Risk Appetite and Intermediation by Swap Dealers*

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ABSTRACT

We find that intermediary risk appetite plays an important role in the availability of dealer hedging services provided to real economy firms. We show that dealers intermediate the swap exposures of different clienteles and hedge some residual risk in the futures market. Using novel data on WTI crude oil swaps and futures positions of individual dealers, we present evidence that dealers hedge bespoke contracts with standard, liquid instruments and face basis risk. We conclude that the equilibrium quantity of basis risk taken, and therefore the amount of intermediation service available at a given price, is correlated with risk appetite.

Keywords: Dealers, Hedging, Risk Appetite, Intermediation service

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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

We study the liquidity provision and risk management of swap dealers using a novel panel of swap positions and related futures positions. We relate these behaviors to fundamental, balance sheet data for the individual dealers. In particular, we examine how the risk appetite of dealers impacts their intermediation of client demands for derivative exposure. We find strong evidence linking dealer risk appetite to the provision of swap dealing services to customers, and hence to the hedging decisions of firms in the real economy.

Why should dealer risk appetite be relevant for understanding swap dealing? A traditional view suggests that risk appetite should have little connection to the derivatives book: dealers provide derivatives exposure to clients, offset some risk with other customer flow, and simply delta hedge the residual risk in the futures or spot market. If dealers face limits to arbitrage, however, their intermediation activity is more consequential. We find that management of a dealer's commodity derivatives trading book provides a rich environment for examining risk management and risk taking by a financial institution. 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. Dealers emphasize that their market making activities in commodities

[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

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 clients. Historically, dealers also engaged readily in arbitrage activities or relative value trades across instruments.[2] Dealers in commodities face limits to arbitrage constraints that make their risk appetite relevant.

Our paper contributes to the literature highlighting the role of financial intermediaries in asset pricing. Recent research suggests that the risk-bearing capacity of dealers plays an important role in determining asset prices, because the pricing kernel of financial intermediaries, and not households, is key for explaining the pricing behavior of a wide range of assets (He and Krishnamurthy (2013), Etula (2013), Adrian, Etula and Muir (2014), Brunnermeier and Sannikov (2014), He, Kelly and Manela (2017)). In particular, we examine how the risk appetite of dealers impacts the intermediation of client demand for hedging by real economy firms, and we identify a particular channel - basis risk - through which dealer activity is impacted. Dealers intermediate customer demands for derivatives exposure from clienteles with different profiles, and the dealers imperfectly hedge their risks because they use standard, liquid instruments to hedge bespoke contracts. As risk appetite varies, the equilibrium quantity of basis risk taken also varies. Therefore, the amount of intermediation service available at a given price is correlated with risk appetite.

Our empirical analysis covers the WTI crude oil derivatives market during the period 2007–2015, which offers a compelling setting for evaluating the behavior of swap dealers. The cash-settled market for crude oil-linked swaps is quite large; it is comparable in size to the WTI crude oil futures markets (one of the most active futures markets).

[2]See, for example, the discussions by Kellett (2004) or page 113 of Morgan Stanley's September 30, 2011 10-Q Quarterly Report.

Notably, we can control for demand side effects by incorporating expected production of crude oil and the hedging propensity of producers, as in Acharya, Lochstoer and Ramadorai (2013). On the supply side, we are able to exploit the cross-sectional and time series variation in dealer balance sheets to link risk appetite and activity. Whether by introspection or regulatory restriction, dealers generally reduced their balance sheets as they re-evaluated their business models post-Crisis. Several 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]

Understanding the mechanism by which risk appetite affects the real economy through dealer activity has important implications for policymakers. Market participants have complained that hedging has become more difficult since the financial crisis. 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 highlighted effects they associated with the Volcker Rule that limited proprietary trading activity. The letter 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.". A variety of other regulatory factors have been cited as factors limiting the liquidity for commodity derivatives end-users: Basel constraints that limited balance sheet flexibility, the Federal Reserve proposed stricter rules on bank activity in physical commodities, and public reporting of swap transactions. (See the discussions in Mixon (2018)). Most discussions remain anecdotal in nature.

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

[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*, 5 December 2016.

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 strong evidence that dealer risk appetite is a significant factor affecting the dealer's supply curve for swaps. We also study swap dealers' hedging activity in futures markets. 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. Nonetheless, most dealer futures activity appears to take place in nearby, liquid contracts, supporting the idea that dealers face basis risk in hedging.

We organize our empirical work around predictions from a simple theoretical framework capturing key factors of the swap dealing environment. We model the interaction of risk averse, optimizing producers who desire swap exposure as hedges and risk averse, optimizing dealers who provide the swaps. The dealers hedge their swap exposure in a related futures market, but they face basis risk because the optimal hedge is imperfect. Consistent with our predictions, dealer propensity to provide swap exposure is strongly related to empirical measures of dealer risk appetite. We also find evidence consistent with our prediction that dealers hedged swap exposures more tightly (i.e., took on less basis risk) when balance sheet constraints were tighter (i.e., risk appetite was lower). We therefore conclude that the limits to arbitrage faced by dealers had material effects on the hedging decisions of real economy firms.

The remainder 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 empirical analysis, at first focused on swaps activity and then expanding to incorporate the joint dynamics observed in swaps and futures markets. Section VII concludes.

II. Related Literature

The paper is closely related to the literature focusing on dealer balance sheets and leverage as 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 the prices of financial instruments. Etula (2013) examines the impact of aggregate dealer leverage on commodity price changes and concludes that dealer balance sheets are important for explaining energy price changes. Our work complements this literature in at least two ways. First, our focus on commodity derivatives allows us to control for demand-side shocks, which is a challenging identification problem when examining financial products such as bonds or interest rate swaps. Second, because of the granularity and breadth of the portfolio data employed in this study, we can exploit cross-sectional variation in dealer activities and attributes that remain unexplored in studies utilizing aggregate dealer leverage.

Our work also builds on the findings of Acharya, Lochstoer and Ramadorai (2013). Those authors 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. We incorporate their insights when controlling for the hedging demand of producers, allowing us to identify the link between dealer risk appetite and liquidity provision to hedgers.

Given the crude oil data used in the analysis, our work is also related to the literature specifically focused on that market. Although the markets are large and important, empirical studies of commodity swaps are scant due to data availability. 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 are unable to examine the single commodity swap data or the activities of individual dealers, as we do.

Our paper also contributes to the literature on derivatives pricing and dealer risk management. Our analysis is closely related to the work of Naik and Yadav (2003), 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.Gârleanu, Pesersen and Poteshman (2009) examine the pricing of derivatives when demand pressure matters and 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 models of Vogler (1997) and Viswanathan and Wang (2004). In those papers, multiple 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 representative dealer who first engages with a customer in the swaps market and then manages portfolio risk in a related, public futures market. Those authors focus more on understanding interdealer trading and the implications of a two-tiered market for customer welfare; we take the two-tiered market as given and focus more equilibrium comparative statics for aggregate OTC dealer-client transactions. Further, we test the empirical predictions of the model using an extensive panel of data.

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. 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. We link balance sheet variables and trading VaR measures to dealer liquidity provision in the swaps market and liquidity taking in the futures market. Our empirical focus on quantities transacted also provides a direct connection to the quantities of risk hedged with derivatives by real economy firms.

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 and trends. 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 tend to converge to a net zero level 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.

A number of researchers have concluded that firms using derivatives are often increasing certain types of risk exposures, as opposed to reducing them with 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) 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 significant negative correlation observed between the net futures and net swap positions in the data does 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 decompose the net swap position of dealers 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 exposure increased, resulting in a dealer net long position on the order of 100,000 contracts.

Mixon, Onur and Riggs (2018) examine aggregate 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 commodity 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 significant step forward in understanding the total financial activity of swap dealers in the commodity space.

In Figure 3 we explore the comprehensiveness and variation of business activity through time. 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. We display the three month averages 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 these measures, 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. It is evident that the number of dealers engaged in the single commodity swaps business persistently trended downward after 2012, even as the number with an index swap book remained steady (as further explained in Section V).

In the section that follows, we formulate a simple model that captures these initial observations, and 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 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 Figure 3. Note that we do not explicitly 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.

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. The producers of the commodity are endowed with production Q_0 and hedge 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 substitutes 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 equilibrium quantities traded. For our particular application, we 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. The error structure and parameter values are common knowledge for all participants. 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 trader's demand for futures is denoted by Q^F_{FT}.

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

$$\max_{Q^F_{SD}} E[Q^F_{SD}(f - F) + Q^S_{SD}(k - K)] - \frac{\gamma_{SD}}{2} var(Q^F_{SD}(f - F) + Q^S_{SD}(k - K)). \tag{1}$$

The dealer's optimal futures demand is therefore

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

where Q_{SD}^{S} 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 solves

$$\max_{Q_{FT}^{F}} E[Q_{FT}^{F}(f-F)] - \frac{\gamma_{FT}}{2} var(Q_{FT}^{F}(f-F)) \tag{3}$$

and her equilibrium demand is therefore given by

$$Q_{FT}^{F} = \frac{E[s]-F}{\gamma_{FT}\sigma^2}. \tag{4}$$

The formulation above treats the parameter γ_{FT} as the risk aversion of the futures trader, leading to a futures demand curve with an intercept at $E[s]$ and a slope of $\gamma_{FT}\sigma^2$. Alternatively, we can think of the parameter γ_{FT} as measuring the market impact of futures trading for the dealer (given some level of σ^2). We will use this interpretation when describing the results, as we believe it aids intuition in thinking about swap dealer activity.

As indicated above, the price F clears the market and emerges from the equilibrium condition

$$Q_{SD}^{F} + Q_{FT}^{F} + I = 0. \tag{5}$$

Combining the demand curves and imposing the market clearing condition from Equation (5), the equilibrium futures price is

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

Substituting this price into Equation (2), the equilibrium futures demand by the swap dealer can be expressed as

$$Q^F_{SD} = \rho Q^S_{SD} \left[R - 1\right] - IR, \tag{7}$$

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 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, the portfolio hedge ratio (holding the swaps portfolio constant) is readily linked to changes in dealer risk aversion:

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

and $\frac{\partial R}{\partial \gamma_{SD}} = \frac{-\gamma_{FT}}{(\gamma_{FT}+\gamma_{SD})^2} < 0$.

As γ_{SD} increases and dealer risk appetite declines, the dealer hedge position in futures tends toward the more neutral position $-\rho Q^S_{SD}$ corresponding to the situation when $F = E[s]$. This neutral hedge would also obtain if there were no market impact to 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.

In our empirical analysis, we examine how the futures hedge ratio, for an incremental change in the swap portfolio, evolves over the sample period. For these tests, we take changes in the swap portfolio as exogenous and use regressions to estimate the futures hedge ratio. To interpret the empirical results, it is useful to know the following theoretical results describing how $\frac{\partial Q^F_{SD}}{\partial Q^S_{SD}}$ changes in relation to exogenous variables:

$$\frac{\partial}{\partial \gamma_{SD}}\left[\frac{\partial Q^F_{SD}}{\partial Q^S_{SD}}\right] = \rho\left[\frac{-\gamma_{FT}}{(\gamma_{FT}+\gamma_{SD})^2}\right] < 0 \tag{9}$$

$$\frac{\partial}{\partial I}\left[\frac{\partial Q^F_{SD}}{\partial Q^S_{SD}}\right] = 0 \tag{10}$$

$$\frac{\partial}{\partial \rho}\left[\frac{\partial Q^F_{SD}}{\partial Q^S_{SD}}\right] = \frac{-\gamma_{SD}}{\gamma_{FT}+\gamma_{SD}} < 0 \tag{11}$$

$$\frac{\partial}{\partial \gamma_{FT}}\left[\frac{\partial Q^F_{SD}}{\partial Q^S_{SD}}\right] = \rho\left[\frac{\gamma_{SD}}{(\gamma_{FT}+\gamma_{SD})^2}\right] > 0 \tag{12}$$

The swap dealer's incremental futures hedge ratio is therefore decreasing (i.e., gets tighter) as dealer risk aversion increases, is unaffected by the level of index investment, is decreasing as basis risk for the hedging instrument declines, and is increasing as the market impact of futures trading increases.

B. Equilibrium in the Swap Market

We next solve for the swap market equilibrium and derive empirical predictions relating the size of a dealer's single commodity swap book to his 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 K^* 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 (2).

Specifically, the swap dealer solves

$$\max_{Q^S_{SD}} E[Q^F_{SD}(f-F) + Q^S_{SD}(k-K)] - \frac{\gamma_{SD}}{2} var(Q^S_{SD}(f-F) + Q^S_{SD}(k-K)) \tag{13}$$

and the optimal swap market demand is

$$Q_{SD}^{S} = \frac{E[s] - K}{\gamma_{SD}\sigma^2} - \rho Q_{SD}^{F}. \tag{14}$$

Combining equations (7) and (14) gives $Q_{SD}^{S} = \frac{E[s]-K}{\gamma_{SD}\sigma^2} - \rho\left[\rho Q_{SD}^{S}(R-1) - IR\right]$. Therefore, the equilibrium swap demand by the swap dealer is

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

The producer optimizes his swap demand by solving

$$\max_{Q_P^S} E[Q_0 k + Q_P^S(k-K)] - \frac{\gamma_P}{2} var(Q_0 k + Q_P^S(k-K)) \tag{16}$$

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

$$Q_P^S = \frac{E[s] - K}{\gamma_P\sigma^2} - Q_0. \tag{17}$$

We solve for K^* using the market clearing condition

$$\left[\frac{E[s] - K}{\gamma_{SD}\sigma^2} + \rho IR\right]\left[1 - \rho^2(1-R)\right]^{-1} + \frac{E[s] - K}{\gamma_P\sigma^2} - Q_0 = 0 \tag{18}$$

and find

$$K^* = E[s] - \left[\left[\frac{1}{\gamma_{SD}}\right]\left[1 - \rho^2(1-R)\right]^{-1} + \left[\frac{1}{\gamma_P}\right]\right]^{-1}\sigma^2\left[Q_0 - \rho IR\left[1 - \rho^2(1-R)\right]^{-1}\right] \tag{19}$$

The equilibrium size of the producer's swap book can be found by combining equations (17) and (19). Our testable predictions on the size of swap market are derived from this equilibrium given by

$$Q_P^{S^*} = \frac{-Q_0\left[\frac{1}{\gamma_{SD}}\right] - \rho IR\left[\frac{1}{\gamma_P}\right]}{\left[\frac{1}{\gamma_{SD}}\right] + \left[\frac{1}{\gamma_P}\right]\left[1-\rho^2(1-R)\right]^{-1}}. \tag{20}$$

Using equation (20), we find that several relevant partial derivatives of equilibrium swap demand can be signed unambiguously. 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. Further, $\frac{\partial Q_P^{S^*}}{\partial \rho} > 0$; producers hedge more in equilibrium for higher values of ρ. 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 $E[s]$. In this case, dealers are incentivized to short futures 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 equilibrium swap demand adds to zero ($Q_{SD}^S + Q_P^S = 0$), the partial derivatives for the swap dealer demand are opposite of those for the producer. In the empirical analysis that follows, we examine the size of the swap book from the dealer's perspective. The testable hypotheses therefore includes the effect $\frac{\partial Q_{SD}^{S^*}}{\partial Q_0} > 0$, indicating that dealers are long more swaps if producer endowment increases. The model also predicts that $\frac{\partial Q_{SD}^{S^*}}{\partial I} > 0$, meaning swap dealers are long more swaps swaps if there is more index investment. Further, $\frac{\partial Q_{SD}^{S^*}}{\partial \rho} < 0$ means dealers are long more swaps if the basis risk is lower. We also predict that $\frac{\partial Q_{SD}^{S*}}{\partial \gamma_{SD}} < 0$, or that increased dealer risk aversion acts to reduce the number of swaps held by the dealer.

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. This aggregate 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. This data has not been previously reported or used publicly in aggregate or disaggregated form. 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 also use the size of their non-swap index positions. These non-swap positions include direct futures market holdings by mutual funds, ETFs, or other funds. Similarly, we construct this variable using the raw data used to construct the IID report.

The futures data used in the paper contains position data of daily futures and options on futures 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, by expirations and strike prices of each contract per trader. The span of the futures data matches that of the swaps and starts in December 2007 and ends in October 2015. We aggregate the net value of futures and delta-adjusted options in three contracts linked to WTI: the NYMEX WTI crude oil contract, NYMEX WTI crude oil calendar contract, and the ICE WTI-linked contract. We utilize the month-end positions for dealers who submitted swaps information in the special call; we can therefore match the swaps and futures positions for a given dealer.

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, and Tier 1 Capital Ratio. We also collected Trading Value-at-Risk (VaR) figures for the aggregate trading portfolio, and its interest rate and commodity components, as available. The universe of dealers includes entities that file under both 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.

In the empirical analysis, we also utilize control variables from other data sources. For example, we incorporate the three-month at-the-money WTI crude oil futures volatility and the price of the one-year ahead WTI futures contract (denoted CL13) from Bloomberg. We also include the one-year ahead forecast of U.S. crude oil production, which we construct by summing the 12 nearest monthly forecasts from the Energy Information Administration's baseline model. This provides an ex-ante measure of production that we use to control for anticipated demand. Following Acharya, Lochstoer and Ramadorai (2013), we construct a Zmijewski (1984) z-score as an equally-weighted, trimmed average of z-scores across energy production firms with SIC code 1311. We include publicly traded U.S. firms that were top 50 crude oil producers during the period

2008-2015, and we include the middle 80% of firms with data on a given date in the average. This measure of producer distress is an additional control for producer hedging demand.

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 observations. Visual inspection of aggregate position data in a previous section revealed that dealer net positions changed markedly around the beginning of 2012. Further, the subsamples roughly correspond to different market environments. 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"). As noted by Adrian, Boyarchenko and Shachar (2017), the nature of the rule implementation process led to a variety of measures occurring or being anticipated simultaneously. We present timelines of some key regulatory themes in the Appendix. The timelines demonstrate that regulatory actions in response to the Crisis were not binary events but were, instead, prolonged periods during which multiple regulations in multiple jurisdictions were shaped and implemented. 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.

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 Zmijewski (1984) z-score. There 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

Our empirical analysis contains three key components to map out the channels by which dealer risk appetite affects dealer activity and, ultimately, the provision of hedging services to real economy clients. First, we establish a link between the size of dealer swap books and empirical proxies of risk bearing capacity. We conclude that, holding hedging demand constant, increased risk bearing capacity shifts the dealer supply curve outward. Next, we examine how dealers, given an existing swap book, managed portfolio risk. We explain the time series of an individual dealer's trading VaR with the size of their swap book and the level of market volatility, and we find that dealer VaR exhibited a strong downward trend as risk appetite declined in the sample. This finding is consistent with our prediction that dealers hedge swap liabilities more tightly (e.g., take less basis risk) if risk appetite declines. Finally, we examine the joint dynamics of dealer positions in swaps and futures. We find strong evidence that dealers are intermediating the activities of disparate clienteles with demands that vary over time. We find evidence consistent with our prediction that dealers desire to take on basis risk varied with risk appetite.

A. Relating Liquidity Provision in Swaps to Risk Appetite

In this section, we use panel regressions with dealer fixed effects to understand the link between a dealer's risk appetite and the size of its single commodity WTI swap book. Does a higher than average risk appetite correspond to a larger than average swap book? We use various proxies such as leverage or VaR to equity ratio for dealer risk appetite and generally conclude that the results are qualitatively the same. We conclude that dealer risk bearing capacity is strongly associated with the size of their swap books. After controlling for hedging demand by end-users, we find that increased equity and increased risk appetite is correlated with larger swap exposures for a dealer.

Table II shows the results of our swap book size regression, which strongly confirm the theoretical predictions available from equation (20). Each column in the table presents the results of a panel regression of dealer single commodity swap book size (net long position) explained by dealer risk appetite variables and by demand-side and market control variables. The risk appetite variables are the total equity value for individual dealers and a battery of six empirical proxies for risk appetite. These variables together represent the risk-bearing capacity of the dealer based on its resources and the aggressiveness with which it employs them; the predicted coefficients are positive. We also include two variables explicitly designed to capture variation in the demand for swap exposures by producers: the 12 month forecast for U.S. crude oil production from the Energy Information Administration and a Z-score measuring oil and gas producer financial distress. Both are expected to have positive coefficients. The specifications incorporate other control variables, including the price of one year ahead WTI crude oil futures (CL13), and the WTI 3 month at-the money implied volatility index from Bloomberg. To control for variation in dealer funding conditions, we include the TED spread. Finally, we include the net index investing positions in WTI crude futures. This variable represents the aggregate quantity of WTI futures equivalents due to investors demanding commodity index exposure via index swaps or directly through futures positions. Dealer exposures would be negative, leading to a predicted negative coefficient if an increase in this offsetting exposure is associated with an increase in WTI swaps to hedgers. Independent variables are lagged one month, and t-statistics are in parentheses below coefficients.

The first two rows provide evidence of the importance of risk bearing capacity. Although all specifications include fixed effects, the level of equity for dealers is unambiguously related to the size of client swap books; when dealers are bigger, they exhibit larger swap books. Further, the estimated coefficients for the risk appetite proxies provide support for the prediction that risk appetite is positively related to swap book size at the margin. Of the six empirical proxies, all have the predicted sign and five are significant at the 10% confidence level or higher. The results in the table include several market-level control variables, such as the TED spread. Regression results are quite similar for these risk appetite variables when the regression specification includes both firm and time fixed effects but excludes these market-level control variables. We therefore find that higher than average risk bearing capacity of dealers is strongly associated with a higher than average size of their trading book.

We conclude from the next few rows of the table that the demand for WTI swap exposure is time-varying and predictable. Although coefficents on the EIA forecast of crude oil production have the predicted positive sign in all specifications, none are significant at conventional levels. However, there is stronger evidence that the distress of oil exploration and production firms is linked to their demand for hedging instruments. This proxy for poducer risk aversion is measured by the Zmijewski z-score of large producers in SIC code 1311, following the work of Acharya, Lochstoer and Ramadorai (2013). The coefficient is correctly signed in all instances and is significant at the 10% or higher level in five of the six regressions. Oil producers have a higher propensity to hedge when they exhibit more financial distress.

It is plausible that the price of crude oil would be directly related to the demand for swap exposure by hedgers, even after accounting for the two factors identified above. First, this could be due to 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 and lead to a positive coefficient on the crude price. Second, anecdotal evidence suggests that producers may opportunistically increase hedge positions following price increases.[4] Nonetheless, we find no compelling evidence that the price of crude oil directly affects the demand for swaps. Overall, we conclude that producers demand higher than average hedging exposure when faced with relatively high levels of financial distress, but there is limited evidence that other variables predict the demand for swap exposure.

[4] "American Shale Companies' Rush to Hedge Is Turning the Oil Market Upside Down", Javier Blas, Alex Longley, and Alex Nussbaum, *Bloomberg*, 5 December 2016.

The TED spread and the volatility of crude oil are also included as control variables. If tighter funding conditions lead to a higher TED spread and lower client facilitation business, the TED spread coefficient would be negative. However, the coefficient has a mixture of signs and is never statistically significant. The predicted sign for crude oil volatility is ambiguous, as the model makes no prediction about the variable. One could conjecture that higher volatility leads to more hedging by producers (more swap demand and a positive coefficient) or less swap provision by dealers (less swap supply and a negative coefficient). The coefficient is generally negative in the table, but it also shows up as significantly positive in one case. We do not ascribe any particular significance to these results and view it as a control.

It is useful to provide economic interpretations of the results in Table II using observed variation. For context, note that a relatively large net WTI swap book would be in the low to mid tens of thousands of contracts(see appendix for charts). The distribution in the cross-section is skewed, with a few firms having large books and many having books near zero; the cross-sectional median is generally near zero and the cross-sectional mean fluctuates in the 10,000-15,000 range. Our illustration focuses on the coefficient estimates from the first regression in the table (Risk Appetite Proxy = Assets/Equity = Leverage). The estimated coefficient on dealer equity is 0.24, and one standard deviation in observed equity is roughly USD 24 billion (after removing entity fixed effects from the sample). Therefore, the regression predicts that a dealer's swap book would increase by approximately 5,800 contracts if equity increased one standard deviation. Similarly, a dealer with a one standard deviation increase in leverage is predicted to see a 3,500 contract increase in the size of their swap book (an increase in leverage of 7 multiplied by a coefficient of 501.39). The results confirm the meaningful economic magnitude of changes in risk appetite associated with the size of swap books.

We find that the empirical measures of risk bearing capacity are highly related to the size of the dealer swap books. We conclude that, as dealers are able to bear more risk due to increased equity, the dealer supply curve for swaps shifts outward. Similarly, as dealers became less risk averse - whether measured by increased leverage, increased VaR to equity, increased repo or short-term borrowing, or a lower Tier 1 capital ratio - the dealer supply curve shifts outward.

B. Explaining Variation in Dealer Portfolio Risk

The previous section related risk bearing capacity to a dealer's swap exposure. Next, we take swap exposure as given and explain the dealer's overall portfolio risk. The theoretical prediction is that the risk of dealer portfolios is positively correlated with dealer risk appetite (from equation (8)). Broadly speaking, dealer risk appetite generally declined over the sample, and therefore the testable prediction is that dealer derivatives portfolio risk (per unit of swap exposure) measurably declined.

The columns in Table III display regression estimates for specifications with dealer commodity trading VaR as the dependent variable. Each of the regressions are estimated using lagged independent variables as instruments for the regression, and the table shows variations with and without dealer fixed effects. The results in column (1) suggest that VaR strongly varies in the cross-section and time series with both the general level of crude oil volatility and with the size of dealer swap books. A linear time trend is also highly significant, consistent with dealers persistently reducing trading VaR substantially over the sample. The specification in column (2) includes dealer fixed effects; consequently, the significance on individual dealer swap book size disappears. Nonetheless, the downward trend in otherwise unexplained dealer VaR remains significant. Columns (3) and (4) display specifications with lagged VaR levels as explanatory variables. When dealer fixed effects are allowed in the specification in column (4), the downward trend is highly significant although the level of swap book size and the level of market volatility are insignificant.

The results in Table III strongly support the conclusion that dealers hedged their swap exposures more tightly over the sample period, consistent with anecdotal discussion and the empirical predictions described earlier. Note carefully that the conclusion is not dependent on dealer swap books getting smaller over time; in aggregate, WTI swap books actually increased in magnitude over the sample. Simultaneous with measures of dealer risk appetite declining, dealers took on less unhedged risk over the sample. Therefore, the conclusion is that there was a decline in dealer risk taking, per unit of swap exposure. By what mechanism did dealers reduce their portfolio risk, given their swap book position? In the next section, we explicitly incorporate dealer futures positions in order to understand this result more completely.

C. Risk Management of Dealer Portfolios

The strategy in this subsection is first to quantify a general description of dealer risk management of swap exposures, which has not been done heretofore, and then to provide results on the time variation of risk management. We begin by focusing on aggregate dealer portfolios. The initial analysis presents average levels of dealer futures and option hedge portfolios, broken out by tenor. This novel view of dealer portfolios illustrates the intermediation activities provided by dealers: the portfolios are net long for short-dated instruments and net short for instruments further out the curve. This mimics the dominance of net long swap exposure of index investors at nearby tenors, and the net short positions of hedgers at all other horizons. We go on to estimate models relating the change in the futures and options portfolios to the change in the swap portfolios held by dealers, and we estimate the model over various futures tenors. We conclude that the majority of variation in dealer hedging occurs at the shortest tenors, consistent with intuition. Finally, we provide evidence on the distribution of hedging response coefficients for individual dealers. We find that the coefficients vary in the cross-section, and we provide evidence that the distribution of the coefficients narrowed nearer tighter hedge ratios in the latter part of the sample.

We begin with descriptive statistics on aggregate dealer hedge portfolios. We established in the prior subsection that dealers reduced the unhedged risks in their portfolio over the sample period. One way that dealers might have is that dealers simply began to trade futures hedges that more closely matched the long-dated tenor and risk exposure of swaps, and that swap exposures demanded by clients did not change. This seems unlikely if customers exhibit elastic demand for swap exposure and dealers tend to use near-dated, liquid futures to hedge swaps. Discussions with market participants suggest that long-dated swap exposures became significantly more expensive post-Crisis, and that hedges tended to be for shorter tenors than they had been. A shortening of the tenors means that dealers would take on less basis risk, even if the tenor of their futures hedges did not substantially change. We conjecture that, in equilibrium, swap tenors shortened post-Crisis. In terms of the model, we can think of this as an increase in ρ, the correlation parameter.

Ideally, we would examine the distribution of both swap and futures portfolio exposures, by tenor. Unfortunately, swap exposures are available only in aggregate; detailed data on the tenor of the swap portfolios was not reported. Nonetheless, we are able to examine highly granular data on the futures positions held by dealers. Information on the breakdown of futures portfolios by futures or option contracts, as well as the exact composition of contracts by tenor, is detailed in Table IV. While it is suggested anecdotally that dealers prefer to hedge positions with the most liquid, near-dated futures contracts, there has been little quantitative evidence to support the intuition. The table presents 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 separately and together; option exposures are presented in delta-adjusted futures equivalents. 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.

There are clear patterns that emerge from examination of Table IV. From Panel A, we observe that aggregate net futures and options positions to be positive in period 1 but they drop to a large negative value in period 2, consistent with the time series evidence shown in Figure 1. Despite this level shift affecting most tenor buckets, net exposure in the nearby tenor bucket remain positive and positions in the rest of the tenor buckets remain negative across both periods. We interpret this observation in the context of Figure 2, which showed that net index positions held by dealers shrank in the latter part of the sample. We would expect that near-dated, long futures held as hedges for these products would decline towards zero, which we observe in the futures data. Further, the table shows larger short positions held in longer tenors, which correspond to the net increase in longer-dated, WTI-specific swaps displayed in Figure 2. Hence, the table provides support for the idea that dealers intermediate two very different types of customer demand: short-dated demand for long exposure via index swaps and longer-dated demand for short exposure for hedgers.

We make two other observations on the information in the table. First, we note that net option portfolios held by dealers tend to be small (roughly 5-10% in size) compared to futures net positions for a given tenor. This appears consistent with intuition that futures are the liquid hedge instrument. The major observation we make for Panel B is that there is a substantial drop in open positions held by dealers between period 1 and period 2, with the largest decline in the longer-dated tenor buckets. While the open positions for tenors with less than two years to go fell by about a quarter between the first and second parts of the sample, open positions with tenors greater than two years fell by roughly half. This evidence is consistent with the conjecture made above that the tenor of swap exposures declined in the latter part of the sample, despite the increase in net swap exposure demanded by hedgers.

We next provide analysis relating dealer hedge portfolios, by tenor, to the swap book. We begin with regressions at the aggregate level, summing over all 26 dealers in the sample. We regress the 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 estimate regressions separately for the five different tenor buckets. More formally, we estimate

$$\Delta F_t^M = \alpha + \beta \Delta S_t^I + \gamma \Delta S_t^{SCS} + \varepsilon_t, \tag{21}$$

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.

Table V corroborates 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. Pirrong (1997) estimates variance-minimizing hedge ratios for long-dated swaps hedged with short-dated futures; he finds that the hedge ratios are significantly below one-to-one. In particular, he suggests that a 13-15 month WTI swap would be well hedged using a ratio of 0.5 to 0.6. These lower values reflect the imperfect correlation between short- and long-dated contracts, as well as the generally lower volatility of long-dated contracts. The regression-implied hedge ratios presented in the table appear consistent with swaps books covering relatively long-dated swaps hedged largely with short-dated futures.

The estimates in Table V are economically significant as well. For example, a one standard deviation increase in the net WTI swap exposure due to commodity index swaps is associated with an increase in the futures hedge that is around 15,000 contracts. Similarly, a one standard deviation increase in the net WTI swap exposure due to single commodity swaps is associated with an increase of roughly 19,000 futures contracts. These numbers corresponds to 4-5% of daily trading volume in the WTI futures during our sample.

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

$$\Delta F_{it} = \alpha_i + \beta \Delta S_{it}^{I} + \gamma \Delta S_{it}^{SCS} + \varepsilon_{it}, \tag{22}$$

where ΔS_{it}^{I} is the change in dealer i's net WTI swap exposure due to commodity index swaps, and Δ_{it}^{SCS} 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 regressions fit well according to the R^2. The magnitudes of the coefficients are 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 are for regressions that allow the hedge coefficients to vary 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. Similarly, if the equilibrium swaps transacted in the second period aligned more closely with the available futures hedge, the coefficients would be different across subperiods. The evidence is consistent with these predictions. 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:

$$\Delta F_{it} = \alpha_i + \beta_{i,1} \Delta S^I_{it} D_1 + \beta_{i,2} \Delta S^I_{it} D_2 + \gamma^I_{i,1} \Delta^{SCS}_{it} D_1 + \gamma^{SCS}_{i,2} \Delta^{SCS}_{it} D_2 + \varepsilon_{it}, \tag{23}$$

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. For the regressions presented here, we choose the same breakpoint identified in the earlier part of the paper that splits the sample roughly in half and also corresponds to the apparent shift in market environment.[5]

We refer to equations (9) to (12) to interpret our results on the change in hedging coefficients across subperiods. The model suggests that a decline in the incremental hedge ratio could be caused by an increase in dealer risk aversion, an increase in the correlation ρ, or a decrease in the futures trading impact γ_{FT}. Because it appears unlikely that the price impact of futures trades has diminished post-Crisis, we focus on the first

[5]We have executed this analysis with other breakpoints, and the results are qualitatively the same. In particular, we tried a breakpoint at the beginning of 2013, when public reporting of swap trades began, but the results are quite similar to the ones presented here.

two factors. Our interpretation is that the apparent decline in hedging coefficients is directly and indirectly due to decreases in dealer risk appetite.

The intuition linking real world changes in the correlation factor to the hedge ratio are more subtle than that for risk aversion. For a given tenor and quantity of swaps (and hence a given value of actual correlation), increased risk aversion would cause dealers to sell more futures against a given swap, driving down the equilibrium strike price. (I.e., the dealer supply curve shifts.) In practice, hedgers might substitute shorter-dated swaps in order to hedge a given quantity at higher strike prices than otherwise (or hedge more production at a given price than otherwise). That is, producers might respond to an increase in dealer risk aversion by choosing swaps with a shorter tenor in order to achieve better hedge prices. Anecdotal discussions with market participants suggest they did just that in the latter part of the sample.

To understand why, consider that dealers tend to hedge swaps with short-dated futures, and therefore the hedge is likely to be more effective for shorter-dated swaps rather than longer-dated ones. While the model does not allow for different tenor swaps, the implication is that dealers would typically be hedging shorter-dated swaps in the latter part of the sample. Hence, the interpretation in the model is that the correlation between the swap and futures payoffs would be higher in that part of the sample (e.g., dealers might be hedging a one-year swap with nearby futures instead of a two-year swap with nearby futures). A change in the correlation parameter would reflect this outside-the-model shift, as opposed to a real shift in the correlation structure of prices.

Finally, we provide evidence that the estimated hedge coefficients for individual dealers varied systematically across the two subperiods. We estimated cross-sectional regressions of the change in dealer i's estimated slope coefficient between periods 1 and 2 on the estimated value of the coefficient for period 1. These regressions provide a simple test of whether the estimated coefficients varied randomly or if the change depended on the level in the early part of the sample. The first regression is for index hedging coefficients and generates the following estimates:

$$\beta_{i,2} - \beta_{i,1} = \underset{(-4.98)}{-1.00} - \underset{(-5.61)}{1.10}\ \beta_{i,1} + error, \quad R^2 = 65.5\%, \tag{24}$$

with t-statistics reported in parentheses below the estimated parameters. Consistent with our previous discussion, the results show that the hedge coefficients for a given dealer tended toward -1 in the latter part of the sample. Roughly, dealers with estimated hedge coefficients between zero and -1 in the first part of the sample exhibited somewhat lower estimates in the latter part of the sample, and dealers with estimated coefficients lower than -1 exhibited somewhat higher estimates.

The second cross-sectional regression is for single commodity swap hedging coefficients and generates the following estimates:

$$\gamma_{i,2} - \gamma_{i,1} = \underset{(-2.54)}{-0.43} - \underset{(-2.85)}{0.76}\ \gamma_{i,1} + error, \quad R^2 = 33.6\%. \tag{25}$$

As with the index coefficients, dealers with extreme estimates in the first part of the sample exhibit less extreme values in the second part. If the dealer coefficient was lower than approximately -0.5 in the first part of the sample, the second period estimate was generally higher and closer to -0.5. Dealers with estimated hedging coefficients between zero and -0.5 in the first period generally experienced lower values in the second part of the sample. We view these results as quite consistent with the model prediction that hedge ratios become tighter as risk aversion increases.

VII. Conclusion

Dealers participate in both the swap market and in listed derivatives markets and provide intermediation services to different clienteles. Recent research suggests that their role as intermediaries has significant implications for asset pricing. Our contribution is to provide systematic evidence explaining a) variation in dealers' propensity to provide intermediation services, and b) variation in how they manage the risk of providing these services.

We characterize the liquidity provision and risk management of swap dealers using a novel panel of swap positions and related futures positions. We further relate these behaviors to fundamental, balance sheet data for the individual dealers. We explore the channels through which variation in dealer risk appetite impacts dealer activity, and we identify basis risk as a key factor. Dealers provide customized swap contracts to real economy firms who want to hedge, but the dealers subsequently take on basis risk due to their use of standard, liquid contracts to offset their risk. Dealer propensity to provide swap exposure, and therefore the amount of hedging executed by real economy firms in equilibrium, thus varies with dealer appetite for risk.

References

Acharya, Viral, Lars Lochstoer, and Tarun Ramadorai. 2013. "Limits to Arbitrage and Hedging: Evidence from Commodity Markets." *Journal of Financial Economics*, 109(2): 441–465.

Adrian, Tobias, and Hyun Song Shin. 2010. "Liquidity and Leverage." *Journal of Financial Intermediation*, 19: 418–437.

Adrian, Tobias, Erkko Etula, and Tyler Muir. 2014. "Financial Intermediaries and the Cross-Section of Asset Returns." *Journal of Finance*, 69(6): 2557–2596.

Adrian, Tobias, Nina Boyarchenko, and Or Shachar. 2017. "Dealer Balance Sheets and Bond Liquidity Provision." *Journal of Monetary Economics*, 89: 92–109.

Begenau, Juliane, Monika Piazzesi, and Martin Schneider. 2015. "Banks' Risk Exposures."

Brunnermeier, Markus K., and Yuliy Sannikov. 2014. "A Macroeconomic Model with a Financial Sector." *American Economic Review*, 104(2): 379–421.

Chernenko, Sergey, and Michael Faulkender. 2011. "The Two Sides of Derivatives Usage: Hedging and Speculating with Interest Rate Swaps." *Journal of Financial and Quantitative Analysis*, 46: 1727–54.

Commodity Futures Trading Commission. 2008. "Staff Report on Commodity Swap Dealers and Index Traders with Commission Recommendations."

Etula, Erko. 2013. "Broker-Dealer Risk Appetite and Commodity Returns." *Journal of Financial Econometrics*, 11(3): 486–521.

Froot, Kenneth A., and Jeremy Stein. 1998. "Risk Management, Capital Budgeting and Capital Structure Policy for Financial Institutions: An Integrated Approach." *Journal of Financial Economics*, 47: 55–82.

Gârleanu, Nicolae, Lasse Heje Pesersen, and Allen M. Poteshman. 2009. "Demand-Based Option Pricing." *Review of Financial Studies*, 22(10): 4259–4299.

He, Zhiguo, and Arvind Krishnamurthy. 2013. "Intermediary Asset Pricing." *American Economic Review*, 103(2): 732–770.

He, Zhiguo, Bryan Kelly, and Asaf Manela. 2017. "Intermediary Asset Pricing: New Evidence from Many Asset Classes." *Journal of Financial Economics*, 126(1): 1–35.

Irwin, Scott H., and Dwight R. Sanders. 2012. "Testing the Masters Hypothesis in Commodity Futures Markets." *Energy Economics*, 34(1): 256–269.

Kellett, Jack. 2004. "Energy Swaps." In *Managing Energy Price Risk: The New Challenges and Solutions.* , ed. Vincent Kaminski, 9–44. London:Risk Books.

Mixon, Scott. 2018. "Research Issues in Commodities and Commodity Derivatives." In *Commodities: Markets, Performance, and Strategies.* , ed. H. Kent Baker, Greg Filbeck and Jeffrey H. Harris, 534–554. New York, NY:Oxford University Press.

Mixon, Scott, Esen Onur, and Lynn Riggs. 2018. "Integrating Swaps and Futures: A New Direction for Commodity Research." *Journal of Commodity Markets*, 10(1): 3–21.

Naik, Narayan Y., and Pradeep Yadav. 2003. "Risk Management with Derivatives by Dealers and Market Quality in Government Bond Markets." *Journal of Finance*, 58(5): 1873–1904.

Pirrong, Craig. 1997. "Metallgesellschaft: A Prudent Hedger Ruined, or a Wildcatter on NYMEX?" *Journal of Futures Markets*, 17: 543–78.

Stulz, René. 1996. "Rethinking Risk Management." *Journal of Applied Corporate Finance*, 9: 8–24.

Viswanathan, S., and James D. Wang. 2004. "Inter-Dealer Trading in Financial Markets." *Journal of Business*, 77(4): 987–1040.

Vogler, Karl-Hubert. 1997. "Risk Allocation and Interdealer Trading." *European Economic Review*, 41: 1615–1634.

Zmijewski, Mark E. 1984. "Methodological Issues Related to the Estimation of Financial Distress Prediction Models." *Journal of Accounting Research*, 22: 59–82.

Table I: Summary Statistics - Average Levels

Panel A displays aggregate Dealer swap positions; values are in thousands of delta-adjusted futures equivalents. Panel B contains WTI average prices for 12 month ahead futures (CL13), 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: Market Variables							
Sample Period	**WTI Futures Price**	**WTI Implied Vol**	**Forecast Production**	**Producer Z-Score**	**Non-Swap Index**	**TED Spread**	
2007/12 - 2011/12	88.78	39.87	1,974	-2.73	118,067	0.67	
2012/1 - 2015/10	84.34	27.35	2,940	-2.37	134,721	0.25	
Full Sample	86.63	33.81	2,442	-2.56	126,305	0.47	
Panel C: Individual Dealer Fundamentals							
Sample Period	**Leverage**	**Aggregate VaR**	**Commodity VaR**	**Equity**	**ST Borrow**	**Repo**	**Tier 1 Ratio**
2007/12 - 2011/12	24.05	107.11	18.23	68,577	336,499	121,346	11.5
2012/1 - 2015/10	18.91	49.28	9.11	83,780	240,115	99,978	13.7
Full Sample	21.54	79.26	13.67	76,001	289,120	110,980	12.6

Table II: Relating Risk Appetite to Swap Book Size

The table presents estimated coefficients for panel regressions of the net size of dealer WTI single commodity swap books on dealer-specific risk appetite variables (level of dealer equity and one of the six risk appetite proxies listed in the table header) and demand-side or market control variables (U.S. Crude Oil Production Forecast from the U.S. Energy Information Agency, Sector Z-Score for Oil Producers, price of one year ahead WTI crude oil futures, the TED spread, the WTI 3 month at-the money implied volatility index, and the total quantity of WTI futures equivalents due to commodity index investing). Observed independent variables are lagged one month. T-statistics are in parentheses below coefficients; standard errors are clustered by dealer and time period. Statistical significance at the 10%, 5%, and 1% levels are indicated by the symbols *, **, and ***, respectively. 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
Risk Appetite variables:						
Equity	0.24***	0.24***	0.30***	0.26***	0.27***	0.26***
	(2.83)	(2.97)	(5.51)	(3.32)	(2.99)	(2.33)
Risk Appetite Proxy	501.39**	6.54**	46.91***	1.45*	3.50*	−338.57
	(2.18)	(2.30)	(3.59)	(1.94)	(1.81)	(−1.02)
Demand-side & market controls:						
Production Forecast	3.61	8.19	3.38	3.25	2.31	2.50
	(0.84)	(1.44)	(0.81)	(0.82)	(0.55)	(0.52)
Producer Z-Score	3,286.51*	2,747.21	4,026.48*	4,266.84**	4,850.15**	4,479.35**
	(1.84)	(1.60)	(1.69)	(2.13)	(1.97)	(2.02)
WTI Futures Price	18.30	70.12	−11.16	46.02	13.18	83.82
	(0.19)	(0.79)	(−0.10)	(0.46)	(0.12)	(0.88)
TED Spread	1168.46	1,980.36	−1370.32	341.23	1,401.09	−2,069.01
	(0.44)	(0.76)	(−0.44)	(0.12)	(0.40)	(−0.89)
WTI Implied Vol	−162.55**	−184.82*	−135.13	−79.12	−113.40	81.57*
	(−2.12)	(−1.82)	(−1.34)	(−1.22)	(−1.37)	(1.65)
Index Investing	−6.80	−4.92	−22.96	−10.41	−15.15	−27.86
	(−0.34)	(−0.21)	(−0.92)	(−0.51)	(−0.70)	(−1.30)
Dealer Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R^2 (%)	68.2	68.9	71.6	68.2	67.1	72.1
# obs	1577	1517	1357	1565	1416	1497
# Dealers	20	19	18	20	18	19

Table III: Dealer Trading VaR, Conditioned on Size of the WTI Swap Book

This table displays panel regressions of the log of individual dealer commodity trading VaR on the log dollar volatility of WTI (annualized implied volatility multiplied by the futures price, in thousands of USD), log size of the dealer's WTI single commodity swap book (in thousands of contracts), lagged log commodity VaR, and trend. Regressions are estimated using a constant and lagged values of the independent variables as instruments. Dealer fixed effects are included in designated specifications. T-statistics are in parentheses below coefficients; standard errors are clustered by dealer and time period. Statistical significance at the 10%, 5%, and 1% levels are indicated by the symbols *, **, and ***, respectively. Data are monthly and span the period December 2007 to October 2015.

Independent Variables	**Dependent Variable: Log of Commodity VaR**			
	(1)	(2)	(3)	(4)
Constant	1.926***		0.014	
	(4.016)		(0.262)	
Log Dollar Volatility	0.458***	0.341***	0.001	0.021
	(5.811)	(3.452)	(0.034)	(0.567)
Log Size of WTI Swap Book	0.221**	0.026	0.006**	0.005
	(2.015)	(0.940)	(2.224)	(0.694)
Lagged Log VaR			0.988***	0.923***
			(426.388)	(57.355)
Trend	−0.014***	−0.012***	−0.000	−0.001**
	(−4.184)	(−3.968)	(−0.873)	(−2.559)
Dealer Fixed Effects	No	Yes	No	Yes
# obs	1213	1213	1213	1213
# Dealers	18	18	18	18

Table IV: Average Aggregate Futures Positions of Dealers, by Tenor

This table displays the aggregate futures and delta-adjusted option positions for the 26 dealers. 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

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. 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. T-statistics are in parentheses below coefficients; standard errors are clustered by dealer and time period. Statistical significance at the 10%, 5%, and 1% levels are indicated by the symbols *, **, and ***, respectively.

	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

The table presents summaries of time series regressions for each of the individual dealers in the sample. Quartiles of the observed distribution for coefficients, t-statistics, and R^2 for a given specification are presented. Panel A summarizes the coefficients of the baseline regressions:

$$\Delta F_{it} = \alpha_i + \beta \Delta S_{it}^{I} + \gamma \Delta S_{it}^{SCS} + \varepsilon_{it},$$

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

Panel B summarizes the coefficients of regressions where the slopes are allowed to differ across the two sub-periods:

$$\Delta F_{it} = \alpha_i + \beta_{i,1} \Delta S_{it}^{I} D_1 + \beta_{i,2} \Delta S_{it}^{I} D_2 + \gamma_{i,1} \Delta_{it}^{SCS} D_1 + \gamma_{i,2} \Delta_{it}^{SCS} D_2 + \varepsilon_{it},$$

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.

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	

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.

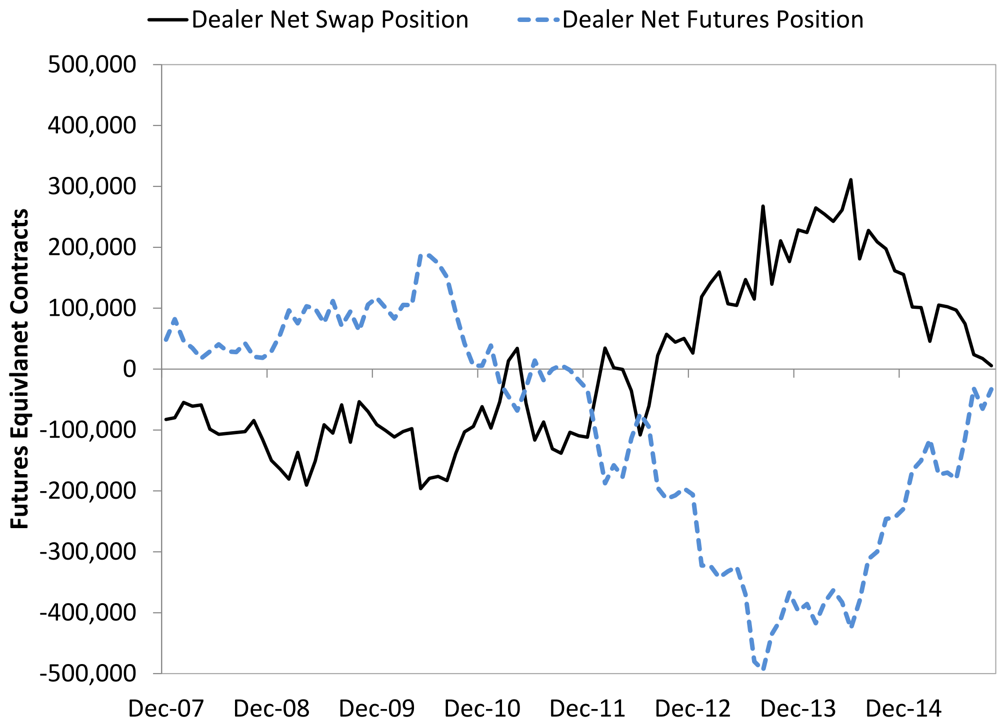


Figure 2: Dealer WTI Exposure due to Index and Single Commodity Swaps

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.

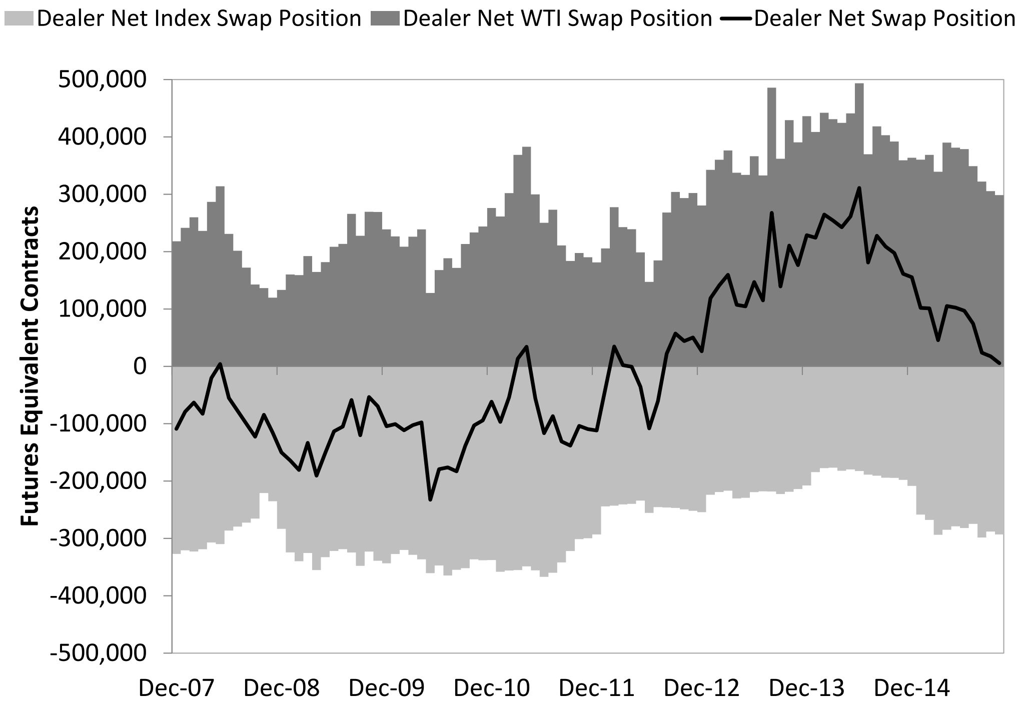
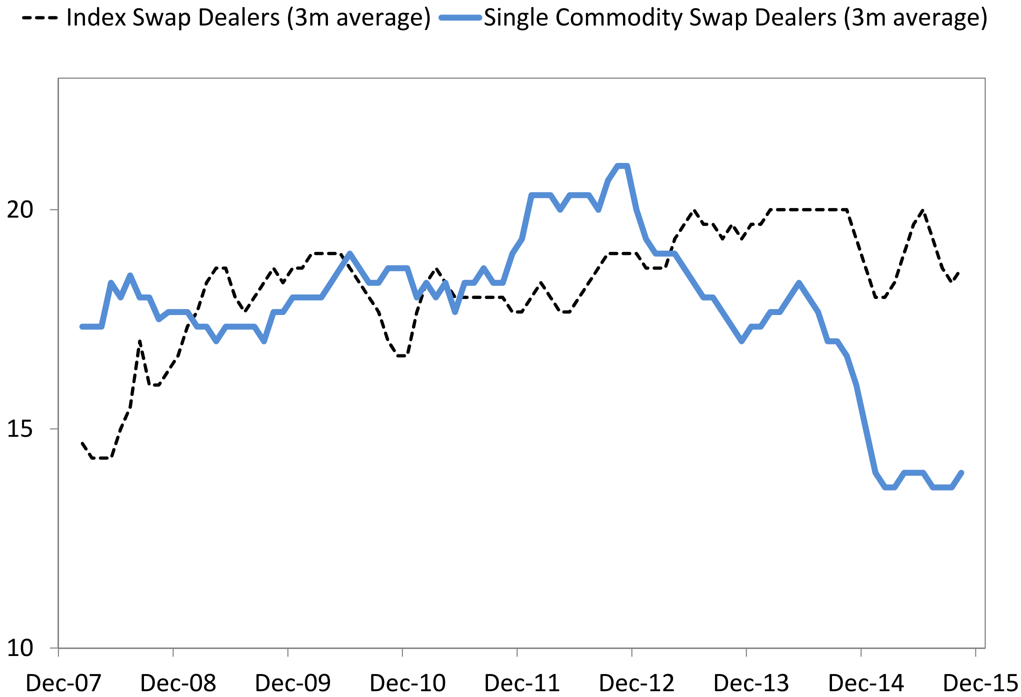


Figure 3: Number of Swap Dealers

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.



Appendices

A. Regulatory Timelines

Volcker Rule

- 21 July 2010: Dodd-Frank Wall Street Reform and Consumer Protection Act enacted. Section 619 ("the Volcker Rule") generally prohibits banking entities from engaging in proprietary trading. The Financial Stability Oversight Council (FSOC) is required to make a study and recommendations on implementation of the Volcker Rule. Restrictions apply by 21 July 2014 unless extended by the Board of Governors.[6]

- 6 October 2010: FSOC requests public comment to inform the required study.[7]

- 18 January 2011: FSOC approves and releases a study formalizing recommendations for implementing the Volcker Rule. Agencies are directed to adopt implementing rules not later than nine months after completion of the FSOC study.

- 7 November 2011: Board of Governors, Federal Deposit Insurance Corporation (FDIC), Office of the Comptroller of the Currency (OCC), and Securities and Exchange Commission (SEC) publish a proposal for implementing the Volcker Rule.[8]

- 14 February 2012: Commodity Futures Trading Commission (CFTC) publishes a proposal implementing the Volcker Rule.[9]

- 10 December 2013: Board of Governors extends the conformance period for the Volcker Rule to 21 July 2015.[10]

- 31 January 2014: Board of Governors, FDIC, OCC, and SEC publish final rule, effective 1 April 2014.[11] CFTC also publishes final rule.[12]

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[6] Dodd-Frank Wall Street Reform and Consumer Protection Act, Public Law 111-203, 124 Stat. 1376.

[7] 75 FR 61758–61760.

[8] 76 FR 68846–68972.

[9] 77 FR 8332–8447.

[10] Order Approving Extension of Conformance Period, available at http://www.federalreserve.gov/newsevents/press/bcreg/bcreg20131210b1.pdf.

[11] 79 FR 5535–5806.

[12] 79 FR 5808–6075.

Position Limits

- 27 November 2007: CFTC publishes a proposed rule to provide an exemption for "risk management positions" in futures contracts, including those tracking commodity indexes; these positions would be exempt from Federal speculative position limits.[13]
- 6 June 2008: CFTC wihdraws proposal for "risk management exemptions".[14]
- September 2008: CFTC staff issues "Staff Report on Commodity Swap Dealers and Index Traders with Commission Recommendations".
- 19 August 2009: CFTC withdraws no-action letters providing relief from Federal position limits on futures to two Commodity Pool Operators/Commodity Trading Advisors.[15]
- 26 January 2010: CFTC publishes proposal to implement futures position limits on certain energy commodities.[16]
- 21 July 2010: Dodd-Frank Wall Street Reform and Consumer Protection Act enacted. Section 737 directs the CFTC regarding commodity futures and economically equivalent swaps.[17]
- 18 August 2010: CFTC withdraws proposal to implement position limits on futures for certain energy commodities.[18]
- 26 January 2011: CFTC publishes proposal to implement position limits for futures and swaps on 28 physical commodities.[19]
- 18 November 2011: CFTC publishes final rule establishing position limits for futures and swaps on 28 physical commodities. Initial limits to take effect on 12 October 2012. [20]
- 2 December 2011: ISDA files suit challenging CFTC final rule on position limits.[21]
- 28 September 2012: CFTC's position limits rule vacated by District Court.[22]

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[13] 72 FR 66097–66103.
[14] 73 FR 32261.
[15] https://www.cftc.gov/PressRoom/PressReleases/pr5695-09.
[16] 75 FR 4144–4172.
[17] Dodd-Frank Wall Street Reform and Consumer Protection Act, Public Law 111-203, 124 Stat. 1376.
[18] 75 FR 50950.
[19] 76 FR 4752–4777.
[20] 76 FR 71626–71706.
[21] International Swaps and Derivatives Association v. CFTC, No.1:11-cv-2146 (D.D.C.); International Swaps and Derivatives Association v. CFTC, No. 11-1469 (D.C. Cir.)
[22] ISDA v. CFTC, 887 F. Supp. 2d 259 (D.D.C. 2012).

- 12 December 2013: CFTC proposes futures and swaps position limits on 28 physical commodities.[23]

Basel III

- 7 September 2009: The Group of Central Bank Governors and Heads of Supervision, the oversight body of the Basel Committee on Banking Supervision (BCBS), agree to modify regulations regarding banking sector capital, leverage, counterparty risk, and liquidity.[24]
- 17 December 2009: BCBS publishes consultative document regarding the implementation of reforms.[25]
- 16 December 2010: BCBS publishes rules text for Liquidity Coverage Ratio.[26]
- 16 December 2010: BCBS publishes rules text for Basel III reforms.[27]
- 15 May 2012: Council of the European Union agree to a general approach on Basel III implementation.[28]
- 1 June 2011: BCBS publishes modified rules text for Basel III reforms, reducing the weight applied to CCC-rated counterparties from 18% to 10% under the standardized credit valuation adjustment (CVA).[29]
- 30 August 2012: Board of Governors, FDIC, and OCC publish proposed rules.[30]
- 7 January 2013: BCBS publishes final text of Liquidity Coverage Ratio.[31]
- 26 June 2013: BCBS publishes consultative document on leverage ratio framework.[32]

[23] 78 FR 75680–75842.
[24] "Comprehensive Response to the Global Banking Crisis", at https://www.bis.org/press/p090907.htm.
[25] "Strengthening the Resilience of the Banking Sector", at https://www.bis.org/publ/bcbs164.pdf.
[26] "Basel III: International framework for liquidity risk measurement, standards and monitoring',' at https://www.bis.org/publ/bcbs188.pdf.
[27] "Basel III: A global regulatory framework for more resilient banks and banking systems", at https://www.bis.org/publ/bcbs189_dec2010.pdf.
[28] "Bank capital rules: General approach agreed ahead of talks with Parliament", at https://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/ecofin/130264.pdf.
[29] "Basel III: A global regulatory framework for more resilient banks and banking systems - revised version June 2011", at https://www.bis.org/publ/bcbs189.htm.
[30] 77 FR 52888–52975; 77 FR 52978–53057; 77 FR 52792–52886.
[31] "Basel III: The Liquidity Coverage Ratio and liquidity risk monitoring tools", at https://www.bis.org/publ/bcbs238.pdf.
[32] ""Basel III leverage ratio framework and disclosure requirements - consultative document", at https://www.bis.org/publ/bcbs251.pdf.

- 26 June 2013: European Parliament and the Council adopt Capital Requirement Regulation (CRR) and Capital Requirement Directive IV (CRD IV), to take effect on 1 January 2014. The CRR is a directly applicable Regulation that applies to banks and their supervisors in the EU. The CRD IV requires Member States to enact legislation conforming to the requirements of the Directive.[33]

- 19 July 2013: BCBS publishes consultative document on liquidity coverage ratio.[34]

- 20 August 2013: Board of Governors, FDIC, and OCC publish proposal for supplemental leverage ratio.[35]

- 10 September 2013: FDIC publishes interim final rule implementing Basel III reforms.[36]

- 11 October 2013: Board of Governors and OCC publish final rule implementing Basel III reforms.[37]

- 29 November 2013: Board of Governors, FDIC, and OCC publish proposal implementing liquidity coverage ratio.[38]

- 12 January 2014: BCBS publishes final text on liquidity coverage ratio.[39]

- 14 April 2014: FDIC publishes final rule implementing Basel III reforms.[40]

- 1 May 2014: Board of Governors, FDIC, and OCC publish final rule implementing supplemental leverage ratio.[41]

- 1 May 2014: Board of Governors, FDIC, and OCC publish proposal revising supplemental leverage ratio calculation.[42]

- 26 September 2014: Board of Governors, FDIC, and OCC publish final rule revising supplemental leverage ratio calculation.[43]

[33] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:176:0001:0337:EN:PDF; http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:321:0006:0342:EN:PDF; http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:176:0338:0436:EN:PDF; http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:208:0073:0073:EN:PDF.

[34] "Liquidity coverage ratio disclosure standards", at https://www.bis.org/publ/bcbs259.pdf.

[35] 78 FR 51101–51115.

[36] 78 FR 55340–55598.

[37] 78 FR 62018–62291.

[38] 78 FR 71818–71868.

[39] "Basel III leverage ratio framework and disclosure requirements", at https://www.bis.org/publ/bcbs270.pdf.

[40] 79 FR 20754–20761.

[41] 79 FR 24528–24541.

[42] 79 FR 24596–24618.

[43] 79 FR 57725–57751.

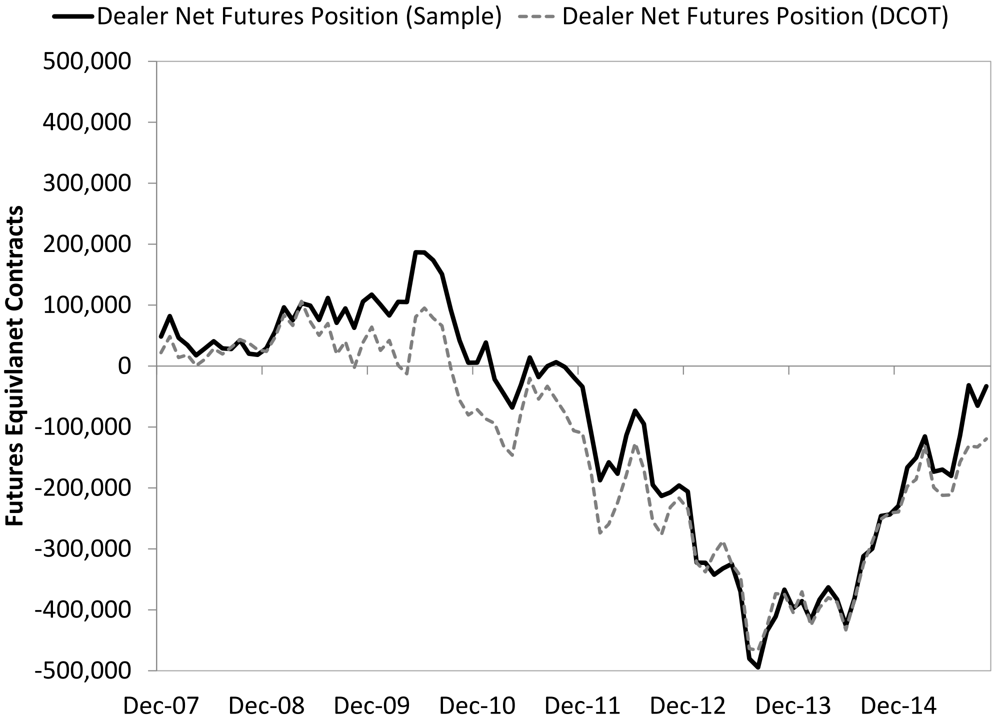
B. Additional Data Analysis

Comparison of Sample Data and Publicly Available Data

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

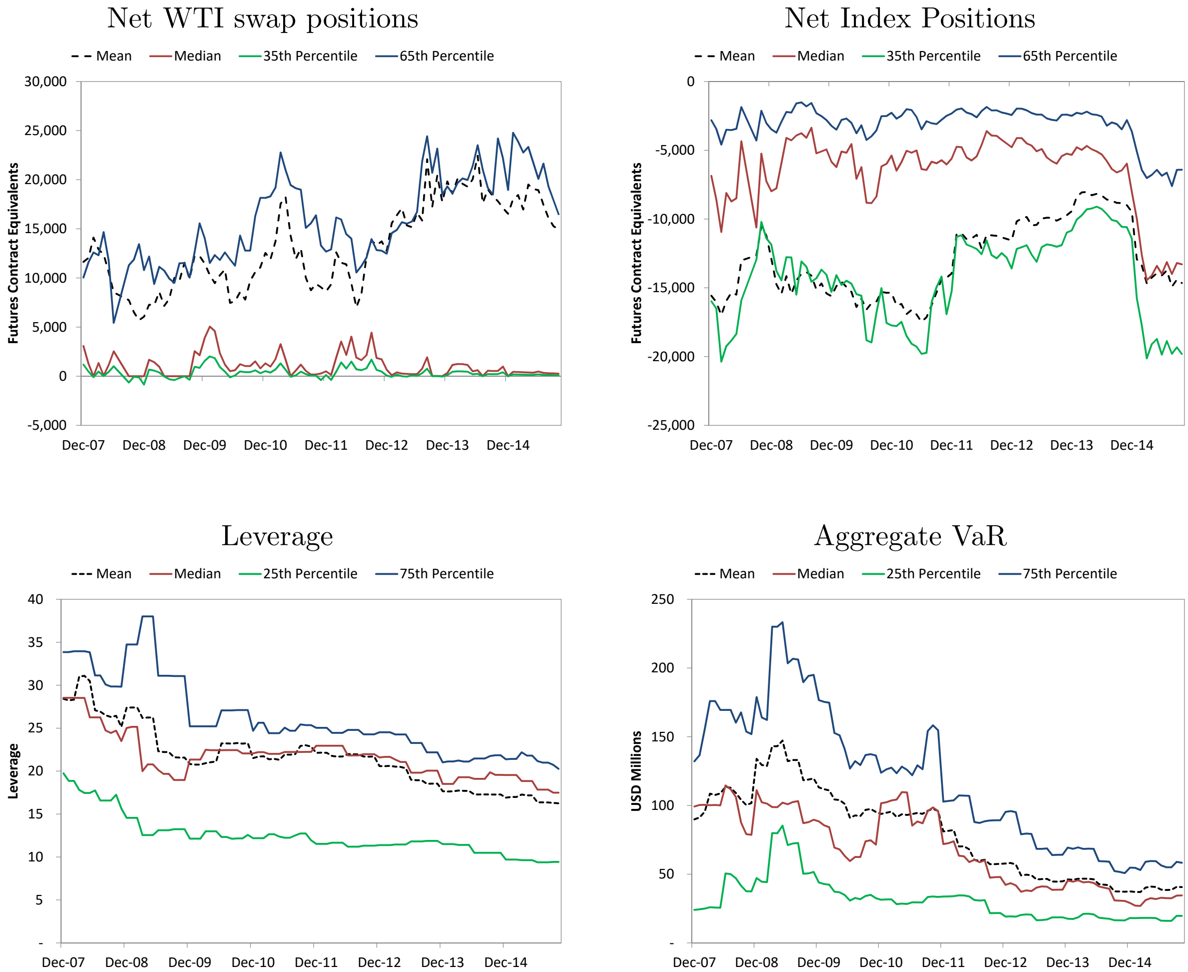
The figure displays both the net futures positions of dealers utilized in this paper, compared with the net "Swap Dealer" futures and option position in NYMEX WTI futures from the CFTC's publicly available Disaggregated Commitments of Traders (DCOT) report.



Time Series/Cross-Sectional Charts for Key Variables

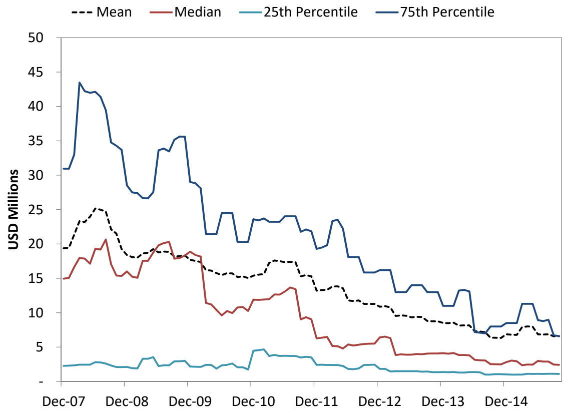
The charts display cross-sectional statistics for each variable, through time. At each point in time, quantile values are computed from the cross-section of data for that date. These values are then displayed for every date in the sample.

Time Series/Cross-Sectional Charts for Key Variables

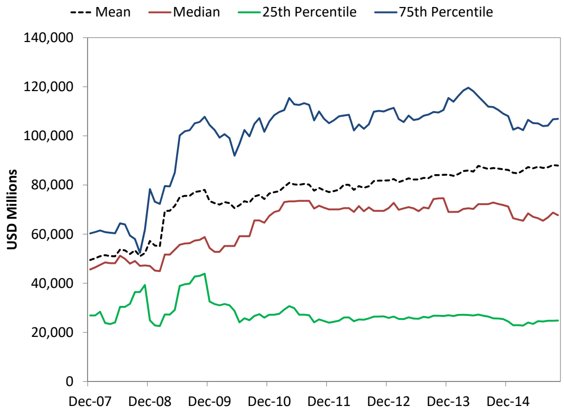


Time Series/Cross-Sectional Charts for Key Variables - continued

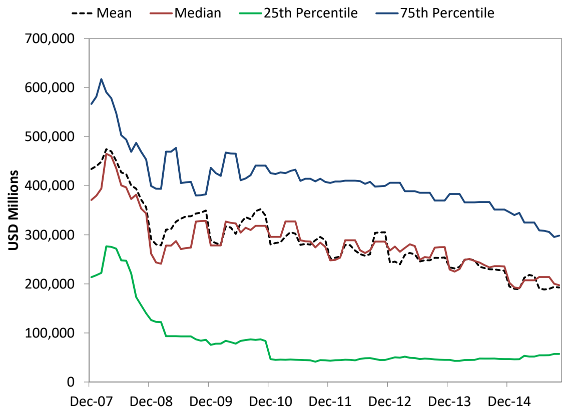
Commodity VaR



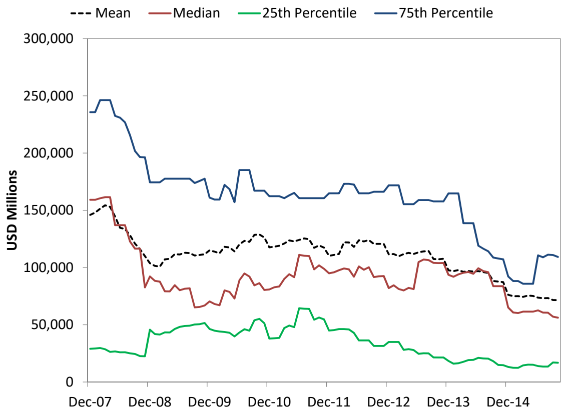
Equity



Short-Term Borrowing



Repo



Tier 1 Capital