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**« MEASURING FINANCIAL INVESTOR PRESENCE
THROUGH TERM STRUCTURE DEFLECTION »**

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Measuring Financial Investor Presence Through Term Structure Deflection^{*}

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ABSTRACT

We estimate the presence of financial investors in commodity futures markets from deflections in the term structure. We argue that large-scale inflows from financial investors cause systematic deviations in nearby futures contracts that reflect excessive buying pressure in commodities. We compare this new speculation indicator to popular existing measures including reported CFTC data and the Hamilton and Wu (2014) risk premium. We find substantial financial investor presence in commodity markets from 2004 to 2014. We show that our new speculation measure is better at explaining the variation in crude oil volatility than other existing measures.

Keywords: Term structure; deflection; financialization; spline interpolation

JEL Classifications: Q40, Q41, O13

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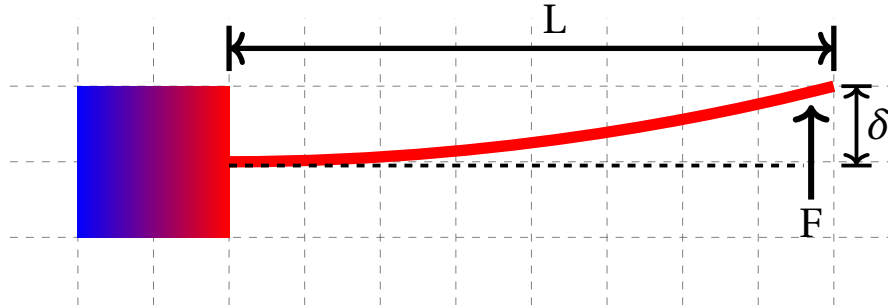
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I. Introduction

In engineering, deflection is a distance, δ , by which a structural element, e.g., a beam of length L , is displaced due to an application of a directional force, F , relative to a situation in which there is no such force (dashed horizontal line in Figure 1 below). Beams may be straight or curved. They may be composed of the same material or of different materials. They may be fixed to a support on one end, as in the illustrative figure below, on both ends or not attached at all. Engineers have derived deflection formulae for most of these scenarios. Deflection, δ is typically proportional to the force F and a polynomial of the length L . For example, under simplifying assumptions, the deflection formula for the end load on a cantilever beam with a single fixed support, as illustrated below, is given by $\delta = \text{constant} \times FL^3$. The term constant depends on the materials from which the beam is made and its cross section. By convention, deflection is positive if the beam is displaced in the positive vertical direction from the dashed horizontal line, which indicates a baseline scenario of $F = 0$.

Figure 1. Beam Deflection

This figure illustrates the deflection of a beam when force is applied. In commodity futures markets, the beam is the term structure of commodity prices, and the force is the price pressure exercised by market participants when simultaneously rolling their contracts on specific days during each month.

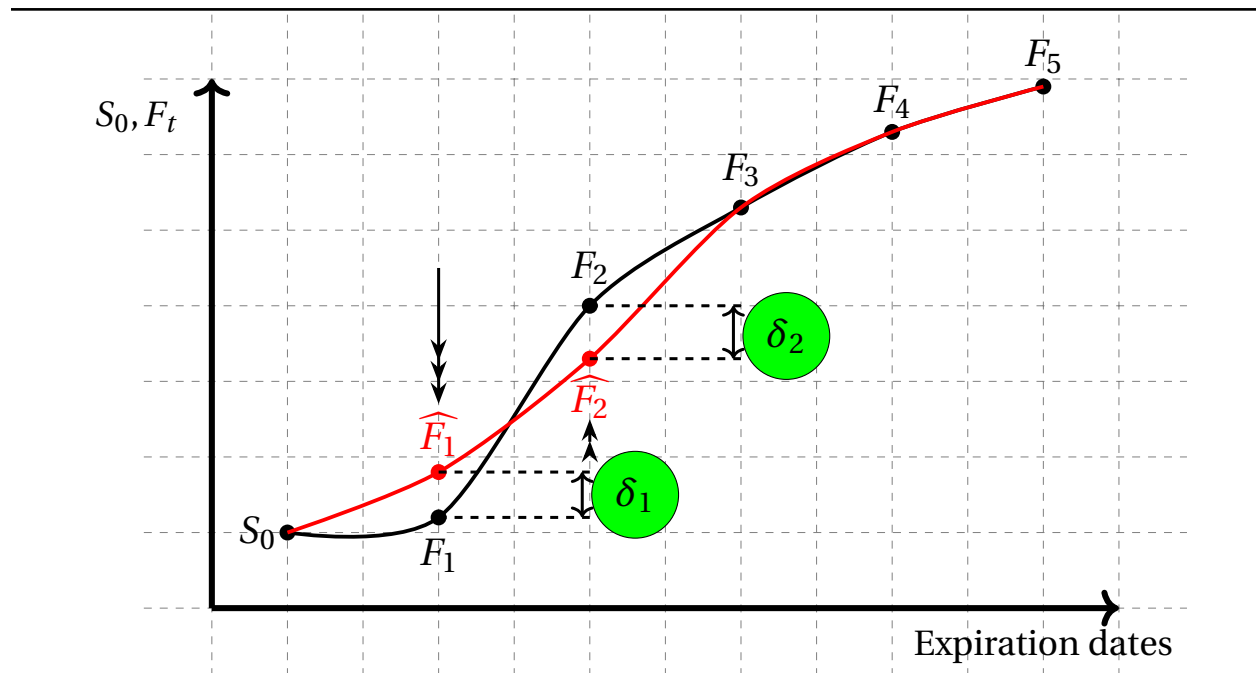


We apply a deflection framework to measure the displacement, δ , of the term structure of commodity futures prices due to the coordinated buying and selling behavior, F , of financial investors. The size of the deflection is used to propose a measure of financial investors presence in commodity futures markets. We argue that deflection has a number of advantages over existing measures such as those constructed from reported CFTC data, the popular Hamilton and Wu (2014) risk premium measure, and the recent two-risk-premia measure of Kang, Rouwenhorst, and Tang (2020). Our framework is illustrated in Figure 2. The beam is understood as the term structure of commodity prices that evolves into a natural smooth backwardation or contango curve. Force is exercised when financial investors simultaneously close the front month contract F_1 and roll into the next nearby futures contract F_2 during the roll period. In this paper, we show that this coordinated behavior which can be observed only during certain days of each

month leads to a deflection of the term structure relative to what would be expected when no force is applied. When financial investors close the nearby contract F_1 , they apply a force that results in a negative deflection, δ_1 of the nearby futures prices, F_1 relative to a term structure where no such force is applied, $\hat{F}_1$. As financial investors jointly roll over into the second nearby futures contract, they apply a force that results in a positive deflection, δ_2 , of the next futures prices, F_2 , again relative to a term structure, $\hat{F}_2$ in which there is no such force. The total price deflection due to the roll denoted by δ is given by $\delta = \delta_2 - \delta_1$. By convention, total price deflection, if any, should be positive if the forces are applied as assumed. We construct the prices $(\hat{F}_1; \hat{F}_2)$ on a hypothetical term structure in which there are no roll forces present (red line) by fitting a third degree polynomial along its length such that it is fixed on one end to the known spot price, S_0 , and connected on the other end to the known three months futures price, F_3 . Guided by the results from engineering, the price deflection metric should be proportional to the directional forces (price pressures) applied by financial investors on the term structure of futures prices. The constant term in the price deflection formula could be thought of to reflect characteristics specific to the underlying commodity such as, for example, storability (similar to the cross-sectional properties of a beam) and liquidity characteristics of the futures market for the commodity (similar to the material properties of a beam).

Figure 2. Term Structure Deflection

This figure illustrates how the term structure of commodity futures prices can be interpreted as a beam that is deflected when force is applied to nearby contracts. $\hat{F}_1$ is pushed down to F_1 while $\hat{F}_2$ is pushed up to F_2 .



The trading of commodities purely for investment purposes and the large-scale inflows from financial investors in commodity markets has been at the center of many recent studies.¹ One of the most debated questions in the financialization literature is the role of financial investors in driving commodity prices and the extent to which these types of investors are active in commodity futures markets. For instance, an integrated oil company like BP generates a large proportion of its business from the extraction and sales of crude oil.² Activity in the futures market therefore serves mainly hedging purposes. On the other hand, BP also has a large trading desk and employs hundreds of oil, gas, and power traders.³ These types of traders use futures contracts and other derivatives to speculate on oil price movements without any involvement in the physical commodity. It is therefore difficult to determine the exact nature of BP and other similar commodity traders in the market.

One specific type of financial investor suspected to impact commodity prices are commodity index traders (CITs). These passive long-only investors tend to follow broad commodity indices that roll over hundreds of billions of dollars on a monthly basis on specific business days. Starting in 2008, the Commodity Futures Trading Commission (CFTC) started collecting the net long futures positions specifically for these types of investors, first on a quarterly basis and later on a monthly frequency. The CFTC stopped the collection and release of this data on October 2015.⁴ Figure 3 shows the net long positions of commodity index traders over the collection period from 2008 to 2015.

This CFTC index investment data suffers from a number of shortcomings. First, the data frequency is irregular and starts in 2008 during the financialization period. A pre-financialization period that would allow to put the size of commodity index investments into perspective is missing. Second, since the index investment data was discontinued in 2015, empirical researchers have no comparable data available for recent years. Third, reported data is subject to classification errors. As in example of the oil company BP above, firms may be classified into once category although they are engaged in activities of both categories. Finally, traders with less than \$500 million of reported net notional value are below the reporting threshold and are therefore excluded from the data. Although individually small, they could collectively form a large share of the invested funds in commodity markets. A number of studies have therefore questioned the quality of the CFTC data (Irwin and Sanders (2011)).

In this paper, we try to address this issue and propose a new measure of speculation in commodity markets that is not based on reported, but on revealed investor behavior. This new

¹See Natoli (2021) for an excellent overview article on this topic.

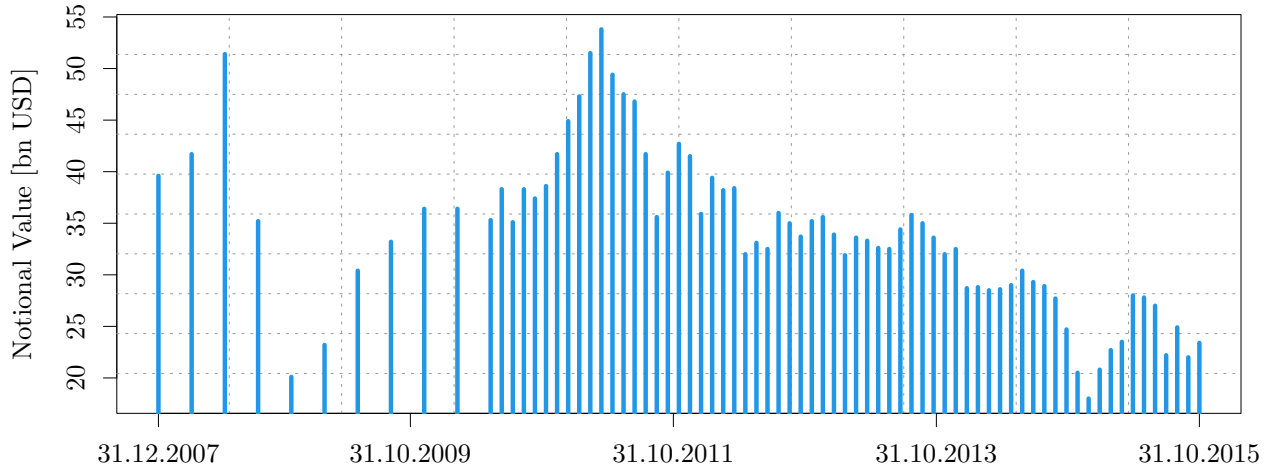
²In 2019, BP produced on average 3.8 million barrels of oil equivalent hydrocarbons per day (BP Annual Report 2019).

³In 2019, BP was holding \$9.98 billion in derivatives for trading purposes (BP Annual Report 2019).

⁴Position data for different types of investors is available at <https://www.cftc.gov/data>.

Figure 3. Reported Net Long Positions for Crude Oil

This figure shows the futures net long positions published in the Index Investment Data from the CFTC. This data was published on a quarterly basis until 2010 when it changed to a monthly reporting frequency. Reporting for this data stopped in 2015.



measure is based on the observation that large-scale inflows from financial investors into commodity markets is usually in the form of futures contracts. Retail investors typically buy shares of commodity ETFs which in turn replicate the commodity returns by taking long positions in futures contracts with the same weights as the index. Large institutional investors such as pension funds and insurance companies tend to invest through commodity swap dealers which in turn hedge themselves through futures contracts.⁵ Both types of investors have in common that the majority of the funds are replicating popular commodity indices such as the S&P GSCI Commodity index or the Bloomberg Commodity index. They also have in common that they follow simple rules by periodically rolling their positions on certain days of each month. These roll dates are publicly announced in advance. For instance, The roll period of the S&P GSCI Index is from the 5th to the 9th business day of each month. Those of the Bloomberg commodity index overlap and are from the 6th to the 10th business day of each month. Given the size of the inflows, these indices continuously roll over hundreds of billions of US dollars on a monthly basis. The sheer size of the funds closing out the maturing front-month contract exercises force on the term structure, pushing prices down during the roll period. At the same time, the price pressure on the new long positions of the next nearby contract push prices up. This can lead to a deflection of the term structure with prices in front-month contracts deviating from a smooth curve that is normally observed in the market. This behavior was first observed by Mou (2011)

⁵A third class of investors are traditional active investors such as hedge funds and CTAs. These types of investors have been present in commodity markets long before the advent of financialization and are not the topic of this paper.

who used this information to propose a trading strategy that is based on front-running the roll dates. In this paper, we use the deflection of the term structure itself as a measure of financial investor presence. We also show in the robustness section that the presence of front-runners does not change the empirical findings in this paper.

Our empirical strategy is illustrated in Figure 4 which is the empirical counterpart of the previous illustrative Figure 2. Consider a term structure that starts with the spot price, omits the following two nearby contracts F_1 and F_2 , and ends with the 12-month contract F_{12} . This situation is shown in Panel A. Based on economic theory, we conjecture that the term structure should be smooth in normal market times.⁶ We use a natural cubic spline interpolation to estimate the omitted contracts F_1 and F_2 as shown in Panel B⁷. In principle, several empirical methods are available to impute the missing values for F_1 and F_2 . Our choice for the cubic spline interpolation is guided by the results from engineering and the fact that this method accommodates the smooth form of the term structure. For any given month, the estimated smooth term structure can be interpreted as the futures curve in the absence of price pressure from financial investors. The estimated smooth futures curve and the realized curve during the roll period of each month are shown in Panel C⁸. The large-scale systematic closing of the front-month contract F_1 during the roll period is pushing prices below the predicted curve, leading to a negative deflection of the term structure. At the same time, sudden demand for futures long positions when rolling over to the next nearby contract F_2 is leading to a positive deflection⁹. We interpret the deflection of the actual futures price from the predicted one $\delta = \delta_2 - \delta_1$ as the degree of speculation in commodity futures markets.

The remainder of this paper is structured as follows: In section II, we give a brief overview of the most relevant work on measuring speculative activity in commodity markets. Our own measure of speculation is developed in more detail in section III. In section IV, we show that speculation is better at explaining the time variation in crude oil volatility than other existing measures. Our results highlight the special role of speculation during the financialization period and the more recent de-financialization phase. Section V offers robustness checks and

⁶For instance, the theory of storage formula predicts a smooth term structure $F_{t,T} = S_t \cdot e^{(r+u-y)(T-t)}$ (Brennan (1958)). Examining a different topic, Hu, Pan, and Wang (2013) estimate a smooth zero-coupon yield curve to identify deviations in the treasury market.

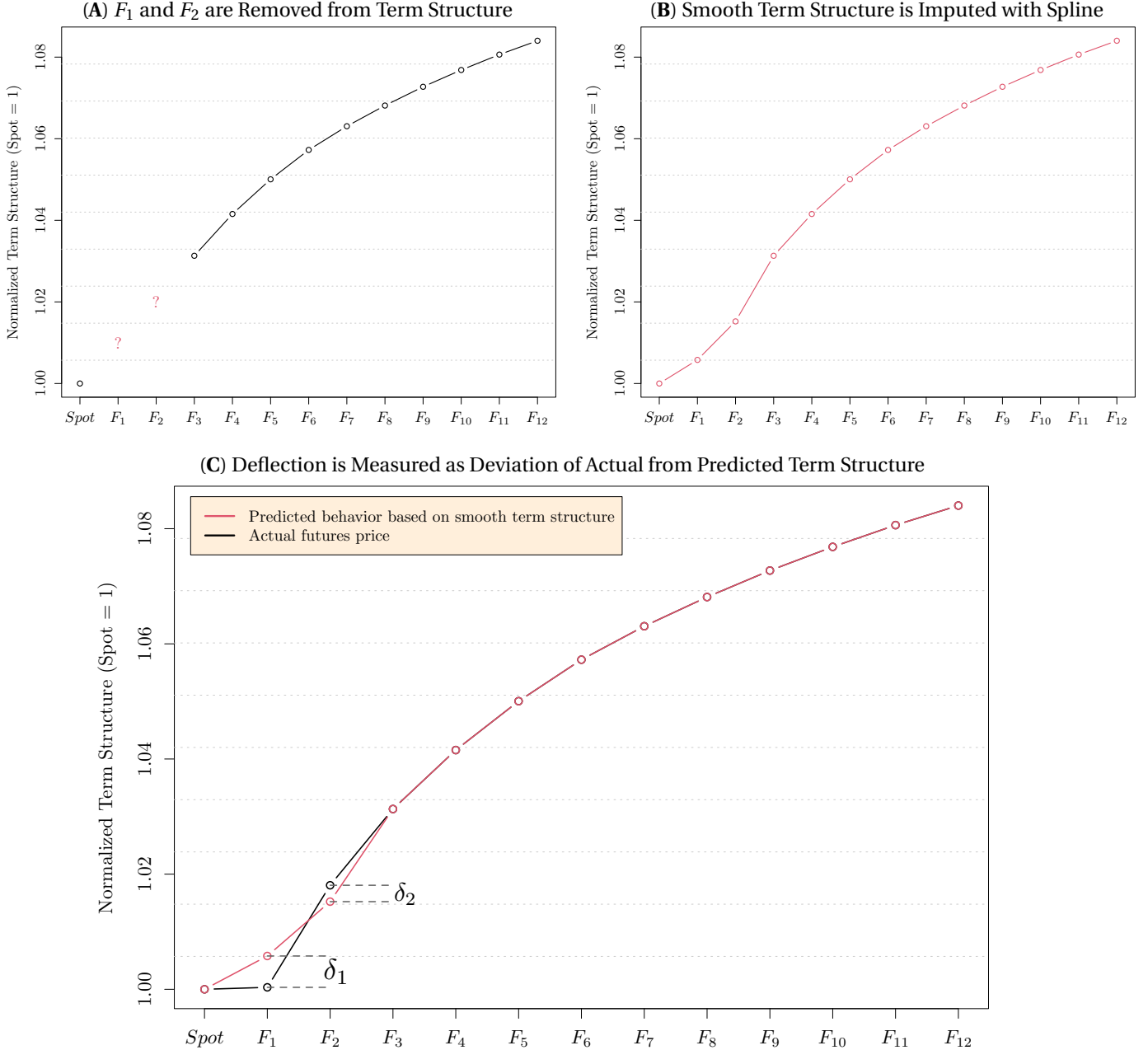
⁷We have experimented with other spline types and different interpolation methods such as polynomial regression and obtain very similar results to the ones presented in the empirical part below.

⁸To improve readability, the curve in Figure 4 shows averaged contango curves during the 5th to the 9th business day normalized to 1 for the spot price. A similar graph can be obtained for backwardation curves.

⁹Note that in the process of rolling over, the second nearby contract F_2 effectively becomes the new front-month contract F_1 until the roll period of the following month.

Figure 4. Term Structure Deflection in Nearby Futures Contracts

This figure illustrates our approach to estimate speculative activity in the front-month (F_1) and second nearby futures contract (F_2). We start with a term structure that omits the first or second nearby futures contract (upper left graph). A natural cubic spline interpolation is used to estimate the price of the missing contracts. This results in a typical smooth term structure that would be expected in the absence of financial speculators (upper right graph). A moderate degree of bending even in the absence of financial investors may be present due to the fact that the front-month contract F_1 is becoming a substitute to the spot contract. Deflection as the difference between actual and predicted values is used to quantify the extent of speculation in commodity futures markets (lower graph).



section VI concludes.

II. Measuring Financial Investor Presence in Commodity Markets: A Brief Overview

The financialization of commodity markets has been one of the most actively researched areas in the commodity literature over the past years. At the center of these studies is the impact from increased financial investor presence on the behavior of commodity markets in general and the following three topics in particular:

One stream of research examines the question whether the increasing presence of financial investors contributes to the well-functioning of commodity futures markets by providing liquidity to producers, or has a distorting effect by driving prices away from their fundamental value (Cheng and Xiong (2014)). Whether financial investors are providers of liquidity or transform into consumers of liquidity appears to be determined by the balance between hedging needs of commodity producers and speculative demand of financial investors (Hamilton and Wu (2014); Sockin and Xiong (2015)).

A second stream of research points to the increased comovement between different types of commodities and between commodities and stock prices (Tang and Xiong (2012)). This topic has practical relevance because commodities and stocks were traditionally known to have zero or even slightly negative correlation (Erb and Harvey (2006)). Starting from zero in 2004, correlations slowly increased and peaked in 2008 when the monthly correlation between stocks and energy commodities jumped to more than 70%. This large shift in correlations had large implications for portfolio managers who made allocation decisions based on zero correlation assumptions and now discovered that their portfolios were more risky than previously thought. The third important research question investigates the extent to which speculation in commodity futures markets is transferred to physical prices for commodities. The link between speculation on a purely financial level and the demand and supply for physical commodities is not straightforward. The question whether and how speculation in commodity derivatives affects energy and daily food prices has generated considerable interest beyond the academic community and is still debated today.¹⁰

The three topics mentioned above, market efficiency, diversification effects, and physical prices, form the predominant share of papers in the financialization literature. Often implicitly, these

¹⁰See for instance the statements by then British Prime Minister Gordon Brown and French President Nicolas Sarkozy in 2009 (Brown and Sarkozy (2009))

studies assume a strong presence of financial in commodity markets. Although data on the increase in net-long positions of financial investors has been monitored and released by regulatory institutions, in particular the CFTC, the extent to which financial investors are active in commodity markets is not known.

A few studies have proposed ways to address this issue, with varying degrees of success and each method with different strengths and weaknesses. One approach is to use reduced form models that are based on VAR analysis or the R-squared contribution of financial versus economic variables. For instance, Adams, Collot, and Kartsakli (2020) show that financial variables can explain the majority of the variation in crude oil volatility during the financialization period, indicating that financial investors are the driving factor in the market. However, the link from financial investors to the explanatory power is only indirect and the validity of this approach is based on the presence of all relevant economic and financial variables in the regression model. The approach that is closest in spirit to our own contribution is the risk premium which measures the return that speculators expect to gain from assuming commodity price risk. In the hedging pressure theory, commodity producers hold futures short position to lock in the price of the commodities to be extracted, mined, or harvested over the next months. This risk premium is usually positive to incentivize financial investors to enter into the futures long positions that are required by producers to establish a trade. During the financialization period, financial investors' massive participation in commodity futures markets reduced the risk premium below zero, indicating that financial investors now outnumbered commercial hedgers and that commodity producers were now the recipients of this risk premium. Our own speculation measure is similar in nature to this approach.

Our paper contributes to the existing literature by proposing a measure of financial investor presence that is not based on investors' stated behavior, but rather on revealed behavior. We thereby exploit the fact that the amount of speculative long positions in commodities is large relative to the size of the commodity market. We argue that trading behavior that is characteristic of financial investors leaves traces in the data that can be used to construct a measure of speculation. In contrast to the risk premium, our measure does not reflect the imbalance between hedgers and speculators in the market but indicates the inflow of financial investors' money that follows typical passive long-only investments. Finally, our paper is related to Hollstein, Prokopczuk, and Tharann (2021), who examine a variety of anomalies in commodity markets that have been previously identified in equity markets. However, while Hollstein et al. (2021) test whether these known anomalies are priced risk factors, our aim is to identify a new type of anomaly in order to draw inference for financial investor presence.¹¹

¹¹Whether our measure of speculation is a priced factor in commodity markets is a different question that we will leave for future research. In theory, a commodity with pronounced deviations from a smooth term structure

III. A Speculation Measure Based on Term Structure Deflection

In this section, we present the design of our speculation measure and compare it to a number of existing alternatives including reported CFTC futures position data, the popular risk premium proposed by Hamilton and Wu (2014), and the two-risk premia measure of Kang et al. (2020). We conjecture a dominant presence of financial investors when the term structure of futures prices shows unusual deflection in nearby contracts during the roll dates. Although these deviations can also occur before or after the roll dates, we focus on these five business days during each month for the following two reasons. First, we know that the trading activity during this time period will be dominated by commodity index traders closing their current front-month contract to roll over in the next nearby long position. Second, outside the roll period and especially between the 18th and the 22nd of each month, the nearby futures contract stops trading and enters into the delivery period. Since most traders will have closed their futures position by that time to avoid physical delivery, the futures contract will be very illiquid. We have noticed deviations in the term structure from a smooth curve during these last trading days that are likely generated by a lack of liquidity rather than financial investors. We therefore focus on the term structure deflection during the five roll dates of each month. The deviations from the smooth curve aggregated over the roll period result in a monthly speculation measure.

Panel A of Figure 5 shows the monthly speculation measure from January 1990 to July 2019. Our sample period includes the 10-year time window from 2004 to 2014 that saw a massive increase in inflows from financial investors and that is therefore labeled as the "financialization" period in the empirical literature. We also include the five years following the financialization period which is characterized by weaker signs of financial investor presence and which have been tentatively labeled "de-financialization" in the literature (Adams et al. (2020); Bianchi, Fan, and Todorova (2020)). The green line shows the deviation of the second nearby futures price F_2 from the smooth term structure. During the roll period, financial investors simultaneously roll into the F_2 contract on a large scale. The buying pressure pushes actual prices above what would be predicted by a smooth term structure. For instance, during the financialization period (January 2004 to May 2014), futures prices in the "rolling-in" contract F_2 are on average 16 U.S. cents per barrel above what would be predicted in normal market times. One crude oil

will be more volatile and should therefore be trading at lower prices everything else equal.

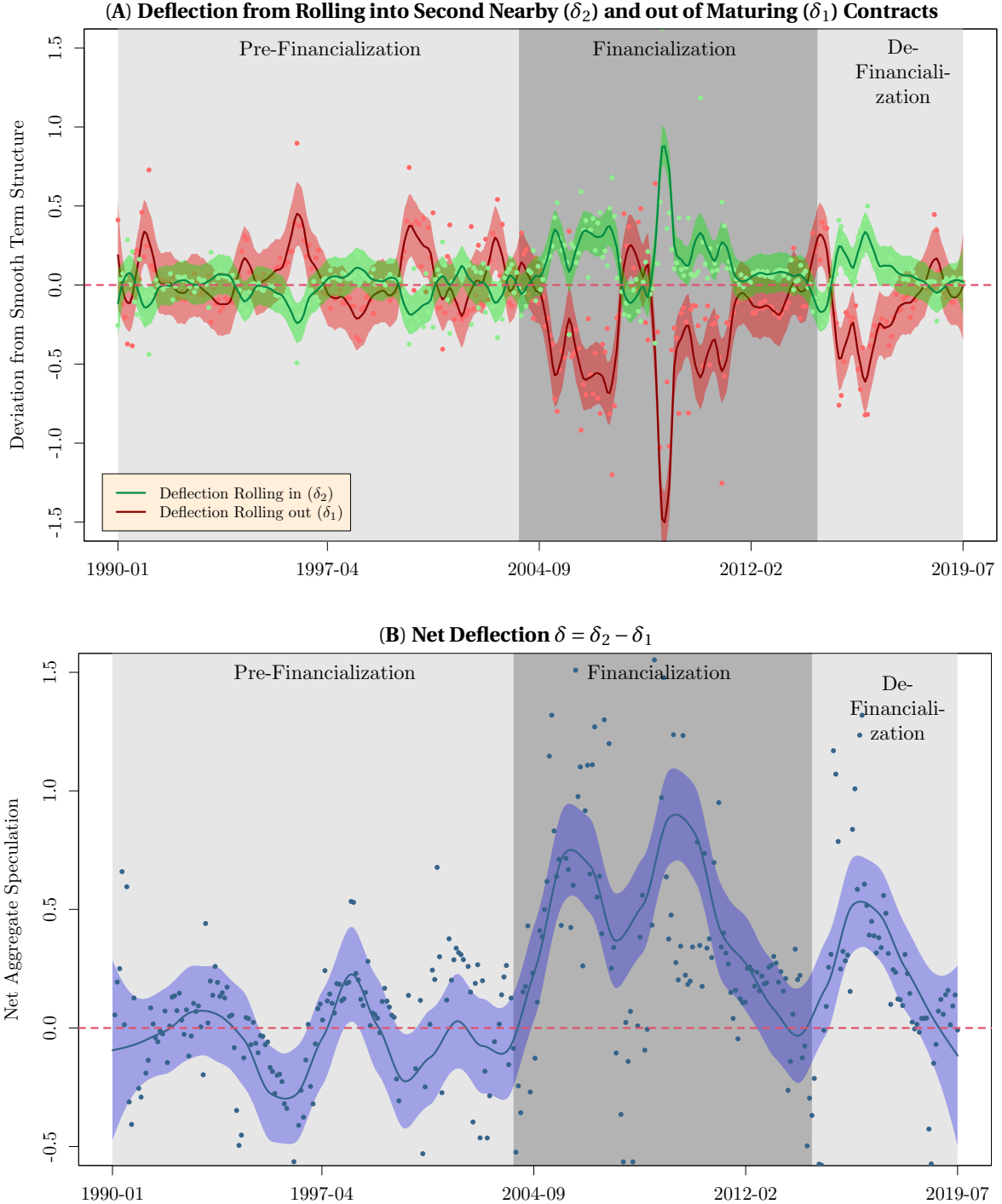
futures contract trades 1,000 barrels. As a consequence, the sheer size of funds being invested reduces the roll return of financial investors by \$160 per futures contract. In contrast, during the pre-financialization period (January 1990 to December 2003), futures prices in the “rolling-in” contract F_2 are on average only 1.4 U.S. cents per barrel below what would be predicted, meaning that the deflection is negative on average and is statistically insignificant. The fact that our smooth term structure does not systematically deviate from the actually observed curve during normal market times is an important finding that confirms our idea that the phenomenon of term structure deflection is indeed unusual.

In a similar way, the red line in Panel A shows the downward price pressure in the maturing “rolling-out” futures contract F_1 during the roll period. The time variation strongly matches that of the green “rolling-in” excess prices which suggests that the funds are being reallocated and therefore rolled over from F_1 to F_2 at the same time. During this process, F_2 becomes the new front-month contract until the roll period of the following month. The average deviation of the “rolling-out” futures prices from the predicted smooth curve during the financialization period is -28 cents or -\$280 per futures contract. The downward price pressure on the “rolling-out” contract, F_1 , is therefore larger than on the rolling-in contract F_2 , possibly due to lower liquidity in the former contract which is close to the maturity date. We measure net deflection as deflection rolling in minus deflection rolling out. We label this measure “deflection” or “speculation” for simplicity. This measure is shown in Panel B of Figure 5¹². As expected, speculation is close to zero and statistically insignificant in the pre-financialization period. When financial investors started to discover commodities as an attractive asset class around 2004, speculation starts to increase to an average of 44 cents per barrel. Since 2014, speculation is positive but at a somewhat lower average of 22 cents. Our results are in line with Adams et al. (2020) and Bianchi et al. (2020). Although these studies use different methodologies both find that commodity markets have entered a period of de-financialization. In the graphs, we add smooth net speculation using a nonparametric regression to highlight the underlying signal. However, the regression results in the empirical part below are based on the unsmoothed version.

¹²The individual components of net deflection, deflection rolling in and deflection rolling out, are almost perfectly correlated at - 0.98. For the empirical part in section IV, we therefore use net deflection as the sum of the components rather than using both components individually.

Figure 5. A Deflection Measure of Financial Investor Presence

This figure shows the time variation in our deflection measure. Monthly values are generated by summing over speculative activity during the roll period (5th to the 9th business day) of each month. Panel A shows that rolling into the next nearby futures contract F_2 generates positive price pressure with actual prices higher than predicted prices (green line). At the same time, rolling out of the maturing front-month contract F_1 generates negative price pressure (red line). Panel B shows net aggregate speculation as deflection rolling into F_2 minus deflection rolling out of F_1 . To highlight the underlying signal, smooth nonparametric regression lines with 95% confidence bands are superposed. We will use the variable “net aggregate deflection” in the empirical part below.



The deflection measure presented in this paper is related to the risk premium in commodity markets. The risk premium RP is derived from the hedging pressure theory (Keynes (1931); Roon, Nijman, and Veld (2000)) and is defined as $RP_t = E_t[S_T] - F_{t,T}$. It measures the return that financial investors expect to make from entering into a futures long position that matures at time T . Since futures prices have to converge to the spot price at maturity ($F_{T,T} = S_T$), a futures price $F_{t,T}$ that is currently below expected spot prices $E_t[S_T]$ incentivizes financial investors to take a long position. In fact, this mechanism is critical to balance the typical oversupply of commodity producers with futures short positions by providing incentives for financial investors to provide the much needed long positions. The risk premium is therefore a measure of imbalance in commodity markets with the size of the risk premium reflecting the expected payment that needs to be offered to attract financial investors into commodities.

The risk premium differs from deflection in a number of important ways. First, risk premium is a measure of incentives, indicating what financial investors should be doing. Deflection on the other hand is a measure of what financial investors are actually doing. For instance, both a positive and negative risk premium is consistent with inflows from financial investors. A positive risk premium was observed in the years up until 2004 and incentivized financial investors to redirect flows into commodity markets. When commodity prices moved on an upward trajectory in the following commodity boom period, inflows gained momentum and increased further despite the fact that financial investors outnumbered hedgers so that the risk premium was now negative. In contrast, the signal coming from our deflection measure is less ambiguous: deflection was zero on average before 2004 and then turned positive when financial investors entered the commodity markets on a large scale.

The risk premium is a latent unobserved variable that needs to be derived. Baumeister et al. (2016) compare recent measures of the risk premium and conclude that the model proposed by Hamilton and Wu (2014) is the most accurate one. Panel A of Figure 6 shows the popular Hamilton and Wu (2014) risk premium from January 1990 to July 2019 (green line). The hedging pressure theory predicts the risk premium to be positive as financial investors need to be compensated to assume commodity price risk. The green line in Panel A is indeed positive until 2004 when it first starts to decline and then turns negative. The timing of this change is in line with the start of the financialization period. Financial investors started to discover commodities as an asset class around 2004 and in the following years, large-scale financial flows were redirected to this new asset class. As a result, financial investors now outnumbered commodity producers. To compensate the imbalance, financial investors now had to pay a premium and producers were the recipients of this premium. A negative risk premium therefore reflects an excessive presence of speculation in the market. This in turn matches the time-variation of

our speculation measure (red line). To facilitate comparison, speculation is measured on an inverted scale on the right y-axis. This highlights the strong comovement between the more established risk premium and our new deflection measure: when the risk premium turns negative during financialization, speculation increases. Both measures also suggest that we have currently entered into a period of de-financialization rather than post-financialization: speculation is declining but has not returned to a pre-financialization level.

Finally, we briefly compare our deflection measure to three other existing alternatives. First, data on reported long positions of financial investors and commercial traders are collected and published by the CFTC. In particular, we compare our deflection measure to the CFTC hedging pressure measure HP_t and to the net trading measure Q :

$$HP_t = \frac{\overbrace{CS_t}^{\text{Commercial Short Positions}} - \overbrace{CL_t}^{\text{Commercial Long Positions}}}{\underbrace{OI_t}_{\text{Open Interest}}} \quad (1)$$

$$Q_t = \frac{\overbrace{CNS_t}^{\text{Commercial Net Short Positions}} - \overbrace{CNS_{t-1}}^{\text{Previous Month's Positions}}}{\underbrace{OI_{t-1}}_{\text{Open Interest}}} \quad (2)$$

In a recent article, Kang et al. (2020) argue in favor of not one, but two risk premia. While financial investors prefer long positions in short-term contracts, commodity producers would prefer hedging several months ahead and would therefore prefer short positions in long-term contracts. As a result, financial investors can receive a risk premium by taking a long-position in long-term contracts, thereby providing liquidity to hedgers, but have to pay a risk premium in short-term contracts in order to attract the liquidity from hedgers. A simple but effective way to estimate this risk premium spread over time is to take the difference between long positions in long-term contracts and long positions in short-term contracts. This measure is labeled as *LTST* ("Long-Term minus Short-Term):

Return from Going Long in Long-Term Contracts

Return Going Long Short-Term

$$LTST_t = R_{LT,t} - R_{ST,t} \quad (3)$$

Panel B of Figure 6 shows the correlation among the five risk measures discussed so far. Empirical correlation among the risk measures is low and also stable over time. One exception is the correlation between COT hedging pressure and the risk premium which was moderately positive in the pre-financialization period and then switches to a negative correlation of equal size during financialization. Finally, Panel C of Figure 6 highlights the correlation between our deflection measure with the other measures. We can confirm that deflection is negatively correlated with the risk premium of Hamilton and Wu (2014) but shows low levels of correlation with the other variables. We therefore conclude that deflection contains sufficient variation of its own that is not captured by any of its competitors. In the following section, we will examine the explanatory power of our speculation measure in a regression of commodity futures return volatility.

IV. Empirical Application

In this section, we examine the extent to which deflection can explain the variation in commodity futures volatility. We show that the explanatory power of our deflection measure is substantially higher than that of the risk premium. In the following, we will concentrate on volatility as the dependent variable which has a number of advantages over commodity returns. First, volatility does not suffer from endogeneity that is plaguing many first-generation empirical studies on financialization: while speculation drives up commodity returns, the upward-trajectory of prices also attracts more speculators. The causal direction is therefore difficult to infer from regressions that use commodity returns as the dependent variable. In contrast, using volatility as the dependent variable does not cause an endogeneity problem: while speculation can increase commodity volatility, higher volatility does not attract more speculation. To the extent that higher volatility discourages investor inflow, our estimates would even slightly underestimate speculation effects.

Second, the growing price pressure that CITs exercise on the term structure during the roll week needs to be released in the following period. For every long position that CITs enter in the new front-month contract F_2 , there needs to be a short position in the same contract by commercial hedgers, arbitrageurs, or by other actively managed positions. These counterparties have in common that they are accommodating the demand from CITs without a particular business

interest in these short positions. We observe a temporary increase in volatility that is likely to be associated with the unwinding of these contracts following the roll period.

Finally, focusing on the volatility of commodity prices is also advocated by the macro literature which shows that volatility rather than the growth rate of commodity prices drives fluctuations in economic activity (Blattman, Hwang, and Williamson (2007); Williamson (2012)).

The volatility estimate that will be used throughout this paper is the range based volatility measure of Alizadeh, Brandt, and Diebold (2002), shown in Eq.(4). This measure is model free and is based on the commodity prices directly rather than returns. In the appendix of this paper, we show that our empirical results also hold for other popular volatility measures such as sample volatility or GARCH(1,1) estimates.

$$\hat{\sigma}_t = (\log(P_{t,max}) - \log(P_{t,min})) \cdot \sqrt{4} \quad (4)$$

This volatility measure enters our estimating equation as follows:

$$\hat{\sigma}_{t+1} = c + \beta_1 \cdot RP_t + \beta_2 \cdot Deflection_t + \beta_3 \cdot HP_t + \beta_4 \cdot Q_t + \beta_5 \cdot LTST_t + \beta_6 \cdot Kilian_t + \beta_7 \cdot \Delta Inventory_t + \beta_8 \cdot TBill_t + \beta_9 \cdot \Delta SP500_t + \beta_{10} \cdot VIX_t + \varepsilon_t \quad (5)$$

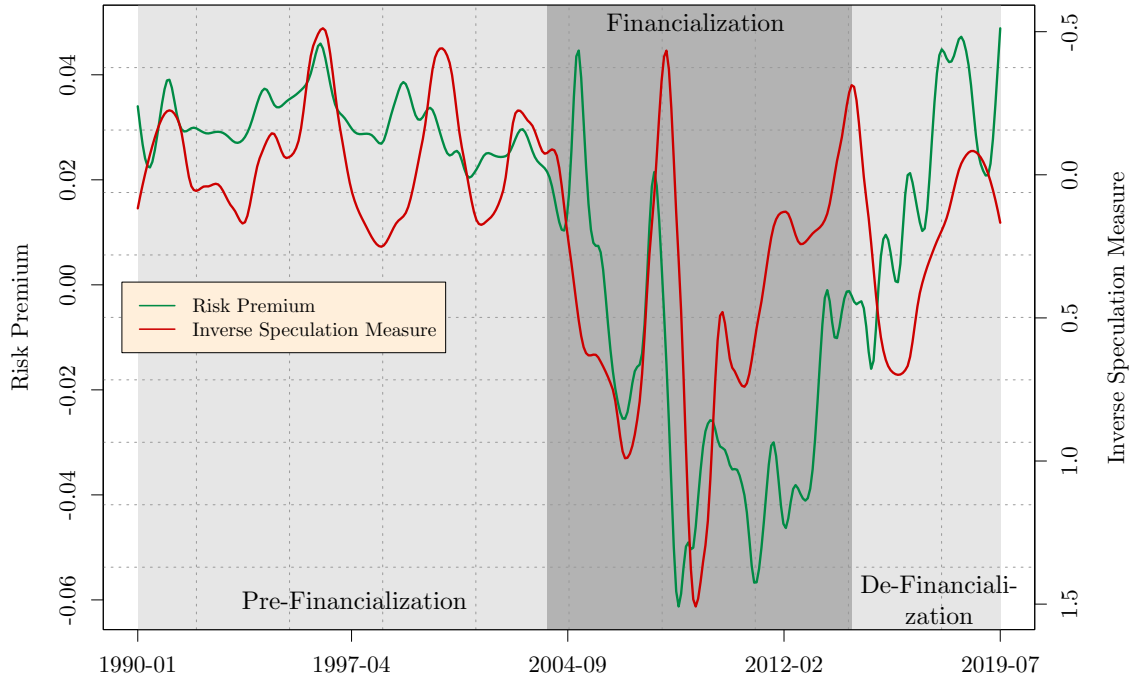
where $\hat{\sigma}_{t+1}$ is the crude oil futures return volatility following the week after the roll period, RP_t is the Hamilton and Wu (2014) risk premium, and $Deflection_t$ is our deflection measure (deflection “going-in” minus deflection “going-out”). We expect that an inflow of speculative funds in month t to be captured by a decline in the RP_t and an increase in $Deflection_t$. We therefore expect the coefficient for RP_t to be negative and that of $Deflection_t$ to be positive. HP_t is the hedging pressure from commercial traders published by the CFTC, Q_t is the CFTC net trading measure, and $LTST$ is the two-risk premia measure of Kang et al. (2020). We show that our deflection measure contains significant explanatory power over and above these alternative measure of investor presence. The remaining variables in Eq.(5) are control variables that capture underlying economic fundamentals and account for the financial crisis that is overlapping in time with the financialization period: $Kilian_t$ is the index of global economic activity proposed by Kilian (2009). It measures the component of global real economic activity that drives the demand for industrial commodities. We use the change in oil inventory levels $\Delta Inventory_t$ to control for the supply of crude oil. Interest rates have been shown to be an important driver of commodity prices (Frankel (2014)) and are captured in Eq.(5) by the 3-month treasury bill $TBill_t$. Finally, we control for two financial variables that have been shown to explain commodity prices and volatility: the returns of the S&P 500 index, $SP500_t$, controls for the influence of the stock market while the CBOE volatility index, VIX_t , controls for the general level of

nervousness in financial markets. Table I shows the regression results where we separate our sample into the periods before, during, and after financialization.

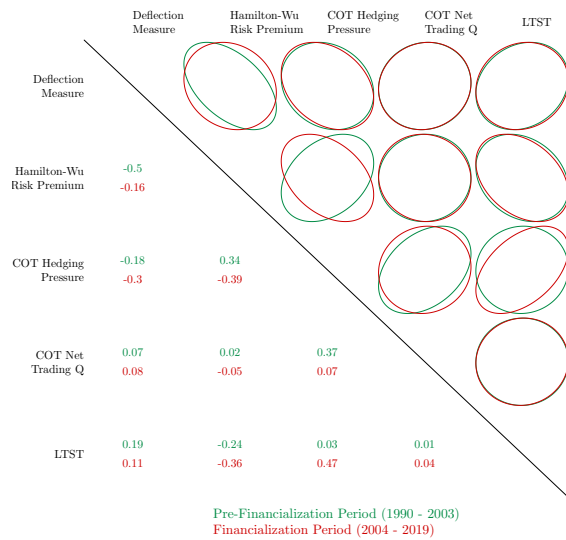
Figure 6. Comparison of Deflection Measure with Existing Measures

This figure compares our deflection based speculation measure with the risk premium proposed by Hamilton and Wu (2014), the Commitment of Traders hedging pressure HP_t , COT net trading Q_t , and the Long-Term minus Short-Term long position measure of Kang et al. (2020).

(A) Inverse Deflection Measure and Smooth Hamilton and Wu (2014) Risk Premium



(B) Correlation Among All Measures



(C) Correlation with Deflection Measure

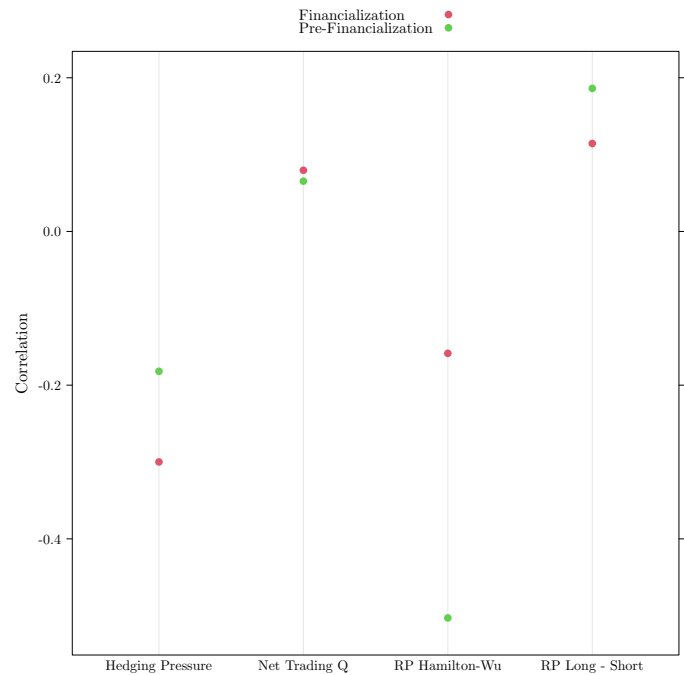


Table I. Impact of Term Structure Deflection on Oil Volatility

The dependent variable in this regression table is the range based crude oil volatility estimated for the 5 days following the roll period. Pre-financialization period: 1990M1 – 2003M12. Financialization period: 2004M1 – 2014M5. De-financialization period: 2014M6 – 2019M7. *** indicate statistical significance at the 1% significance level. Standard errors are based on Newey and West (1987) heteroscedasticity and autocorrelation consistent covariance matrix estimation.

	Dependent Variable: Oil Futures Volatility								
	Pre-Financialization			Financialization			De-Financialization		
Risk Premium	2.77		3.98	−0.54		−0.42*	−0.45		−0.04
Deflection		−5.10**	−3.30**		2.94**	1.30**		4.54***	0.84
Hedging Pressure			−16.55			−22.04*			−24.26
Net Trading Q			4.93			17.51			2.32
LTST			0.09*			−0.22**			0.08
Kilian Index			0.01			−0.01			−0.05**
ΔOil Inventory			−0.23			0.04			−0.54
3-Month T-Bill			0.35			0.58			−0.43
ΔS&P 500			0.16			−0.01			0.07
VIX			0.49**			0.42***			0.38
Obs.	167	167	167	125	125	125	62	62	62
Adj. R-squared	0.02	0.03	0.09	0.04	0.12	0.53	0.01	0.12	0.32

The pre-financialization period serves as the benchmark or “normal market-times” period in which a balanced number of speculators provide liquidity to commodity producers. During this period, speculators were not the dominant actor in the market and large-scale institutional investors such as pension funds or insurance companies had not yet included commodities as an essential part of their portfolios. The full model that includes all control variables shows a negative sign for the deflection coefficient. A one standard deviation increase in deflection, which is associated with an increase of \$0.60, is estimated to reduce crude oil volatility on average by 2 percentage points ($-3.3 \cdot 0.6$). This is an economically large effect given that the average monthly crude oil return volatility is 9.4%. The negative estimate during the pre-financialization period is in line with the notion that speculators contribute to the well-functioning of commodity markets by providing the liquidity for commodity producers to hedge (Brunetti and Reiffen (2014)). Thus, speculators can reduce the volatility of crude oil returns during normal market times. However, the explanatory power of this model is low: economic and financial variables explain less than 10% of the variation in crude oil volatility. The middle columns of Table I show the regression results for the financialization period. The literature has not established a clear consensus on the beginning of the financialization period: while some scholars have pointed out that inflows into commodity markets started to increase already in 2004 (Bicchetti and Maystre (2012)), others have found the characteristic change in commodity price behavior to start only after 2008 (Adams and Glück (2015)). Since our deflection measure presented earlier in Figure 4 appears to be changing into a high speculation regime in 2004, we use this date as the start of the financialization period for our regressions in Table I. However, we also show in Table II in the robustness section that our findings remain qualitatively unchanged when using 2008 as the starting point. In contrast to the pre-financialization estimates, we obtain strongly significant results when estimating the same model over the financialization period from January 2004 to May 2014. The risk premium has the expected negative sign in the first column and deflection has the correct positive sign in the second column. The risk premium is not statistically significant using HAC robust standard errors and explains about 4% of the total variation in a simple regression (first column). In contrast, deflection is statistically and economically significant and can explain 12% of the variation in crude oil volatility (second column). To put the coefficient into context, a \$1 increase in net deflection, meaning that the observed futures prices are \$1 above or below the estimated smooth futures curve, increases crude oil futures volatility on average by 3 percentage points. While this effect is economically large, a \$1 increase in speculation would also be a large shock of roughly 1.7 standard deviations (one standard deviation is 60 cents). The coefficient on deflection is somewhat lower when adding the full set of control variables in column three. From the set of regressions during financialization we conclude that deflection is much better at ex-

plaining the variation in crude oil volatility than the risk premium. Although our speculation measure is related to the risk premium and other measures of financial investor presence such as hedging pressure or the Kang et al. (2020) two risk premium measure, it contains sufficient own variation that is not captured by existing variables.

The de-financialization period starts with the oil price drop in June 2014 that was to a large extent caused by the shale oil boom in the United States and coincides with a general decoupling of crude oil prices and stock prices. As a consequence, the deflection coefficient turns insignificant in the full model that contains all control variables. This finding is in line with a number of recent empirical papers that report findings of a de-financialization, i.e. a period of positive but declining financialization (Adams et al. (2020); Bianchi et al. (2020)).¹³ From Table I we conclude that financial investor speculation as indicated by our deflection measure is statistically and economically significant from 2004 onwards, is substantially better at predicting crude oil volatility than the risk premium, and has entered into a period of de-financialization since 2014. The measure we proposed in this paper is intuitive and easy to reproduce and can serve regulatory institutions and research with an up-to-date monthly indicator of financial investor presence in commodity futures markets.

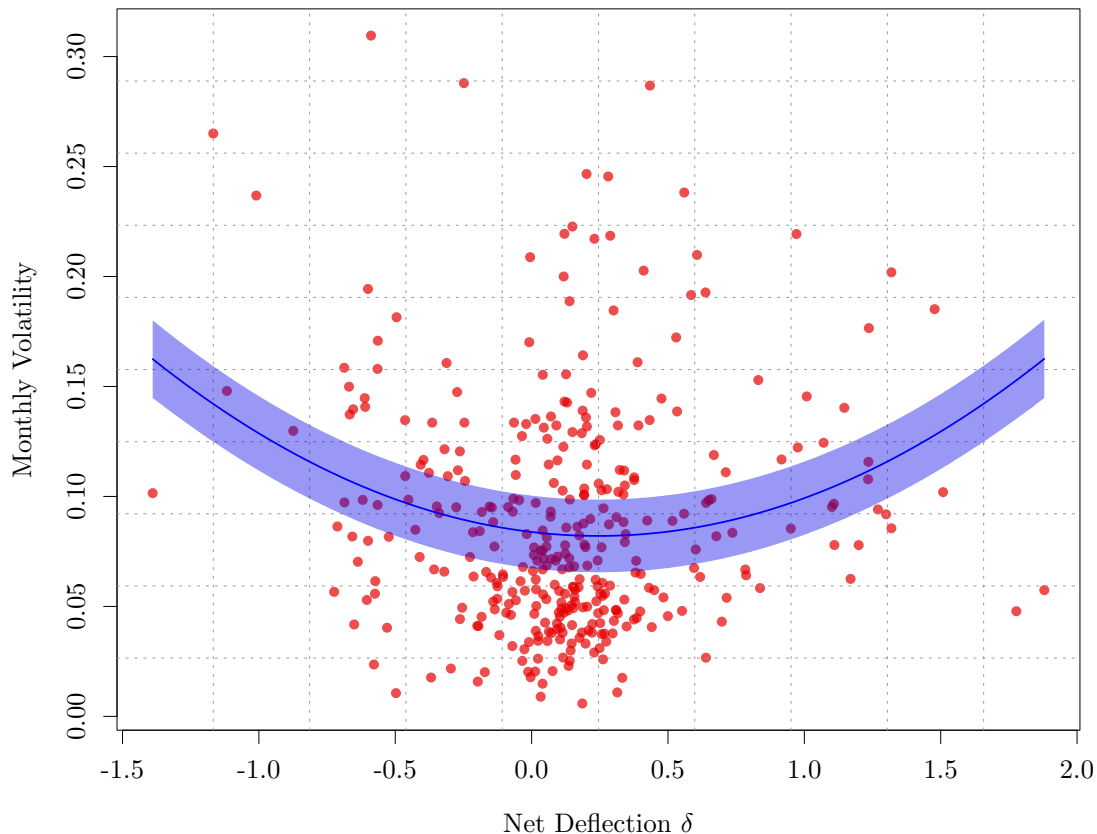
One of the salient features of the empirical results so far is that deflection appears to have a negative impact on volatility during normal market times but increases volatility during the financialization period. This finding is surprisingly robust across multiple regression specifications that we present in the robustness section. We would therefore like to briefly comment on this finding. Figure 7 plots crude oil volatility on the y-axis against deflection on the x-axis. A simple polynomial regression line of volatility on deflection and deflection² is added to emphasize the underlying structure of the data. The coefficient of deflection is negative while the estimate for deflection² is positive. Both coefficients are statistically significant on the 5% level. The fact that the presence of financial investors in commodity markets can improve liquidity and market efficiency is in line with a number of papers (for a recent contribution, see Lauter, Prokopczuk, and Trück, 2022). The negative coefficient that we estimate for the pre-financialization period is therefore not in conflict with the positive coefficient that is reported for the following financialization period. Financialization is characterized by an excess demand from financial investors. Instead of providing liquidity, investors now consume liquidity, reduce market efficiency, and contribute to higher volatility. Our results indicate that a certain amount of financial investors are needed for the well-functioning of commodity futures markets but

¹³Whether the current de-financialization period is the beginning of an eventual post-financialization period is not clear at this time. In a recent article from January 2021, The Economist estimates that commodity assets under management have reached a record of \$640bn (<https://www.economist.com/finance-and-economics/2021/01/12/commodity-prices-are-surging>).

that a large number of investors can cause harm (Cheng, Kirilenko, and Xiong (2015)).

Figure 7. Volatility Smile of Deflection

This figure shows the scatterplot of crude oil volatility and deflection from 1990 to 2019. The regression curve is a second-order polynomial regression which indicates that deflection can reduce volatility for low levels of investor presence.



V. Model Extensions and Robustness

In this section, we complement the main regression table, Table I, with a number of robustness tests. Our aim is to increase the transparency and credibility of our main empirical findings presented in the paper. We begin with Table II below which shows a replication of our main regression Table I using a different starting date for the financialization period. The majority of studies report the year 2004 as the beginning of the financialization in commodity markets (see for instance Tang and Xiong (2012)) because it coincides with the beginning of substantial inflows from financial investors. Other studies point out that the behavior in commodity prices did not change before 2008 and therefore mark 2008 as the beginning of financialization

(e.g. Adams and Glück (2015)). Since there is no consensus in the literature concerning the exact starting date of financialization, Table II uses the later date in 2008 that coincides with the bankruptcy of Lehman Brothers. The main conclusion about the importance of our speculation measure remains unchanged: speculation is highly significant during the financialization period and beyond and continues to be the main driving factor of crude oil volatility, with an R-squared of almost 70% during the financialization period. One change worth mentioning is the insignificant speculation measure in the pre-financialization period. However, the conclusions from our main table remain unchanged.

Table II. Replication of Table I with Different Financialization Dates (September 2008 to May 2014)

The dependent variable in this regression table is the range based crude oil volatility estimated for the 5 days following the roll period. Pre-financialization period: 1990M1 – 2008M8. Financialization period: 2008M9 – 2014M5. De-financialization period: 2014M6 – 2019M7. *** indicate statistical significance at the 1% significance level. Standard errors are based on Newey and West (1987) heteroscedasticity and autocorrelation consistent covariance matrix estimation.

	Dependent Variable: Oil Futures Volatility								
	Pre-Financialization			Financialization			De-Financialization		
Risk Premium	0.28		0.12	−2.00		−0.46*	−0.45		−0.04
Deflection		−2.39**	−1.58		3.87***	1.81***		4.54***	0.84
Hedging Pressure			−4.54			−9.63			−24.26
Net Trading Q			0.11			10.64			2.32
LTST			0.05			−0.42			0.08
Kilian Index			0.00			−0.03**			−0.05**
ΔOil Inventory			−0.06			−0.75			−0.54
3-Month T-Bill			0.49			16.37***			−0.43
ΔS&P 500			0.18			0.03			0.07
VIX			0.34**			0.46***			0.38
Obs.	223	223	223	69	69	69	62	62	62
Adj. R-squared	0.00	0.01	0.03	0.13	0.19	0.69	0.01	0.12	0.32

Next, we investigate the extent to which our speculation measure is affected by noticeable oil related events such as hurricanes, wars, and other supply disruptions. These events have in common that they have large short-term implications but are more muted at the far end of the futures curve. If these events impacted the shape of the term structure, it could reduce the effectiveness of our identification strategy: deviations from the expected futures price at F_1 and F_2 could be a combination of both, speculation and the shock. Table III below lists the main oil related events over our sample period and contains wars, oil spills, super contango, and a number of hurricanes that are a recurring phenomenon in the U.S. Gulf Coast region which contains clusters of oil processing plants and refineries. The third column of this table also shows the months in our sample that could be potentially affected by a certain event. To address the impact of these events, we replace deflection during the impact dates listed in column 3 by their time series forecast using a simple AR(3) model. Since our speculation measure has distinct autoregressive time-series characteristics, modeling and forecasting results in a good fit that is intended to reflect the expected level of speculation in the absence of any disruptive events. We therefore impute the speculation measures by forecasted values on the event dates rather than using previous month's values or missing values. Table IV below is a replication of our main regression table in the paper using imputed speculation values for the event dates. The results in Table IV are qualitatively and quantitatively very similar to our main regression findings in Table I. To conclude, disruptive events that change the shape of the term structure do not appear to affect our empirical identification strategy in a significant way.

Table III. List of Notable Oil Price Impact Events

This table lists the main oil related events during our sample period from 1990 to 2019. These events have the potential to change the shape of the term structure by having a larger effect on the front-end rather than the far end of the futures curve.

Event Name	Event Date	Impact Date
Gulf War	2nd Aug 1990 – 28th Feb 1991	Sep 1990 – March 1991
Gulf War Oil Spill	23rd January 1991	February 1991
Kuwaiti Oil Fires	January 1991 – February 1991	February 1991 – March 1991
US sends forces to Iraq	8th October 1994	November 1994
Super Contango	January 2009	February 2009
Super Contango	February 2009	March 2009
Deepwater Horizon	20th April 2010	May 2010
US Shale Boom	July 2014 – January 2015	August 2014 – Feb 2015
Hurricanes in the Gulf Coast		
Andrew	26th August 1992	September 1992
Danny	18th July 1997	August 1997
Georges	29th September 1998	October 1998
Bret	23rd August 1999	September 1999
Lili	3rd October 2002	November 2002
Claudette	15th July 2003	August 2003
Cindy	6th July 2005	August 2005
Katrina	29th August 2005	September 2005
Rita	24th September 2005	October 2005
Humberto	13th September 2007	October 2007
Dolly	23rd July 2008	August 2008
Gustav	1st September 2008	October 2008
Ike	13th September 2008	October 2008
Isaac	28th August 2012	September 2012
Harvey	26th August 2017	September 2017
Nate	7th October 2017	November 2017

Table IV. Replication of Table I Controlling for Extreme Events

The dependent variable in this regression table is the range based crude oil volatility estimated for the 5 days following the roll period. Pre-financialization period: 1990M1 – 2003M12. Financialization period: 2004M1 – 2014M5. De-financialization period: 2014M6 – 2019M7. *** indicate statistical significance at the 1% significance level. Standard errors are based on Newey and West (1987) heteroscedasticity and autocorrelation consistent covariance matrix estimation.

	Dependent Variable: Oil Futures Volatility								
	Pre-Financialization			Financialization			De-Financialization		
Risk Premium	2.77		4.52	−0.54		−0.40*	−0.45		0.02
Deflection		−2.58**	−1.75		3.91***	1.36*		4.98***	1.37
Hedging Pressure			−17.36			−21.96*			−23.38
Net Trading Q			4.81			16.97			2.37
LTST			0.09*			−0.21**			0.07
Kilian Index			0.01			−0.01			−0.04**
ΔOil Inventory			−0.29			−0.01			−0.51
3-Month T-Bill			0.38			0.51			−0.56
ΔS&P 500			0.15			0.01			0.07
VIX			0.51**			0.41***			0.38
Obs.	167	167	167	125	125	125	62	62	62
Adj. R-squared	0.02	0.01	0.08	0.04	0.19	0.53	0.01	0.13	0.32

Finally, we are aware of, and would like to briefly comment on the fact that not all futures contracts in commodity markets need to be rolled over during the roll dates of large commodity indices. On the one hand, traditional active investors such as commodity trading advisors and hedge funds may front-run the roll dates in an attempt to extract a roll premium. On the other hand, some funds such as the Goldman Sachs Enhanced Curve Long Only Strategy are explicitly targeted to roll at different dates. However, we believe that this fact does not impair our empirical strategy: the financialization phenomenon that has led to the transformation of commodity markets has been mainly caused by passive long-only commodity index traders that started to direct large investment inflows into commodities around 2004. We are not concerned with traditional active investors that have been present in the market before and have arguably contributed to the well-functioning of the market ¹⁴. In Table V, we empirically test for the potential presence of front-runners in crude-oil futures markets. We obtain the 10-day front-running deflection measure using the procedure described in this paper but measured at 10 days prior to the beginning of the official roll dates. We then obtain excess deflection as the difference between deflection and front-running deflection. This measure is intended to capture the effect of deflection during the official roll dates once deflection prior to the official roll dates is accounted for. The empirical findings in Table V are very close to those obtained from our main Table I in the paper. Financial investors have an attenuating effect on volatility during normal market times but increase volatility during the financialization period. Excess deflection has further lower explanatory power during the de-financialization period when the full set of control variables is included. From Table V we conclude that the presence of front-runners does not change the main findings in our paper.

¹⁴Also, the amount of assets under management such as that of the Goldman Strategy (Ticker: ENHG266P) mentioned above is fairly small relative to the amount of passive funds in commodity futures markets. For instance, the AUM of ENHG266P was only \$2bn in 2019 which was less than 1% of the amount invested by commodity index traders.

Table V. Replication of Table I Controlling for 10-Day Front-Runners

The dependent variable in this regression table is the range based crude oil volatility estimated for the 5 days following the roll period. Pre-financialization period: 1990M1 – 2003M12. Financialization period: 2004M1 – 2014M5. De-financialization period: 2014M6 – 2019M7. *** indicate statistical significance at the 1% significance level. Standard errors are based on Newey and West (1987) heteroscedasticity and autocorrelation consistent covariance matrix estimation.

	Dependent Variable: Oil Futures Volatility								
	Pre-Financialization			Financialization			De-Financialization		
Risk Premium	2.77		5.21 *	−0.54		−0.45**	−0.45		−0.09
Deflection		0.65	2.49		3.07*	1.54*		5.22*	−1.16
Hedging Pressure			−18.27			−25.60**			−28.69
Net Trading Q			4.69			17.98			5.29
LTST			0.09			−0.20**			0.09
Kilian Index			0.01			−0.01*			−0.05**
ΔOil Inventory			−0.25			0.19			−0.55
3-Month T-Bill			0.38			0.71			−0.15
ΔS&P 500			0.15			0.02			0.11
VIX			0.52**			0.43***			0.40
Obs.	167	167	167	125	125	125	62	62	62
Adj. R-squared	0.02	0.01	0.08	0.04	0.04	0.52	0.01	0.01	0.32

VI. Conclusion

In this paper, we propose a new measure of financial investor presence in commodity futures markets that we label *deflection*. Common existing measures are based on reported data that is released by regulatory institutions and commodity exchanges. In contrast, the measure we propose here is based on revealed behavior of commodity investors rather than self-reported data. We show that during normal market times, the term structure of crude oil futures prices can be well approximated by a smooth curve. In contrast, during the 10-year financialization period from 2004 to 2014, observed first and second nearby futures prices deviate on average by 44 cents per barrel. During the roll period, financial investors are exiting the maturing front-month contract on a large scale which pushes prices below the smooth term structure. At the same time, the coordinated investments into the second nearby contract increases prices above the estimated smooth level. While our deflection measure is related to the risk premium in commodity markets, it contains sufficient own variation to motivate its use. Deflection also captures investor presence to an extent that the risk premium cannot. Our deflection measure can explain 12% of the variation in monthly crude oil volatility. In contrast, the popular Hamilton and Wu (2014) risk premium can explain only 4% of the variation over the same time period. The deflection measure presented in this paper replicates a number of regularities in the data that have been discussed in the financialization literature: no systematic speculation in the years prior to 2004, distinct and statistically significant speculation during the financialization period, and positive but reduced speculation in the following de-financialization period. Our measure is easy to replicate and only requires the prices of individual futures contracts as input. It has the potential to serve as a real-time measure of financial investor presence and could guide commercial hedgers and policy makers in commodity futures markets.

REFERENCES

- Adams, Z., and T. Glück, 2015, Financialization in commodity markets: A passing trend or the new normal?, *Journal of Banking and Finance* 60.
- Adams, Zeno, Solène Collot, and Maria Kartsakli, 2020, Have commodities become a financial asset? evidence from ten years of financialization, *Energy Economics* 89.
- Alizadeh, Sassan, Miachel W. Brandt, and Francis X. Diebold, 2002, Range-based estimation of stochastic volatility models, *The Journal of Finance* LVII, 1047–1091.
- Bianchi, Robert J., John Hua Fan, and Neda Todorova, 2020, Financialization and de-financialization of commodity futures: A quantile regression approach, *International Review of Financial Analysis* 68.
- Bicchetti, David, and Nicolas Maystre, 2012, The synchronized and long-lasting structural change on commodity markets: Evidence from high frequency data.
- Blattman, Christopher, Jason Hwang, and Jeffrey G. Williamson, 2007, Winners and losers in the commodity lottery: The impact of terms of trade growth and volatility in the periphery 1870-1939, *Journal of Development Economics* 82, 156–179.
- Brennan, Michael J, 1958, The supply of storage.
- Brown, G., and N. Sarkozy, 2009, Oil prices need government supervision.
- Brunetti, Celso, and David Reiffen, 2014, Commodity index traders, hedging, limits to arbitrage, *Journal of Financial Markets* 21, 9–37.
- Cheng, Ing Haw, Andrei Kirilenko, and Wei Xiong, 2015, Convective risk flows in commodity futures markets, volume 19, 1733–1781 (Oxford University Press).
- Cheng, Ing Haw, and Wei Xiong, 2014, Financialization of commodity markets.

- Erb, Claude B., and Campbell R. Harvey, 2006, The strategic and tactical value of commodity futures.
- Frankel, Jeffrey A., 2014, Effects of speculation and interest rates in a "carry trade" model of commodity prices, *Journal of International Money and Finance* 42, 88–112.
- Hamilton, James D., and Jing Cynthia Wu, 2014, Risk premia in crude oil futures prices, *Journal of International Money and Finance* 42, 9–37.
- Hollstein, Fabian, Marcel Prokopczuk, and Björn Tharann, 2021, Anomalies in commodity futures markets *.
- Hu, Grace Xing, Jun Pan, and Jiang Wang, 2013, Noise as information for illiquidity, *The Journal of Finance* 68, 2341–2382.
- Irwin, Scott H., and Dwight R. Sanders, 2011, Index funds, financialization, and commodity futures markets, *Applied Economic Perspectives and Policy* 33, 1–31.
- Kang, Wenjin, K. Geert Rouwenhorst, and Ke Tang, 2020, A tale of two premiums: The role of hedgers and speculators in commodity futures markets, *Journal of Finance* 75, 377–417.
- Keynes, J.M., 1931, Mr. keynes' treatise on money, *The Economic Journal* 41, 241–249.
- Kilian, Lutz, 2009, Not all oil price shocks are alike: Disentangling demand and supply shocks in the crude oil market, *American Economic Review* 99, 1053–1069.
- Mou, Yiqun, 2011, Limits to arbitrage and commodity index investment: Front-running the goldman roll.
- Natoli, Filippo, 2021, Financialization of commodities before and after the great financial crisis, *Journal of Economic Surveys* 35, 488–511.
- Roon, Frans A. De, Theo E. Nijman, and Chris Veld, 2000, Hedging pressure effects in futures markets, *Journal of Finance* 55, 1437–1456.

Sockin, Michael, and Wei Xiong, 2015, Informational frictions and commodity markets, *Journal of Finance* 70, 2063–2098.

Tang, Ke, and Wei Xiong, 2012, Index investment and the financialization of commodities, *Financial Analysts Journal* 68, 54–74.

Williamson, Jeffrey G., 2012, Commodity prices over two centuries: Trends, volatility, and impact, *Annual Review of Resource Economics* 4, 185–206.

VII. Appendix

This paper focused on the volatility of crude oil prices. Since volatility is a latent unobserved variable the estimation method can influence the main empirical findings. In this appendix, we compare our range based volatility measure to other popular measures such as the sample volatility and GARCH(1,1) volatility. The purpose of this section is to demonstrate that our main empirical results remain robust to the choice of the volatility model. All three measures have in common that they are computed from daily data following the week after the roll period. The tensions in commodity markets build up during the roll week of each month. During the 5th to the 9th business day, a large fraction of the open positions in the front-month contract are closed and reopened in the second nearby contract. We capture the extent to which this tension is released, causing volatility in the following week. The following equations summarize the volatility measures.

The sample volatility is shown in Eq.(6). The index number n denotes the five days of the week following the roll week. Because a certain week per month is examined, we multiply with $\sqrt{4}$ to obtain monthly volatility.

$$\sigma_t = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (R_i - \bar{R})^2} \cdot \sqrt{4} \quad (6)$$

The GARCH(1,1) volatility is shown in Eq.(7). We take the average over the five daily volatility estimates and multiply by $\sqrt{4}$ to obtain a monthly estimate.

$$\sigma_t = \frac{1}{n} \sum_{i=1}^n \sqrt{\omega + \alpha \cdot \epsilon_{t-1}^2 + \beta \cdot \sigma_{t-1}^2} \cdot \sqrt{4} \quad (7)$$

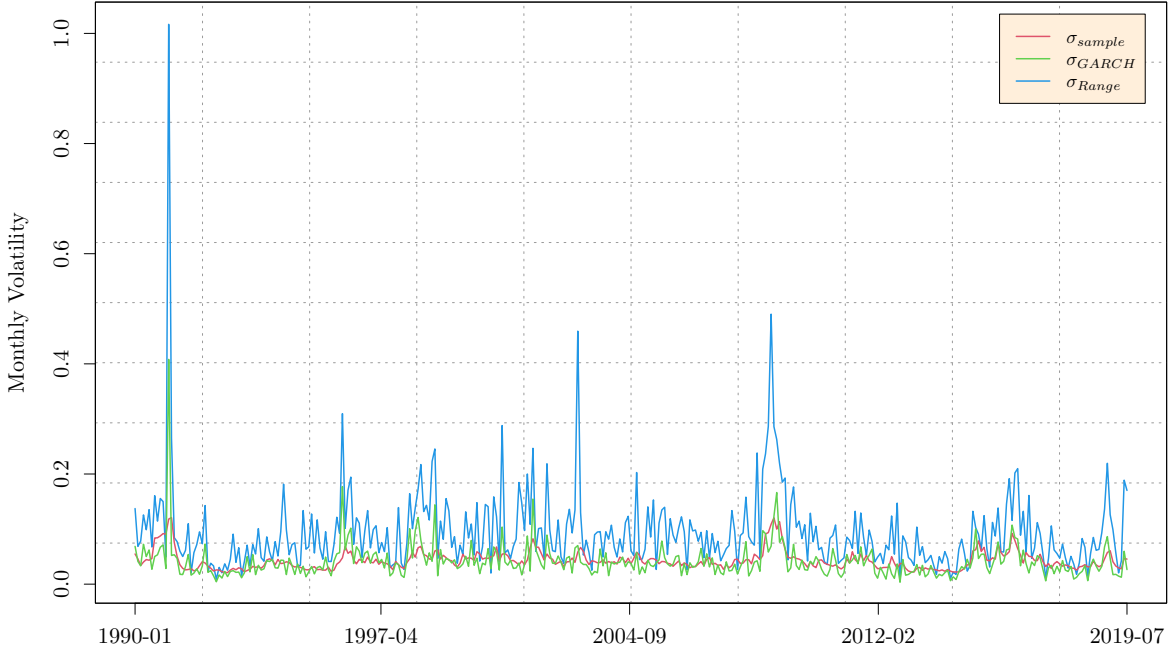
The volatility estimate used throughout the paper is the range based volatility measure of Alizadeh et al. (2002), shown in Eq.(8). Note that this measure is based on the commodity prices directly rather than returns.

$$\sigma_t = (\log(P_{t,max}) - \log(P_{t,min})) \cdot \sqrt{4} \quad (8)$$

Figure A1 compares the time variation of the volatility measures. Although there is a strong degree of comovement with correlation among the three measures exceeding 0.68 on average, range based volatility is higher and volatility spikes are more pronounced.

Figure A1. Three Popular Models of Time-Varying Volatility

This figure shows the monthly time-varying volatility using sample volatility (red line), standard GARCH(1,1) (green line), and the range based volatility estimator of Alizadeh et al. (2002) (blue line). Volatility is estimated for the week following the roll period resulting in one observation for each month.



In Figure A2 we compare the coefficient of deflection across the three volatility models. The coefficients are based on the full model that includes all control variables. They differ only by the way the left-hand-side variable of the equation is estimated. We can confirm our previous observation which suggests that more financial investors decrease volatility in normal times but will increase volatility during the financialization period. Although there are some differences in the size of the estimated deflection coefficient across the three volatility measures, our empirical findings remain robust to the choice of the volatility model.

Figure A2. Deflection Coefficient Estimates for Three Volatility Models

This figure shows the estimated deflection coefficient for the full regression model that was used in Eq.(5). The volatility measure on the left-hand-side of the equation is the sample volatility (red bars), GARCH(1,1,) volatility (green bars) or the range based volatility estimator (blue bars).

