index**		
2007/12 - 2011/12	87.40	39.66	1,977	-2.73	118,067		
2012/1 - 2015/10	84.34	27.35	2,940	-2.37	134,721		
Full Sample	85.88	33.57	2,453	-2.55	126,305		
Panel C: Individual Dealer Fundamentals							
Sample Period	**Leverage**	**VaR**	**Commodity VaR**	**Equity**	**ST Borrow**	**Repo**	**Tier 1 Ratio**
2007/12 - 2011/12	23.94	97.41	16.52	62,146	281,127	108,321	11.5
2012/1 - 2015/10	18.98	45.07	8.55	77,311	209,051	88,842	13.7
Full Sample	21.49	71.52	12.58	69,647	245,476	98,686	12.6

Table II: Dealer Trading VaR Explained by Trend and Control Variables

This table displays a panel regression of individual dealer trading VaR on a trend, equity level of that dealer, and implied volatility indices. Regression results are also displayed for specifications with the lagged VaR statistic included. Dealer fixed effects are included in all specifications. T-statistics are in parentheses below coefficients; coefficients with absolute t-statistics larger than 1.96 are highlighted in gray. Data are monthly from December 2007 to October 2015.

	Dependent Variable					
	Aggregate VaR		Interest Rate VaR		Commodity VaR	
Trend	-1.017	-0.076	-0.690	-0.025	-0.150	-0.017
	(-22.22)	(-3.43)	(-15.59)	(-1.25)	(-17.75)	(-4.77)
Equity	0.254	0.018	-0.123	-0.020	-0.055	-0.004
	(5.03)	(0.86)	(-2.59)	(-1.06)	(-7.08)	(-1.29)
VIX	0.613	0.184				
	(4.25)	(2.92)				
MOVE			0.072	0.054		
			(1.74)	(2.93)		
WTI Implied Vol					0.007	-0.010
					(0.40)	(-1.58)
Lagged VaR		0.916		0.924		0.910
		(55.51)		(44.40)		(45.71)
Dealer Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Adj R^2 (%)	74.8	96.4	75.7	96.9	82.9	97.1
# obs	1719	1700	1572	1553	1534	1516
# Dealers	19	19	19	19	18	18

Table III: Relating Risk Appetite to Single Commodity Swap Book Size

The table presents estimated coefficients for a panel regression of the net size of dealer WTI single commodity swap books on demand side variables (U.S. Crude Oil Production Forecast, Sector Z-Score for Oil Producers), market control variables (lagged price of one year ahead CL13 oil futures, the TED spread, WTI 3 month at-the money implied volatility index), supply side variables (equity for each dealer, net size of the dealer's WTI-index swap book, aggregate non-swap index investment in WTI futures), a time trend, and a proxy for dealer risk appetite. T-statistics are in parentheses below coefficients; coefficients with absolute t-statistics larger than 1.96 are highlighted in gray. Data are monthly and span the period December 2007 to October 2015.

Independent Variables	**Risk Appetite Proxy**					
	Assets/ Equity	VaR/ Equity	Commodity VaR / Equity	ST Borrow/ Equity	Repo/ Equity	Tier 1 Ratio
Production Forecast	16.12	17.27	11.47	14.12	17.76	12.12
	(4.30)	(4.53)	(3.02)	(3.79)	(4.24)	(3.19)
Producer Z-Score	4,067.78	3,191.95	3,341.54	4,717.35	5,600.89	5,484.44
	(1.60)	(1.24)	(1.22)	(1.86)	(2.05)	(2.10)
CL13 Lagged Price	128.81	136.94	53.26	140.66	147.04	202.82
	(2.19)	(2.25)	(0.81)	(2.34)	(2.19)	(3.24)
TED Spread	-110.99	1041.70	-1257.53	-395.27	247.88	-1925.92
	(-0.07)	(0.64)	(-0.74)	(-0.25)	(0.14)	(-1.23)
WTI Implied Vol	-123.34	-191.30	-143.43	-59.30	-81.75	95.46
	(-1.28)	(-1.88)	(-1.38)	(-0.64)	(-0.75)	(1.14)
Equity	0.26	0.25	0.30	0.27	0.28	0.26
	(12.33)	(11.91)	(10.05)	(13.12)	(10.63)	(8.24)
Net Index Swap Book	-0.45	-0.33	-0.12	-0.45	-0.44	-0.34
	(-5.62)	(-4.09)	(-1.11)	(-5.63)	(-5.28)	(-4.40)
Non-Swap Index	0.00	0.01	-0.01	-0.01	-0.01	-0.04
	(-0.04)	(0.30)	(-0.29)	(-0.22)	(-0.27)	(-1.03)
Trend	-230.41	-195.25	-125.30	-185.53	-288.47	-121.27
	(-2.39)	(-2.05)	(-1.29)	(-1.93)	(-2.58)	(-1.24)
Risk Appetite Proxy	508.08	5.80	44.95	1.42	2.94	-479.89
	(6.00)	(7.72)	(6.15)	(5.17)	(4.27)	(-2.41)
Adj. R^2 (%)	68.5	68.8	71.2	68.4	67.4	71.8
# obs	1611	1550	1386	1599	1447	1529
# Dealers	20	19	18	20	18	19

Table IV: Average Futures Positions of Dealers, by Tenor

This table displays futures and delta-adjusted option positions for the 26 dealers in the sample. Values are in thousands of futures equivalent contracts and include the NYMEX WTI contract, ICE WTI contract, and NYMEX WTI Calendar swap contract. Data are monthly from December 2007 to October 2015.

Panel A: Net Positions - thousands of futures-equivalent contracts							
Instrument	**Sample Period**	**0 - 3m**	**3m - 1yr**	**1yr - 2yr**	**2yr - 3yr**	**3yr+**	**Total**
Futures + Options	2007/12 - 2011/12	169.8	-37.7	-46.1	-17.3	-15.7	53.0
Futures + Options	2012/1 - 2015/10	52.7	-165.3	-113.7	-24.5	-5.7	-256.5
Futures + Options	Full Sample	113.1	-99.5	-78.8	-20.8	-10.8	-96.9
Futures	2007/12 - 2011/12	184.9	-13.8	-38.8	-17.4	-19.1	95.8
Futures	2012/1 - 2015/10	62.0	-151.0	-108.3	-21.7	-2.5	-221.5
Futures	Full Sample	125.4	-80.2	-72.5	-19.5	-11.1	-57.9
Options	2007/12 - 2011/12	-15.1	-23.9	-7.3	0.1	3.5	-42.7
Options	2012/1 - 2015/10	-9.3	-14.3	-5.4	-2.8	-3.2	-35.0
Options	Full Sample	-12.3	-19.3	-6.4	-1.3	0.2	-39.0

Panel B: Open Positions							
Instrument	**Sample Period**	**0 - 3m**	**3m - 1yr**	**1yr - 2yr**	**2yr - 3yr**	**3yr+**	**Total**
Futures + Options	2007/12 - 2011/12	700.9	855.5	510.0	261.8	243.0	2,571.1
Futures + Options	2012/1 - 2015/10	528.5	705.7	404.3	140.3	100.7	1,879.6
Futures + Options	Full Sample	617.4	783.0	458.8	203.0	174.1	2,236.3
Change from Period 1 to 2		-24.6%	-17.5%	-20.7%	-46.4%	-58.6%	-26.9%

Table V: Hedging Regressions, by Tenor

The table presents coefficients for the aggregate time series regression

$$\Delta F_t^M = \alpha + \beta \Delta S_t^I + \gamma \Delta S_t^{SCS} + \varepsilon_t,$$

where ΔF_t^M is the change in net positions in futures portfolio M for Dealers, ΔS_t^I is the change in net WTI swap exposure due to commodity index swaps, and Δ_t^{SCS} is the change in net WTI swap exposure due to single commodity swaps on WTI. T-statistics are in parentheses below coefficients; coefficients with absolute t-statistics larger than 1.96 are highlighted in gray. All regressions incorporate the same aggregate swap exposures as independent variables, and the cases $M = 1, ..., 8$ reflect Dealer futures portfolios for varying instruments and tenors as the dependent variable. Regressions are estimated using positions for all tenors in Cases 1,2, and 3; regressions 4-8 use only contracts expiring during the timeframe specified for that regression. Case 1 and Cases 4-8 incorporate futures and delta-adjusted options, while Cases 2 and 3 break out futures and options, respectively. Data are monthly and span the period December 2007 to October 2015.

	Dependent Variable		**Independent Variables**		**Adj. R^2 (%)**
Case	**Expiries**	**Instrument**	**Δ Index Swaps**	**Δ WTI Swaps**	
1	All	Futures + Options	-0.96	-0.44	43.42
			(-6.40)	(-5.15)	
2	All	Futures only	-0.90	-0.40	36.46
			(-4.38)	(-4.54)	
3	All	Options only	-0.06	-0.04	1.55
			(-0.63)	(-1.92)	
4	0 - 3m	Futures + Options	-0.78	-0.15	32.62
			(-5.53)	(-3.38)	
5	3m - 1yr	Futures + Options	-0.26	-0.07	6.69
			(-2.19)	(-1.61)	
6	1yr - 2yr	Futures + Options	0.00	-0.16	15.26
			(-0.03)	(-3.59)	
7	2yr - 3yr	Futures + Options	0.05	-0.04	2.09
			(1.03)	(-2.48)	
8	3 yr+	Futures + Options	0.02	-0.02	1.21
			(0.69)	(-2.22)	

Table VI: Hedging Regression Coefficients for Individual Dealers

Panel A summarizes the coefficients of the baseline time series regression for each dealer $i = 1, ..., 26$:

$$\Delta F_{it} = \alpha_i + \beta \Delta S^I_{it} + \gamma \Delta S^{SCS}_{it} + \varepsilon_{it},$$

where ΔS^I_{it} is the change in dealer i's net WTI swap exposure due to commodity index swaps, and Δ^{SCS}_{it} is the change in dealer i's net WTI swap exposure due to single commodity swaps on WTI.

Panel B summarizes the coefficients of the regression allowing the slopes to change for each of the 26 dealers:

$$\Delta F_{it} = \alpha_i + \beta_{i,1} \Delta S^I_{it} D_1 + \beta_{i,2} \Delta S^I_{it} D_2 + \gamma_{i,1} \Delta^{SCS}_{it} D_1 + \gamma_{i,2} \Delta^{SCS}_{it} D_2 + \varepsilon_{it},$$

where D_1 is a dummy variable taking the value 1 up to December 2011 and 0 afterwards and D_2 is a dummy variable taking the value 0 up to December 2011 and 1 afterwards.

Panel C reports the results of the cross-sectional regression of the change in dealer i's estimated slope coefficient between periods 1 and 2 on the estimated value for period 1. Data are monthly and span the period December 2007 to October 2015.

Panel A: Baseline Hedging Regressions

		Δ Index Swaps		Δ WTI Swaps		Adj. R^2 (%)
Percentile	Intercept	Coefficient	T-Stat	Coefficient	T-Stat	
25%	-113.14	-0.98	-4.98	-0.83	-6.59	15.6
50%	-10.76	-0.78	-2.63	-0.52	-4.47	31.2
75%	67.13	-0.37	-1.40	-0.23	-1.65	50.0

Panel B: Hedging Regressions with Subsamples

		Δ Index Swaps		Δ WTI Swaps		Adj. R^2 (%)
Percentile	Intercept	Period 1 Coefficient	Period 2 Coefficient	Period 1 Coefficient	Period 2 Coefficient	
25%	-113.61	-1.00	-1.01	-0.83	-0.93	20.5
50%	-12.65	-0.82	-0.97	-0.48	-0.68	35.7
75%	94.44	-0.29	-0.74	-0.15	-0.28	51.8
# Dealers	26	22	21	21	19	

Panel C: Cross-Sectional Regression on Period 1 Slope Coefficients

Dependent Variable	Intercept	T-stat	Slope	T-stat	R^2 (%)
$\beta_{i,2}$ - $\beta_{i,1}$	-1.00	-4.98	-1.10	-5.68	65.5
$\gamma_{i,2}$ - $\gamma_{i,1}$	-0.43	-2.54	-0.76	-2.85	33.6

Figure 1: Dealer Net Positions in WTI Swaps and Futures, 2007-2015

The figure displays the net WTI swap exposure and net WTI futures and options positions, both aggregated across the 26 Dealers in the sample. Exposures are measured in delta-adjusted futures equivalent contracts. Swap exposure includes both implied WTI exposure via commodity index swaps and direct WTI exposure via single commodity swaps. Futures positions include the NYMEX WTI contract, ICE WTI contract, and NYMEX WTI Calendar swap contract. Data are monthly from December 2007 to October 2015.

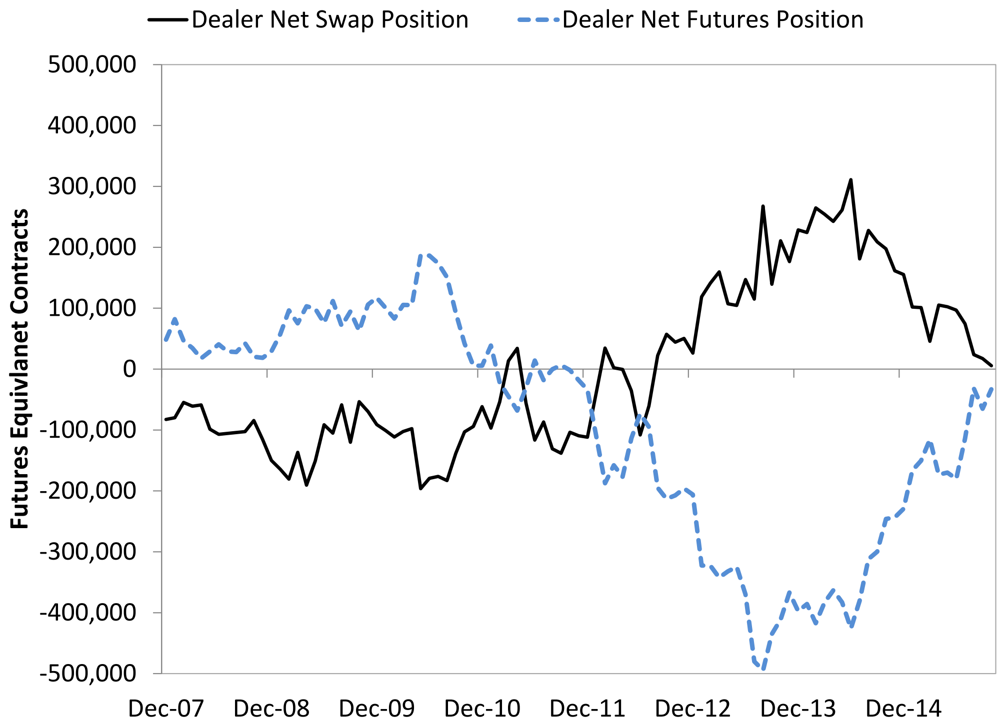


Figure 2: Dealer WTI Exposure due to Index and Single Commodity Swaps

The figure displays dealer net WTI exposure due to index swaps, net WTI exposure due to WTI single commodity swaps, and net WTI swap exposure. Values are aggregated across the 26 Dealers in the sample. Data are monthly from December 2007 to October 2015.

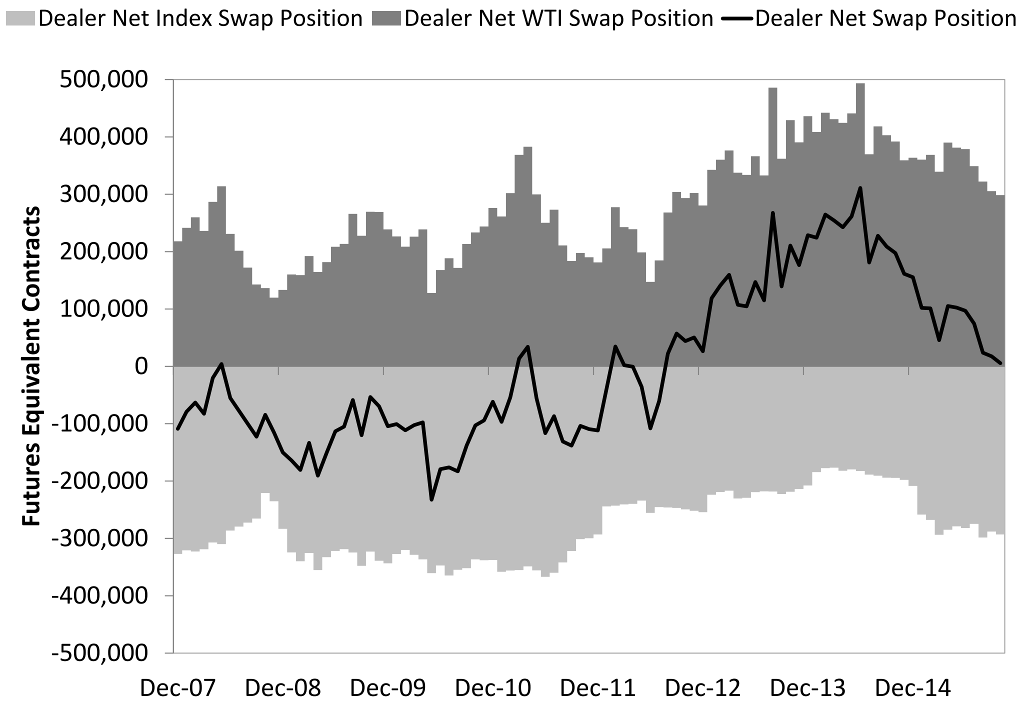
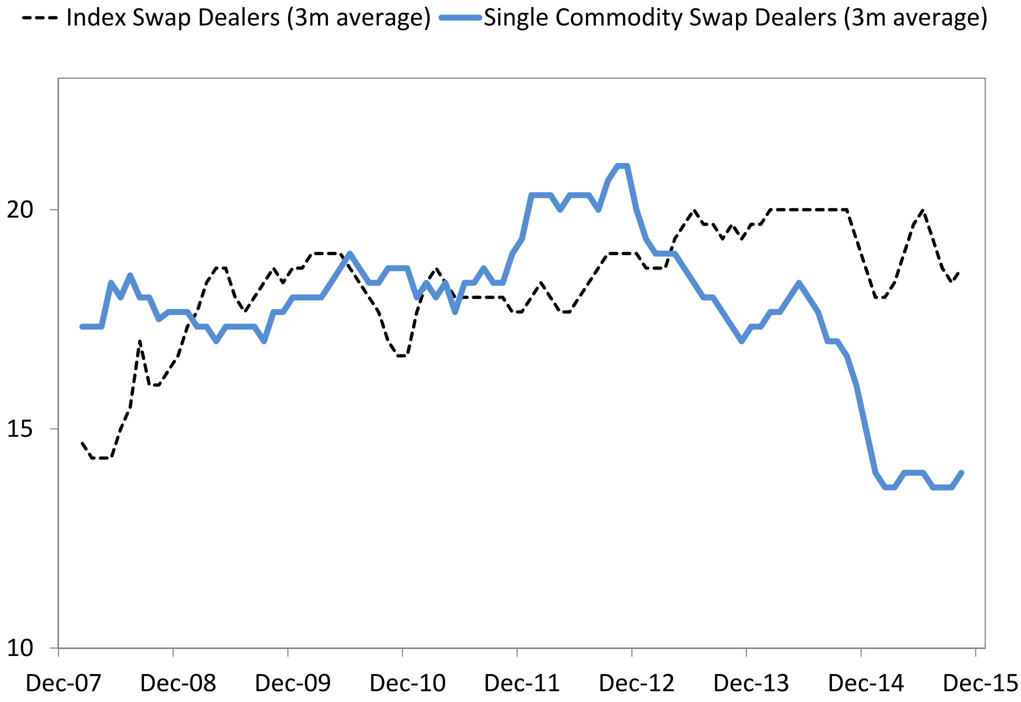


Figure 3: Number of Swap Dealers

The figure displays three-month moving averages of the count of swap dealers reporting non-zero net positions in commodity index or WTI swaps. Dealers are excluded from the count if they hold net swap positions less than 100 contracts.



A. Appendix

Figure A1 compares the net futures position of the dealers in our sample with the dealers' net positions from the publicly available DCOT dataset.

Figure A1: Futures Positions of Dealers–Sample Data vs. DCOT

The figure displays both the net futures positions of Dealers utilized in this paper, compared with the net "Swap Dealer" futures and option position in NYMEX WTI futures from the CFTC's publicly available Disaggregated Committments of Traders (DCOT) report.