Cheap Money, Geopolitics and Supernormal Backwardation of the WTI Forward Curve

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ABSTRACT

Financial speculators frequently trade in the most liquid short-tenor contracts. We study repeating patterns of sharply steepening slopes in the WTI forward curve to investigate whether, after controlling for macroeconomic variables, physical market fundamentals, and basic arbitrage, calendar spread behavior is partly explained by speculation related to assessed geopolitical risk. We estimate WTI forward curve backwardation using the slope component from the parsimonious Dynamic Nelson-Siegel factor model, and then regress the resulting time series on a variety of economic, financial, and geopolitical variables. Results show that geopolitical risk in juxtaposition with low interest rates explains a significant percentage of the slope variation from 2011 to 2021. We then investigate whether there is evidence to support the common narrative that speculators buy the geopolitical threat and sell the event. We find confirmation of the hypothesis. We further study the dynamic effects of interest rate and geopolitical risk on speculative activity using a Factor-Augmented Vector Autoregression analysis. Impulse response functions from the latter indicate that independent shocks related to geopolitical threat result in heightened supernormal backwardation for a month or more. We recommend changing margin requirements in WTI futures markets in light of these findings to disincentivize this speculative behavior.

Keywords: Speculation, backwardation, oil, futures, geopolitics.

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1. INTRODUCTION

Debate continues regarding how geopolitical risk and speculation in oil futures markets influence price outcomes. As oil prices skyrocketed into triple-digits in the late 2000s and early 2010s—levels not seen since the immediate aftermath of the Iranian Revolution—a large literature emerged to assess how much, if any, of this rise in prices was due to "speculation" as oil futures contracts had been "financialized" (Vansteenkiste, 2011). As oil prices rose above $100 a barrel in 2008, alarms were raised before the U.S. Senate Committee on Homeland Security and Government Affairs (Masters, 2008). Proposals were presented to the Commodity Futures and Trading Commission (CFTC) for stricter regulations on derivative positions to limit speculation in futures markets (FIA, 2011). Several comments submitted to the CFTC

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in 2011 supported stricter regulation, arguing that commodity index funds and other vehicles had indeed allowed speculative activities in futures markets to exceed significantly the more tethered trading that supported physical market activity and hedging (CFTC, 2011).

The CFTC approved a final rule for position limits on futures and swaps on October 18, 2011. The new rule, which CFTC said was authorized by the Dodd-Frank Wall Street Reform and Consumer Protection Act legislation, included the New York Mercantile Exchange WTI contract and "establishes that no trader may hold or own a position in the same commodity if the position exceeds a spot-month position limit of 25% of the 'estimated spot-month deliverable supply' (Greenberger, 2013)." The rules also provided that non-spot month limits would bar traders from holding positions that exceed 10% of the first 25,000 contracts and 2.5% thereafter for either all months combined or an individual month. At the time, it was suggested that these rules were not sufficiently restrictive. The rule was challenged in court and reissued in 2016 (CFTC, 2016) but in the end, no final rulemaking has been implemented. The CFTC published a new notice of proposed rule-making in the Federal Register on February 27, 2020 (CFTC, 2021).

The same debate on the influence of speculation on oil price formation in WTI futures pricing took hold again during the period in 2021 and early 2022 when Russia amassed troops on the border of Ukraine. Oil prices rose from $76 a barrel at the beginning of January 2021 to $120 in early June 2022. The policy salience of the issue is driven home over the course of 2022 by rising global concerns about inflation and US President Biden's intense focus on the impact of high gasoline prices on American consumers. As the US President seeks policy levers to bring down the price of oil, surprisingly little debate has focused on the inflationary role of money manager speculation in oil futures markets and related policy remedies (Krause, 2022). In its research brief from June 2022, Citi Research explains that passive investors are "longer positioned than ever" based on "price momentum and strong backwardation" and it notes "investor positioning remains tilted toward West Texas Intermediate US based futures markets given higher margin requirements on European exchanges" (Morse et al., 2022).

Our inquiry, which does not cover the period of extreme volatility that erupted after Russia's invasion of Ukraine, offers further evidence that speculative activity linked to geopolitical risk is influencing oil price outcomes. Specifically, we investigate the possibility that speculative activity in the most liquid short tenor spot month contracts for West Texas Intermediate crude oil (WTI) on the New York Mercantile Exchange (NYMEX) has contributed to repeating patterns of sharply steepening slopes in the WTI forward curve in the 10-year time period of 2011 to 2021. We control for macroeconomic variables, physical market fundamentals, and basic arbitrage, and assess whether calendar spread behavior is partly explained by speculative activity related to assessed geopolitical risk.

We find evidence of conditions that appear to be present when the WTI forward curve extends into a steeper backwardation than physical market fundamentals and basic arbitrage would justify. We discuss those conditions and evidence that correlates them to assessed geopolitical risk and low interest rates and offer recommendations for US futures markets regulatory changes that could help reduce large passive investor positionings in front month contracts.

2. LITERATURE REVIEW

Leading analysis from Juvenal and Petrella (2015) and concurrent academic research suggested that much of the price increase to $100 per barrel prior to the 2009 financial crisis was demand driven, as the global economy grew from 2006–2008. Still, others suggested that a reasonable portion of price volatility was, indeed, speculation driven, especially the price spike to $140 per barrel and above. Notably, subsequent research dissented from the common demand driven explanation by citing theoretical literature showing that inventory management may increase price volatility under uncertainty (Singleton, 2010). Using CFTC data, Singleton argued that hedge funds, passive investors through index funds, and others contributed significantly to price levels and volatility. His work was followed by another significant study (Büyükşahin et al, 2013) which tested empirically the predictive power of aggregate long oil futures positions of commodity index traders on the spread differentials between WTI and Brent prices. Other researchers tested for a cointegrating relationship between spot and future prices noting that they were "evocative" of speculative expectations (Kaufmann, 2011). A later analysis (Kaufmann and Connelly, 2020) sought to identify specific periods during which market fundamentals did not explain observed variation in oil prices and argued that the 2008 deviation, in particular, was best explained by speculation.

In the same vein, Pagano et al (2019) suggested activity of investors in Exchange Traded Funds in oil (ETF) raised warnings that large ETF-induced trading could exacerbate price swings during times of market turmoil. The rolling of front month positions by US oil ETF USO contributed to the West Texas Intermediate crude oil futures wild gyrations in 2020 (Collins, 2020). Todorov (2021) extended this work by testing the price impact of ETF trading on the slope of future curves. Using a model independent approach for replicating the underlying spot market (fundamental) value of a futures contract and then decomposing demand, Todorov identified price distortions related to high demand from ETF activity during calendar rebalancing, e.g. shifting positions at expiry (Todorov, 2021). He concluded that leverage-induced rebalancing can have significant influence on price movements in oil markets, causing prices to diverge from physical market fundamentals.

In light of subsequent price spikes in 2014-2015 and again in late 2021-early 2022, we revisit and extend this literature with a focus on the ten-year period after the end of the 2011 Arab Spring during which volatility in oil markets had become similarly notable. Specifically, we consider repeating patterns of extremes in the West Texas Intermediate crude price (WTI) forward curve slope and seek explanations that go beyond fundamental variables such as the cost of storage and the cost of money. In doing so, we extend the literature by revealing sufficient explanatory power that a variety of economic, financial, and geopolitical variables offer in explaining a significant percentage of variation in the WTI forward curve slope. While low interest rates for prolonged periods of time fuel bubbles in a variety of markets, their effect on oil market speculation in periods of geopolitical instability require greater attention, particularly when stress testing large positions held by commodity traders and fund managers controlling overweighted asset allocations by pension funds and other institutional investors toward commodity speculation.

We seek to demonstrate that the shape of the WTI curve in periods of high geopolitical risk and rising open interest from financial players exhibits more backwardation than is justified based on fundamentals for the cost of storage and interest rates in the period following 2011-2012 and extending into 2021.

Nearly a century ago, Keynes famously hypothesized that forward curves of commodity markets should exhibit a degree of "normal backwardation" (Keynes, 1930), which Kolb (1992) has studied more recently in a number of commodity futures markets. Normal backwardation, as envisioned by Keynes, applies equally to forward curves that are upward and downward sloping, and maintains that longer-tenor expected futures prices may be lower than the shorter-tenor futures prices adjusted for time value, cost of storage, etc. because, he hypothesized, most short positions will be taken by physical producers looking to hedge their exposure to potentially falling prices. Thus, he hypothesized that financial and other traders who take long positions in these markets are providing a valuable hedge to physical producers and demand a compensation commensurate with the risk premium to provide this service, hence making the longer-tenor futures prices lower than otherwise predicted by pure no-arbitrage theory.

Later theoretical developments enriched models of forward curves by integrating storage and examining option values for producers and physical storage market players (Litzenberger and Rabinowitz, 1995; Pindyck, 2004; Mire, 2000; Carter et al, 1983). This literature has also questioned the basic Keynesian assumption: Surely, some natural physical buyers in commodities markets, e.g. refineries, may take long positions for hedging purposes as well. Therefore, the existence of normal backwardation may occur when the balance of hedging and speculation is tilted in favor of short positions, but the forward curve may tilt in the opposite direction (negative normal backwardation would be an awkward term to describe this, but it is less confusing than "normal contango") when the balance of hedging is tilted in favor of long positions. Therefore, the degree of normal backwardation in any given epoch may be treated as an empirical object of investigation.

Energy markets are governed simultaneously by financial arbitrage as well as physical storage constraints. Simple no-arbitrage arguments suggest that future prices at shorter tenors, say one month, should be equal to the discounted price at longer tenors, say twelve months. Otherwise, assuming interest rates to be constant and zero cost of storage, as a baseline for simplicity, assume that the shorter tenor price was lower than the discounted longer tenor price. Then, one would borrow to buy (long) the short tenor contract and sell (short) the longer tenor contract, and by assumption the difference in price would be more than sufficient to compensate for interest on the loan, thus yielding an arbitrage profit. Allowing for the positive cost of storage merely augments the formula by adding the annual cost of storage as a percentage of the price to the annual interest rate when discounting the longer-term contract price. Proving equality in the opposite direction is easier if we consider a trader who already has some inventory. Assume that the short tenor price is higher than the discounted longer tenor price, then the trader would sell out of its inventory in the short term and simultaneously buy back the same amount at the longer tenor, investing the proceeds of the first sale at the interest rate assumed to be constant. By hypothesis, this also yields an arbitrage profit.

Hence, the no-arbitrage argument suggests that if interest rates were constant, longer tenor futures prices should be higher than expected future spot prices by exactly the amount that makes the latter equal to the discounted value of the former. Of course, the real-world shape of the forward curve depends not only on expected future spot prices but also on cost of storage and potential variability in interest rates, especially if the latter are correlated with prices. Nonetheless, in all instances, the role of storage remains critical for no-arbitrage arguments, which means that those with the ability to buy into or sell out of storage thus earn a "convenience yield" for the service that they provide by reducing price volatility (buying into storage when short-term prices are too low, and selling out of storage when they are too high). Of course, this role is constrained at both extremes: When the amount in storage approaches zero, the ability to prevent price spikes is limited, and vice versa as storage nears capacity, limiting the ability to prevent prices from falling precipitously (even to negative levels, as we saw in April 2020). In this regard, Mason and Wilmot underscored the link between U.S. inventory holdings and convenience yields in their study of variation in convenience yields related to the fracking boom and subsequent lifting of the U.S. export ban (Mason and Wilmot, 2020).

We seek to test the hypothesis that with cheap money, financial speculators are more likely to buy the most liquid short-tenor contracts, thus resulting in what we call supernormal backwardation—the tendency of the forward curve to be more downward sloping or less upward sloping than it would have been otherwise, taking into consideration no-arbitrage as well as normal backwardation arguments. Estimating a structural model that captures all of these factors seems infeasible, and our previous wavelet analysis of the data has suggested that there is fundamental non-stationarity in the relationships between geopolitics, financial liquidity and oil prices, with different variables leading others at different phase shifts in different periods (Abdel-Latif et al, 2020). We use several methodologies to contribute to the literature by providing an alternative measurement of the degree of speculation in oil price formation during times of low interest rates. Methodologically, we first apply a parsimonious Dynamic Nelson-Siegel factor model to decompose WTI forward curve dynamics. Then, we use the "slope" component of this decomposition as our measure of forward curve backwardation in two different types of regression analysis.

3. METHODOLOGY

Our results build on two methods that have been used increasingly in the literature over the past decade. We begin by utilizing a recently popular approach to modeling crude forward curve dynamics that borrows from the 1980s methods for analyzing US Treasury debt market yield curve dynamics. In this regard, WTI forward curve dynamics exhibit three stylized facts, which are similar to dynamics of Treasury yield curve dynamics:

1. Tendency to move in tandem. The primary explanatory variable for the WTI forward curve is its "Level," whether all futures prices at different tenors are high or low.
2. When the nearest contract price is too high, the curve tends to be downward sloping and vice versa. Hence, the second most important explanatory variable is "Slope."
3. Curve dynamics exhibit "volatility backwardation" (shorter tenor prices vary more than their longer term counterparts), which requires a third component: "Curvature."

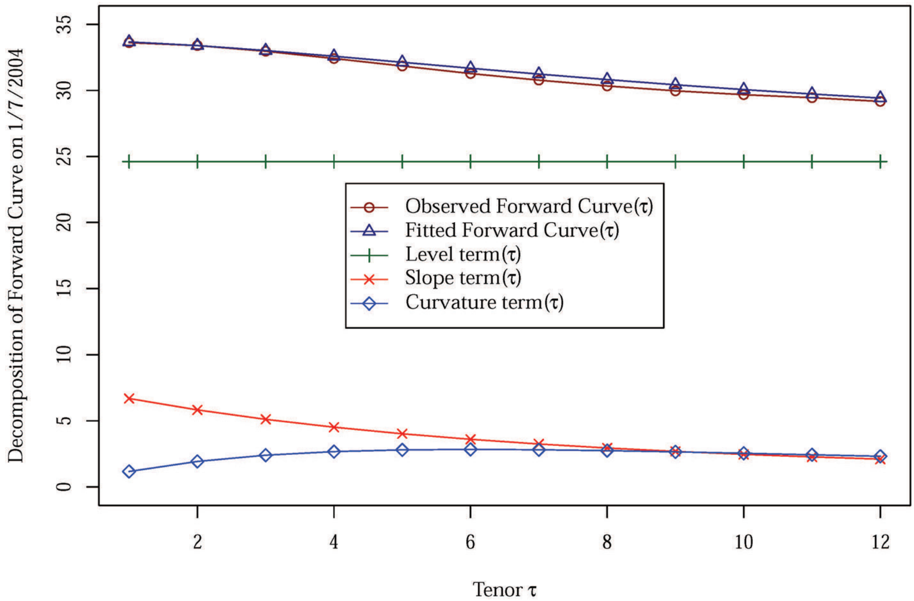
Several recent papers have used the parsimonious representation of these stylized facts by estimating the decomposition of the Treasury yield curve (now applied to WTI forward curve or forward yields calculated thereof by taking differences of log futures prices) into time varying level (L_t), slope (S_t) and curvature (C_t) (Spenser and Bredin, 2019; Bredin et al, 2020). Specifically, we estimate a dynamic extension of Nelson and Siegel (1987) that has been used to different ends elsewhere in the literature, e.g. in Bredin et al (2020) to study holding period returns from WTI carry:

$$F_t(\tau) = L_t + S_t\left(\frac{1-e^{-\tau\lambda}}{\tau\lambda}\right) + C_t\left(\frac{1-e^{-\tau\lambda}}{\tau\lambda} - e^{-\tau\lambda}\right) + \epsilon_t(\tau).$$

Further details of the econometric model are presented in the Appendix.

Figure 1 illustrates the decomposition of forward curve on 1/7/2004 into these three dynamic factors. The estimated value of L_t for that day was \$24.62, the estimated S_t was \$9.51 and the estimated C_t was \$7.74. Using our estimated $\lambda = 0.299$, we plot the three components as functions of tenor τ as well as the actual and fitted forward curves on that day. We can see

FIGURE 1
Decomposition of the Forward Curve into Level, Slope and Curvature



that the level of the curve was relatively low at the time, around \$25, but the short term prices were relatively elevated in the aftermath of the Iraq war, thus the downward sloping slope term, while the curvature term ensured that the rate of decline of futures prices as tenor increased was decreasing. Parameter estimates are provided in Table 2 in the Appendix, together with several plots of actual vs. fitted forward curves as well as time series of the three dynamic factors. The model fit for forward curve dynamics is remarkably good. Regressing time series of futures prices at tenors 1 through 12 on fitted values from the dynamic DNS model, the R^2 of all regressions exceed 0.996.

3.1 Static Analysis of Term Structure

In a second stage, we conduct dynamic model estimation including data on financial liquidity, geopolitical risk and futures market positions in the analysis. The last set of variables is motivated by Singleton (2010), which found that oil futures market participation by hedge funds and passive investors played a pivotal role in oil price levels and volatility. The first two variables are motivated by the well-known fact that increased liquidity due to quantitative easing has inflated several asset prices, including commodity prices. In this regard, Abdel-Latif and El-Gamal (2020) have shown that the dynamics of petrodollar recycling have served to amplify swings in oil prices through the financial liquidity channel. In addition, Abdel-Latif and El-Gamal (2022) have shown that the massive investments of major oil producers in pursuit of diversifying their economies away from oil are likely, under the current long-term prospects of relatively low oil prices and high geopolitical risk, to fail in achieving their objective. Instead, those massive investments will merely hasten petrodollar recycling reversal, thus contributing directly to the likely deceleration in global financial liquidity as central banks taper and then reverse their asset purchases over the next three years, unless another financial crisis and/or recession, potentially hastened by Russia's invasion of Ukraine, triggers yet another round of quantitative easing.

We first utilize more transparent regression analysis to investigate the partial correlations of the degree of backwardation in the WTI forward curve with a variety of physical, financial and geopolitical variables. Because of the obvious endogeneity between inventories and level of backwardation, as discussed in the introduction, we use instrumental variables for the inventory variables in regressions, where 23-day lags (one more than the typical number of trading days in a month). Results are reported in Table 2. The first regression (1) includes mainly physical market variables, the second (2) includes broad financial variables that may influence carry decisions, the third (3) includes net commitment of traders' positions by trader type, and the fourth (4) adds geopolitical threat and event risk indices.

3.2 Factor-Augmented Vector Autoregression

We then proceed to implement a simpler version of the dynamic factor analysis of Juvenal and Petrella (2015) by conducting a two-step FAVAR analysis similar to the simpler of two analyses pursued by Bernanke et al (2005). The latter had built on the dynamic factor analysis suggested by Stock and Watson (2002) and generated condence intervals for impulse response functions using the bootstrap method of Kilian (1998). The theoretical properties of this procedure were studied econometrically in Bai et al (2016), who suggested better estimation of the factors using Maximum Likelihood instead of Principal Component Analysis, as well as better ways for constructing condence intervals for the impulse response functions. In their nal version, Juvenal and Petrella (2015) used the rst-step principal component analysis to initialize an EM algorithm search to obtain MLE estimates of the dynamic factors (Bańbura and Modungo, 2014).

We could have likewise started with MLE estimates of factor loadings and followed with EM estimation using the R package MARSS. However, because Bernanke et al (2005) had found that the two-stage PCA estimation was similar to the fully Bayesian procedure, we will be content with using this simpler approach. Our main outputs from this analysis are impulse response functions to geopolitical threat and activity risks. Our measures of geopolitical threat and activity are those of Caldara and Iacoviello (2018), which are derived from automatic text searches of major newspapers on war threats vs. war escalation, terror threats vs. terrorist events, and so on, c.f. https://www.matteoiacoviello.com/gpr.htm. We focus on responses of the level of backwardation (DNS estimated slope) and inventories at the U.S. and global levels, as well as responses of the term premium and the commitments of trader positions for various categories. For each analysis, we estimate a FAVAR (23) model (23-day lag corresponding to just above the number of trading days in a month) with five factors estimated using principal components and the one variable representing the impulse in each analysis. Following Bernanke et al (2005), the identification strategy is implemented by using residuals from the regression of the five factors on factors obtained from "slow-moving" variables that are not expected to respond to financial market conditions at the daily frequency (indicated by * in the list of all variables in Table 5 in the Appendix).

4. RESULTS

4.1 Effects of Cheap Money

The Dynamic Nelson-Siegel model predicts most of the WTI forward price movements that have transpired in recent years, with the exception of the sharp market collapse that took place in 2014 and during the COVID-19 lockdowns in April 2020 (see Figures 6 and 8 in the Appendix). These two deep contango periods reveal the contribution of studying supernormal backwardation that preceded them—as surprisingly cheap money, indicated by negative Term Premia, incentivized the carry trade (buying CL1 and possibly selling longer-term tenors such as CL12, where CL1 is the front month futures contract price and CL12 is the 12th month) causing the forward curve to become less upward sloping or more downward sloping, depending on market fundamentals. This described pattern (negative Treasury term premia, excessive WTI forward curve backwardation) fits well with the episodes that lasted practically for the entire year 2014 and 2019, before mounting inventories precipitated the two deep discounts in prompt tenors (U.S. and global inventories are shown in Figure 9; backwardation patterns before these two crises are shown in Figure 10 in the Appendix).

Even if CL12 is not sufficiently high during these episodes, traders may still speculatively buy CL1 in anticipation of its value rising in the future, without locking in their profits by shorting CL12. In this case, net long positions observed in CFTC positions of traders should rise. Buying of CL1 in either the hedged or unhedged cases leads to a fast accumulation of crude inventories. If fundamentals traders prevent CL12 from falling further or CL1 from rising sufficiently to stop the carry trade, even as storage capacity is exhausted, a crisis ensues as the price of CL1 collapses and the forward curve goes into steep contango. A similar episode had occurred shortly after the Financial Crisis in 2008, but we focus here on those two episodes in 2014 and 2019—in part because some EIA data, especially on storage capacity utilization, is only available starting March 2011.

4.2 Regressions

The Hausman-Wu test strongly rejects OLS exogeneity assumptions in all regressions in Table 1, so we report the IV regression results only, although the OLS results are not qualitatively different. Estimation was conducted using the ivreg package in R, and tests of the null hypothesis of instrument weakness resulted in rejection for all endogenous variables in all models. The main interesting results from these regressions, are the following:

- Financial variables add roughly 25% to the explanatory power of the Slope factor in WTI forward curve term structure, and net trader positions add another 40% of explanatory power.
- When we add the geopolitical risk variables to the analysis in (4), the effect of net long positions taken through money managers on supernormal backwardation becomes statistically insignificant. In its place, we see the frequently hypothesized effect of "buying the threat and selling the event" (positive first coefficient and negative second). The net positions of commercial and physical traders remain significant and in the same direction of this geopolitical trade.
- Only after we include the geopolitical risk variables does the effect of one-year Treasury term premium, which measures interest rate deviations from their expectations, become significant. The direction is as predicted: When term premium falls, it leads to greater carry trade (buying of CL1), and hence supernormal backwardation, but only once we account for geopolitical risk variables. This is consistent with the view that unexpectedly low interest rates can fuel bubbles in all markets, but they tend to migrate to the oil market mainly when there is a geopolitical "story" to justify unreasonably high prices.
- The remaining coefficients in the full model (4) are consistent with what we would expect:

TABLE 1

Backwardation IV Regressions vs. Fundamentals, GPR, and Financial Variables (Commitments of Traders interpolated to Daily; Variables defined in Table 5 in Appendix)

	Dependent variable:			
	Backwardation			
	(1)	(2)	(3)	(4)
GPR_THREAT				0.031***
				(0.004)
GPR_ACT				–0.047***
				(0.006)
MMnetlong			0.014***	0.005
			(0.004)	(0.004)
SDnetlong			–0.032***	–0.038***
			(0.003)	(0.003)
Physnetlong			0.031***	0.023***
			(0.004)	(0.004)
ACMTP01		1.173	–1.717*	–3.212***
		(1.308)	(1.026)	(1.165)
ACMRNY01		–0.192	–2.169***	–3.447***
		(0.242)	(0.223)	(0.270)
SP500ret		5.765	–3.480	–2.937
		(12.180)	(9.495)	(9.441)
VIX		–0.133***	–0.132***	–0.119***
		(0.032)	(0.025)	(0.025)
Credit Spread Corporate		–8.381***	0.544	–0.021
		(0.609)	(0.535)	(0.537)
Hurricane_Threat	–0.076***	–0.068***	–0.011	–0.012
	(0.015)	(0.014)	(0.011)	(0.011)
Hurricane_Event	–0.063***	–0.053***	–0.016	–0.020
	(0.022)	(0.020)	(0.016)	(0.016)
IGREA	0.110***	0.085***	0.060***	0.049***
	(0.005)	(0.005)	(0.004)	(0.004)
log(US Storage Slack)	5.398***	5.554***	–5.721***	–7.037***
	(0.364)	(0.364)	(0.481)	(0.499)
log(Global Oil Inventory)	–6.861***	–20.390***	–40.538***	–54.084***
	(1.732)	(3.308)	(2.986)	(3.463)
Industrial Prod Growth	3.949	–30.847***	39.795***	51.906***
	(10.805)	(10.117)	(8.106)	(8.164)
US Distillate Supply	0.001**	0.0005	–0.00003	0.0003
	(0.0005)	(0.0005)	(0.0004)	(0.0004)
US Refining Utilization Rate	0.022	–0.061*	0.019	0.003
	(0.031)	(0.034)	(0.028)	(0.027)
US Econ Policy Uncertainty	–0.028***	–0.007***	–0.016***	–0.014***
	(0.002)	(0.002)	(0.002)	(0.002)
Constant	73.928***	213.958***	342.038***	458.221***
	(15.476)	(30.457)	(27.088)	(31.135)
Observations	2,599	2,599	2,599	2,599
R^2	0.445	0.541	0.722	0.726
Adjusted R^2	0.443	0.538	0.720	0.723

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

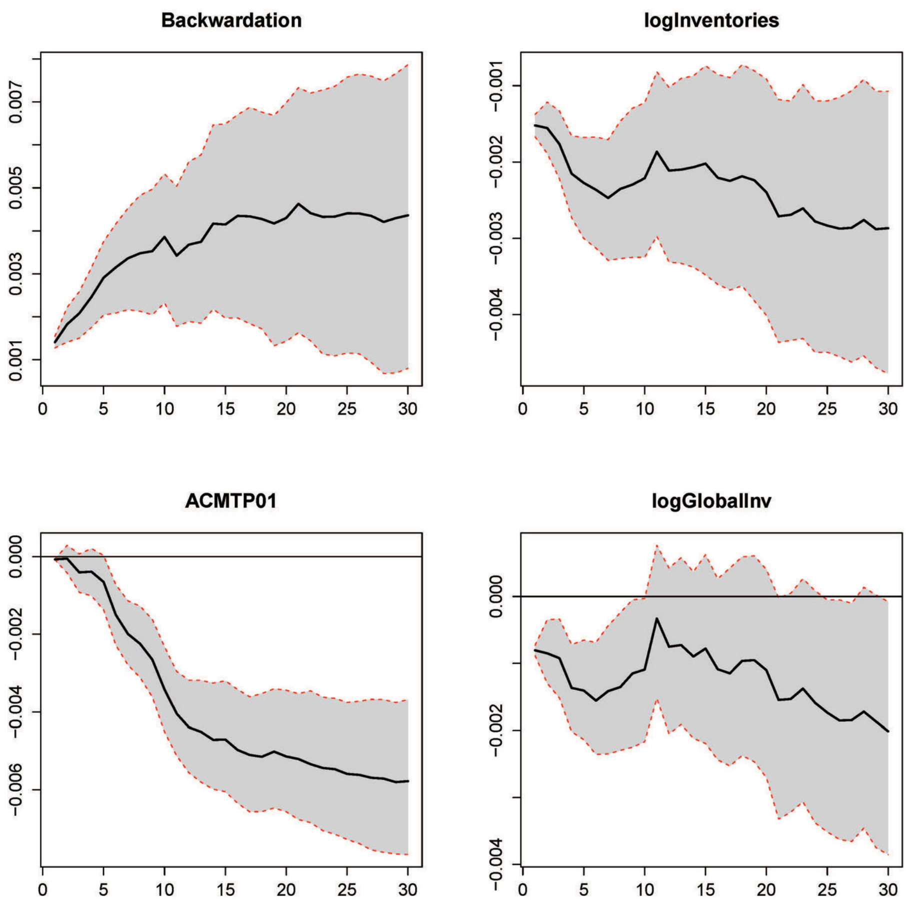
- Cheaper money contributes to higher CL1 (and backwardation).
- Higher uncertainty, whether financial (measured by VIX) or real (measured by US Economic Policy Uncertainty Index) results in lower CL1.
- Higher levels of real economic activity contribute positively to higher CL1.
- Higher levels of log global oil inventory prevent oil prices from rising too far.
- Higher levels of slack storage capacity prevent prices from rising too far.

4.3 FAVAR Time Series

The time series and its FAVAR(23) predicted counterpart for a few select series are shown in Figure 11 in the Appendix. Figures 3 and 4 reconfirm the importance of geopolitical risk factors shown in the static analysis of the previous section.

- The level of backwardation jumps up following either a surprise increase in geopolitical threat or activity, but the jump following a threat persists longer than that after an actual event—and we note that geopolitical events typically take place after a geopolitical threat had already been registered.
- Inventories are depleted both at the U.S. and global levels, perhaps in reaction to and to temper the price increase due to the geopolitical risk shock.

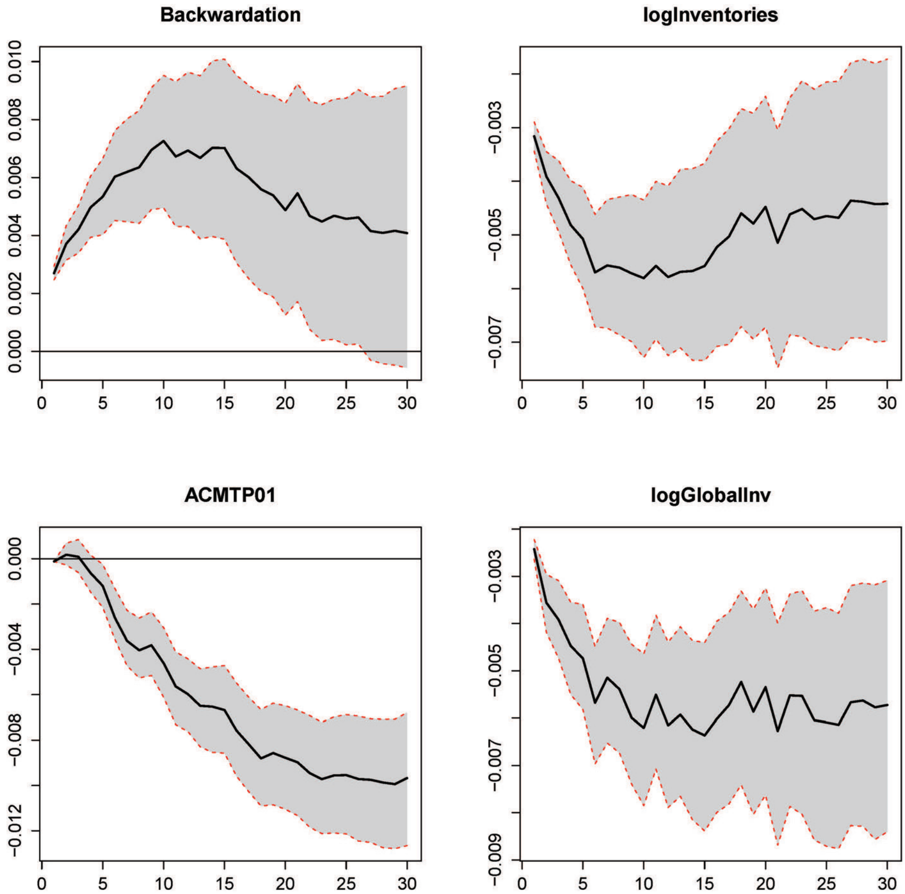
FIGURE 2
Impulse Response Functions to A Shock in GPR_THREAT



- Interest rates decline much more than expected by the purely economic-financial ACM model, starting about a week after the geopolitical shock, but persisting and increasing over time. Forecast variance decompositions suggest that the full model explains a substantial (nearly 95%) percentage of inventory fluctuations, and the geopolitical risk factors contribute about two to 6 percent of that—suggesting that geopolitical risk factors by themselves are not sufficient to explain a significant percentage of inventory fluctuations, but serve as a catalyst together with cheap money policies to drive carry trades that affect inventories significantly.

FIGURE 3

Impulse Response Functions to A Shock in GPR_ACT



5. DISCUSSION AND CONCLUSION

Our regression analysis revealed that speculators do often buy the geopolitical risk and sell the event, as commonly hypothesized by many but (to our knowledge) not shown empirically before this study. We also find that interest rate effects on speculative behavior in WTI become pronounced only in conjunction with geopolitical risk—suggesting that while low interest rates for prolonged periods of time fuel bubbles in a variety of markets, their effect on oil market speculation is particularly strong when coupled with a geopolitical risk story to justify unreasonably high prices (as our previous research had suggested was the case during the Arab Spring years 2011-2014). This finding contributes a more nuanced interpretation of the impact of low interest rates which heretofore has been theorized to decrease price volatility (Gruber and Vigfusson, 2013).

Financial and geopolitical variables together explain a very significant percentage of the variation in WTI forward curve slope, thus suggesting that regulators might wish to pay special attention to the effect of speculative activity during and around periods of low interest rates and heightened geopolitical risk. Dynamic analysis using our Factor Augmented VAR confirmed that independent shocks either to geopolitical threat or (sudden, if not preceded by threat) events result in sustained heightening of supernormal backwardation for a month or more.

This research thus shows the importance of financial liquidity and geopolitical variables in explaining fluctuations in oil prices more generally, which we had emphasized in an earlier book (El-Gamal and Jae, 2009) and several research articles (El-Gamal and Jae, 2018; Abdel-Latif and El-Gamal, 2020; Abdel-Latif et al, 2020; Abdel-Latif and El-Gamal, 2022). It contributes to the body of empirical evidence that justifies stricter position limits and/or margin requirements for early tenor oil futures contracts. This paper has focused, in particular, on the speculative component in oil price fluctuations as measured by the slope of the WTI forward curve. We combined two methods from the literature—namely Dynamic Nelson-Siegel factor analysis and Factor-Augmented Vector Autoregression—to study the contemporaneous and dynamic impacts of fundamental, financial and geopolitical variables on WTI forward curve term structure. We identified important financial and geopolitical variables that explain when and how speculative behavior in crude futures seems to take place. Thus, we have contributed to the literature on speculation in oil markets, hopefully suggesting important considerations for regulators when studying market and global conditions that may be conducive to speculative activity in the market. Such extreme fluctuations may result in crises, for example, as Treasury term premia become very negative and storage capacity is exhausted, which may trigger further super-contango crises as we have witnessed most dramatically last year.

Since financial and geopolitical variables together explain a very significant percentage of the variation in WTI forward curve slope historically, we suggest that regulators need to pay special attention to the effect of speculative activity during and around periods of low interest rates and heightened geopolitical risk. Our analysis contributes to evidence needed to support mechanisms to limit volumes for early tenor oil futures contracts and to investigate, as suggested by Citi, the large role of passive investors in fueling upward price movements, with an eye to discouraging such investors from exacerbating the negative financial effects of geopolitical crises. This is consistent with the recommendation in Chan et al. (2015) that US exchanges need to strengthen volatility-based margin requirements. We sharpen this policy recommendation by suggesting that CFTC should require US exchanges make margin call requirements, especially for early-tenor contracts, based on volatility not only of the front month contract but also on the degree of market backwardation. These margin requirements should also be lower for positions held to hedge physical exposure as opposed to speculative positions, in parallel to accounting standard FASB 133, which provides tax disincentives for speculative trading in derivatives. Toward that end, to aid policy makers in acting under Section 5 authorities to address unreasonable fluctuations, and to allow researchers to shed further light on the problem and potential remedies, CFTC should require and release to the public a more transparent and detailed breakdown of positions held in WTI in order more easily to identify the volume of positions held by passive investors and/or financial speculators.

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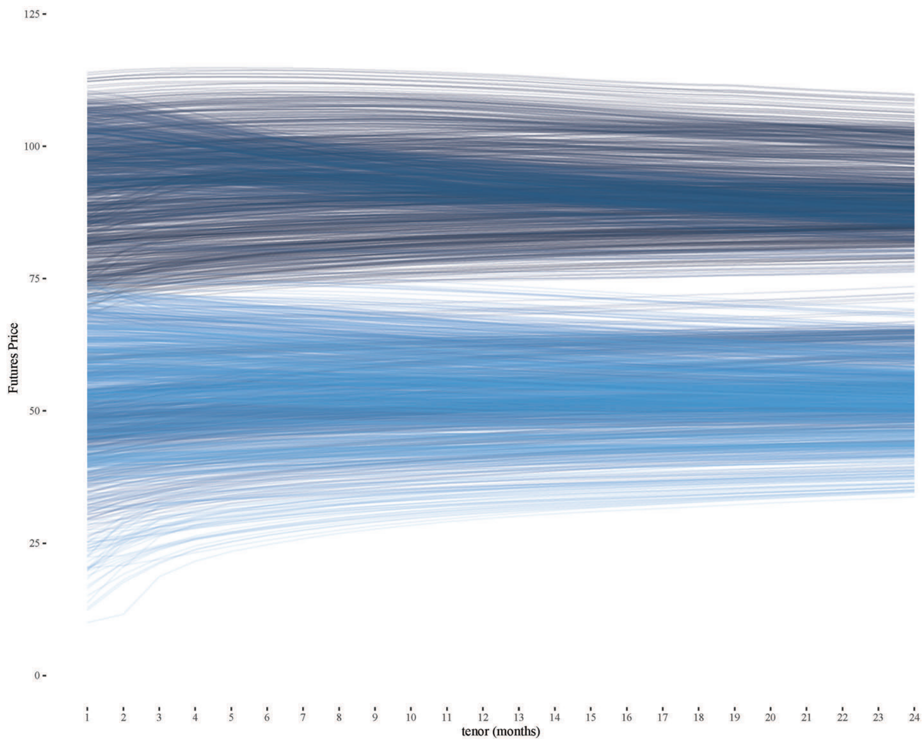
APPENDIX

The three stylized facts of forward curve dynamics are shown in Figure 4

FIGURE 4
Forward Curves over Time



Formally, the Dynamic Nelson-Siegel model of (Diebold et al, 2004) to explain these dynamics consists of the measurement equations:

$$F_t(\tau) = L_t + S_t\left(\frac{1-e^{-\tau\lambda}}{\tau\lambda}\right) + C_t\left(\frac{1-e^{-\tau\lambda}}{\tau\lambda} - e^{-\tau\lambda}\right) + \epsilon_t(\tau),$$

together with the mean-reverting vector autoregression state equations describing the law of motion for our variables of interest:

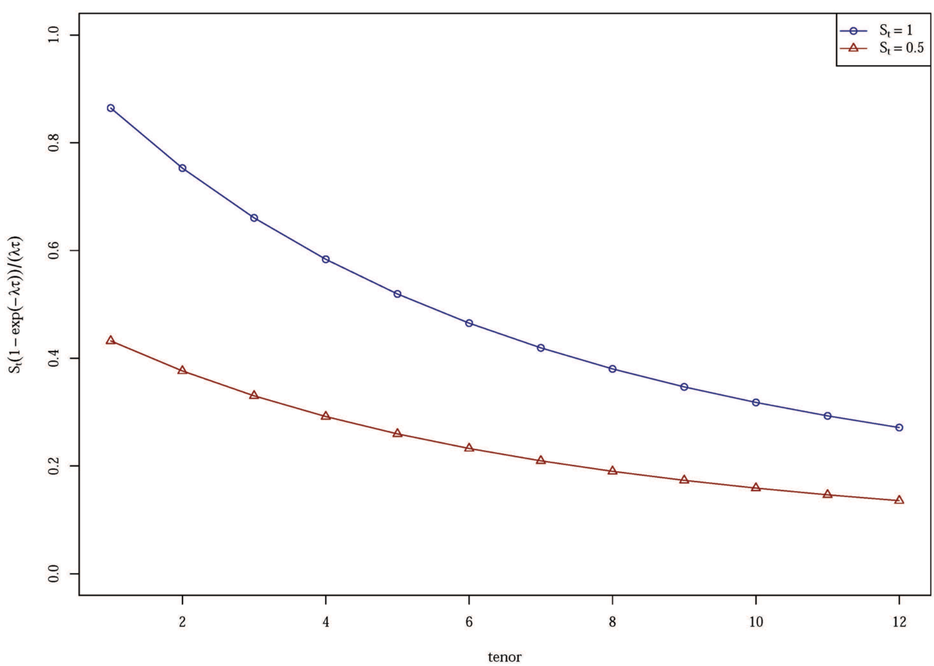
$$\begin{pmatrix} L_t - \mu_L \\ S_t - \mu_S \\ C_t - \mu_C \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix} \begin{pmatrix} L_{t-1} - \mu_L \\ S_{t-1} - \mu_S \\ C_{t-1} - \mu_C \end{pmatrix} + \begin{pmatrix} \eta_t(L) \\ \eta_t(S) \\ \eta_t(C) \end{pmatrix}$$

This state-space model has 20 parameters: λ, σ^2 which we assume to be the variance for all elements of $\epsilon_t(\tau)$, six parameters defining the 3×3 contemporanious covariance matrix of the vector $(\eta_t(L), \eta_t(S), \eta_t(C))$, nine parameters for the autoregressive parameters a_{ij}, and three parameters for the means (μ_L, μ_S, μ_C). The parameters are estimated via MLE Kalman-filter (due to nonlinearity in , using Nelder-Mead optimization at first and then BFGS until convergence), assuming contemporaneous joint normality of the vector $\epsilon_t(\tau), \tau \in \{1,\ldots,12\} \sim N(0, \sigma^2 I_{12})$ as well as the vector $(\eta_t(L), \eta_t(S), \eta_t(C)) \sim N(0, Q)$ using the R state space model package statespacer. The estimation reported below used only the forward curve data up to the 12th month, because futures with higher tenors trade significantly less frequently. As commonly done in this literature, Table 2 reports point estimates along with estimated standard errors for the most basic model parameters. The remaining fifteen estimated parameters are elements of the covariance matrices of ϵ, which do not lend themselves to easy interpretation.

TABLE 2
Dynamic Nelson-Siegel Parameter Estimates

Parameter	Value	S.E.
λ	0.299	0.012
σ^2	1.556	0.010
μ_L	3.422	28.93
μ_S	–0.71	13.09
μ_C	3.234	8.583

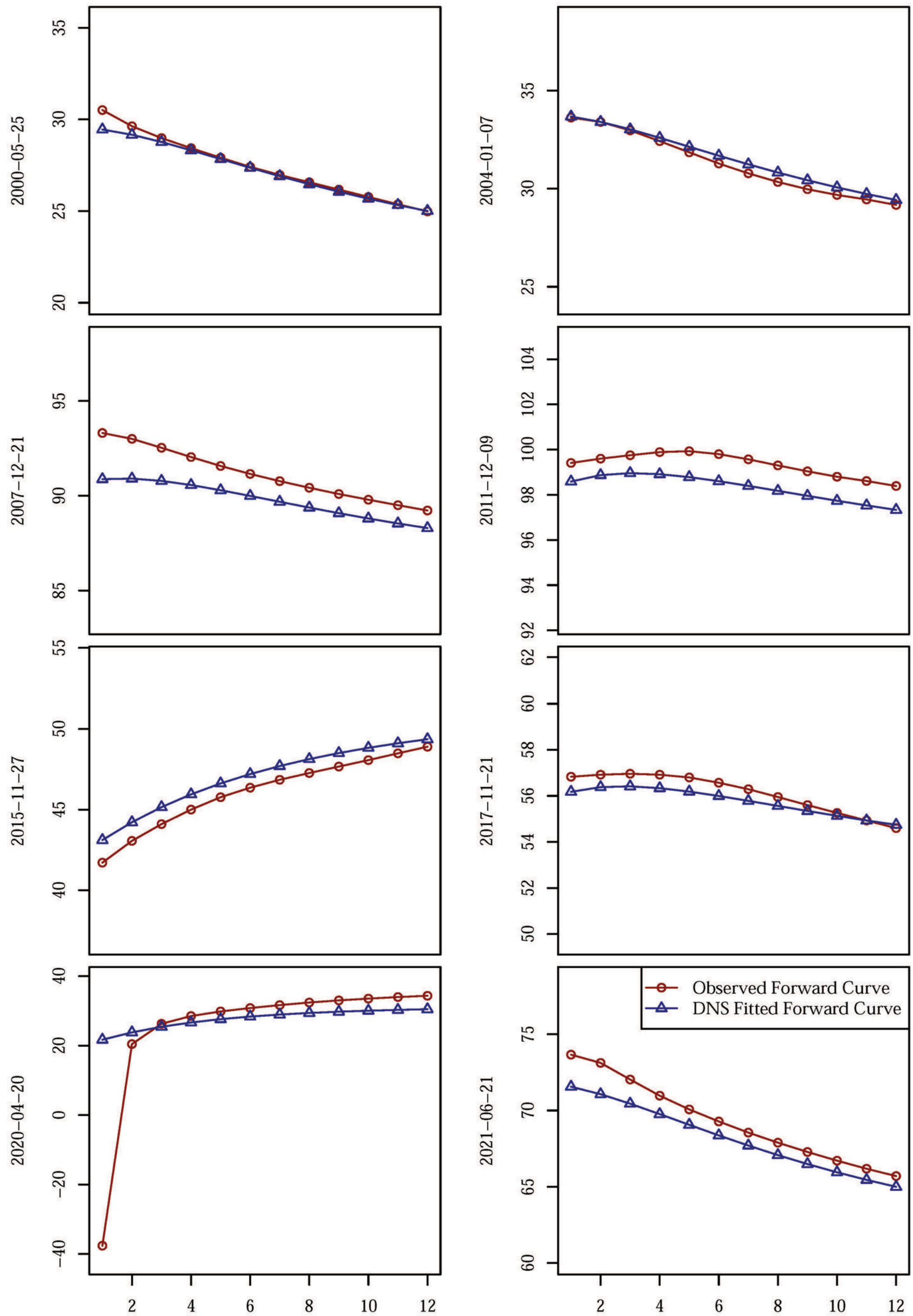
FIGURE 5
Illustration of the function $S_t\,(1-e^{-\tau\lambda})/(\tau\lambda)$ for $S_t \in \{0.5, 1\}$ and $\lambda = 0.2985328$



Please note that the function $(1-e^{-\tau\lambda})/(\tau\lambda)$ multiplied by a positive slope term S_t is downward sloping, as illustrated in Figure 5 for the values of $S_t \in \{0.5, 1\}$ and the estimated value of $\lambda = 0.2985328$. Thus, larger values of the DNS estimated "slope" corresponds to higher degrees of backwardation. The goodness of fit of the model is illustrated by comparing the observed and fitted forward curves for several dates, as shown in Figure 6.

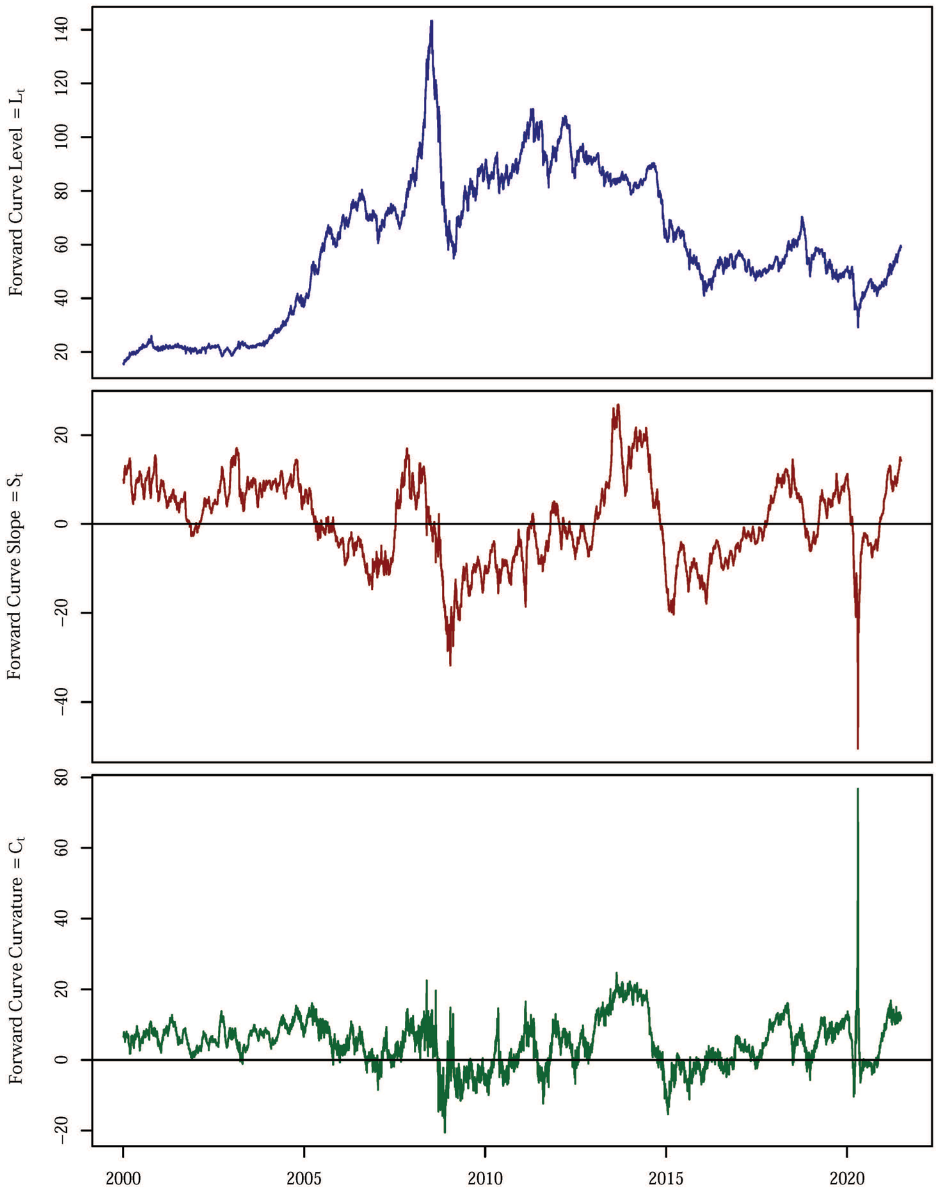
FIGURE 6

Dynamic Nelson-Siegel Model Predicted (blue) vs. Actual (red) on Different Dates (Shown on y axes)



The time series of the estimated three series L_t, S_t and C_t is shown in Figure 7:

FIGURE 7
Time Series of Estimated Dynamic Nelson-Siegel Components



Goodness of fit of the estimated DNS model are shown for different tenors in Figure 8

FIGURE 8
Goodness of Fit of Dynamic Nelson-Siegel Estimation

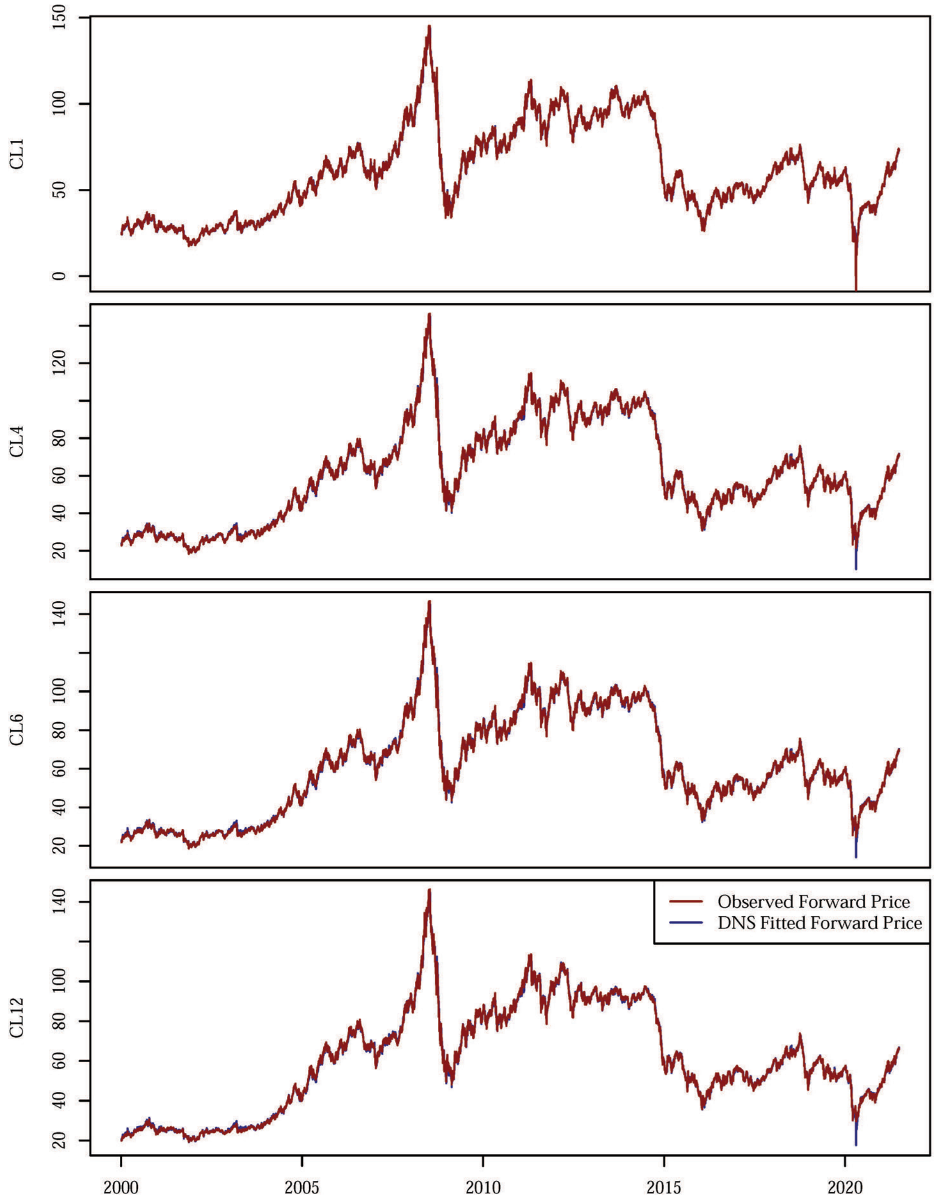


FIGURE 9
U.S. and Global Inventories Series

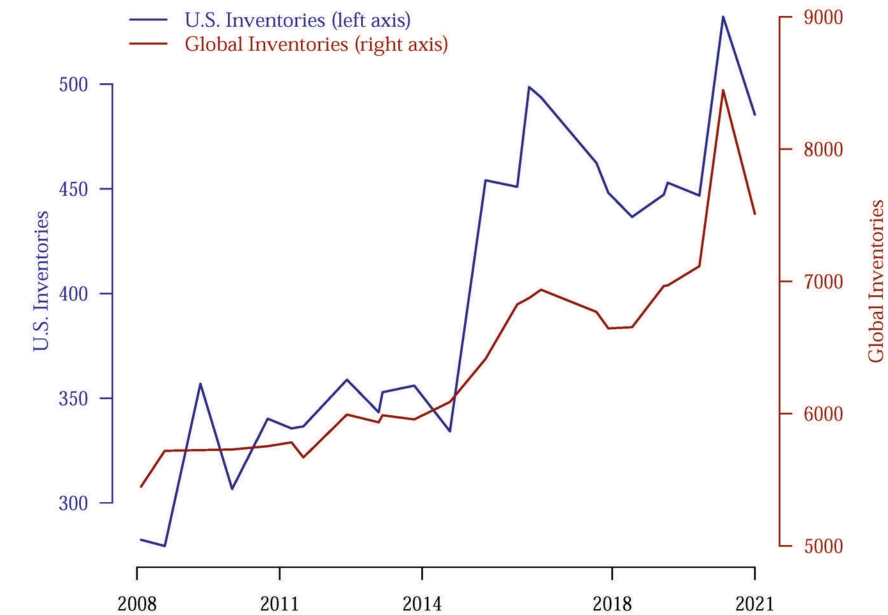


FIGURE 10
Backwardation Patterns before Crises

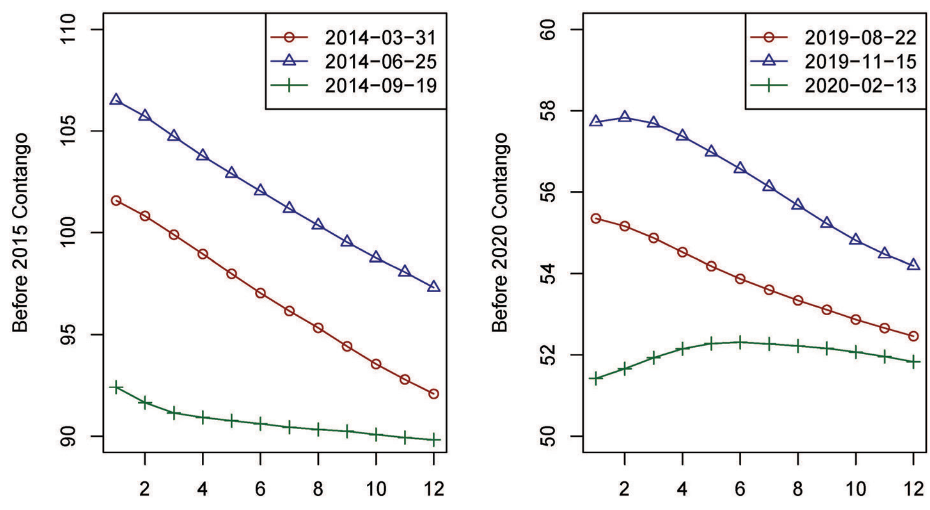


FIGURE 11
Goodness of Fit of FAVAR model

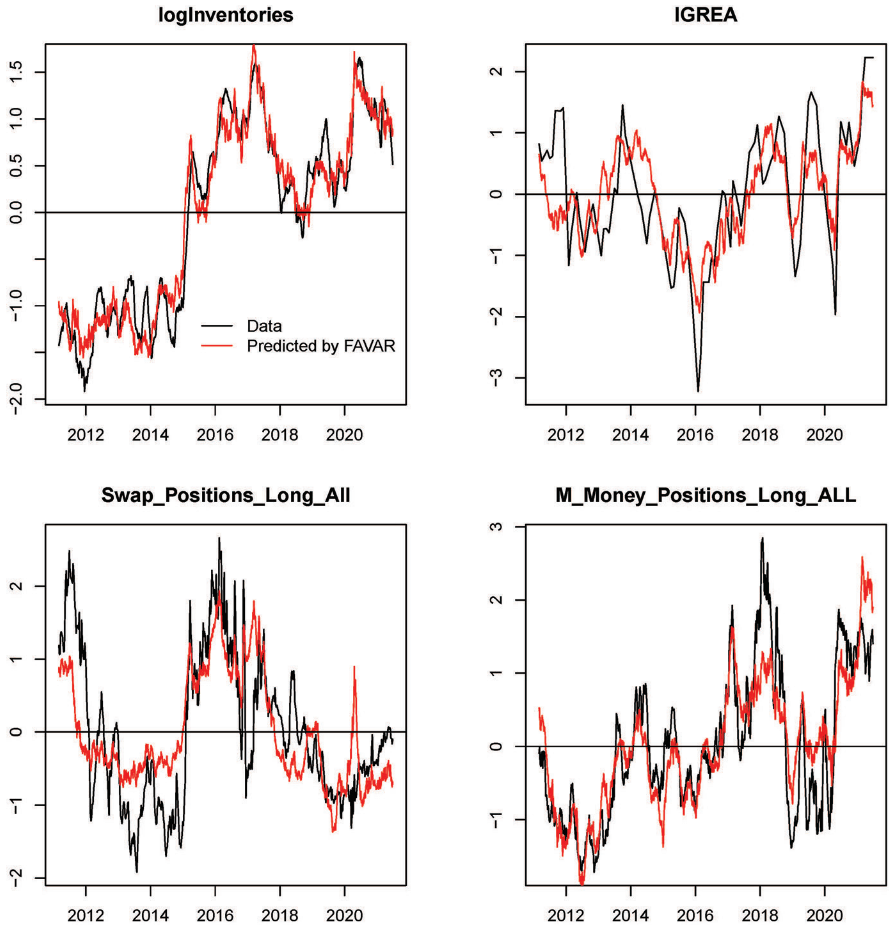


TABLE 3
Percentage of Forecast Variance Explained by GPR_THREAT & Full Model

	Variables	Contribution	R.squared
1	Backwardation	0.02	0.78
2	logInventories	0.02	0.94
3	ACMTP01	0.03	0.73
4	Prod_Merc_Positions_Long_ALL	0.01	0.78
5	Prod_Merc_Positions_Short_ALL	0.03	0.84
6	Swap_Positions_Long_All	0.01	0.54
7	Swap__Positions_Short_All	0.00	0.90
8	Swap__Positions_Spread_All	0.01	0.58
9	M_Money_Positions_Long_ALL	0.00	0.73
10	M_Money_Positions_Short_ALL	0.00	0.69
11	M_Money_Positions_Spread_ALL	0.01	0.84
12	logGlobalInv	0.01	0.93

TABLE 4
Percentage of Forecast Variance Explained by GPR_ACT & Full Model

	Variables	Contribution	R.squared
1	Backwardation	0.02	0.79
2	logInventories	0.06	0.95
3	ACMTP01	0.04	0.74
4	Prod_Merc_Positions_Long_ALL	0.00	0.78
5	Prod_Merc_Positions_Short_ALL	0.00	0.84
6	Swap_Positions_Long_All	0.07	0.62
7	Swap__Positions_Short_All	0.00	0.91
8	Swap__Positions_Spread_All	0.00	0.57
9	M_Money_Positions_Long_ALL	0.00	0.73
10	M_Money_Positions_Short_ALL	0.00	0.70
11	M_Money_Positions_Spread_ALL	0.01	0.84
12	logGlobalInv	0.06	0.93

TABLE 5
List of Variables used in FAVAR Analysis

	List of Variables	Source
1	Backwardation	DNS calculated from CME CL1-CL12
2	logInventories	log of EIA crude stock excludings SPR
3	ACMY01	NYFED (one year yield)
4	ACMY02	NYFED (two year yield)
5	ACMY03	NYFED (three year yield)
6	ACMY04	NYFED (four year yield)
7	ACMY05	NYFED (five year yield)
8	ACMY06	NYFED (six year yield)
9	ACMY07	NYFED (seven year yield)
10	ACMY08	NYFED (eight year yield)
11	ACMY09	NYFED (nine year yield)
12	ACMY10	NYFED (ten year yield)
13	ACMTP01	NYFED (one year term premium)
14	ACMTP02	NYFED (two year term premium)
15	ACMTP03	NYFED (three year term premium)
16	ACMTP04	NYFED (four year term premium)
17	ACMTP05	NYFED (five year term premium)
18	ACMTP06	NYFED (six year term premium)
19	ACMTP07	NYFED (seven year term premium)
20	ACMTP08	NYFED (eight year term premium)
21	ACMTP09	NYFED (nine year term premium)
22	ACMTP10	NYFED (ten year term premium)
23	ACMRNY01	NYFED (one year predicted yield)
24	ACMRNY02	NYFED (two year predicted yield)
25	ACMRNY03	NYFED (three year predicted yield)
26	ACMRNY04	NYFED (four year predicted yield)
27	ACMRNY05	NYFED (five year predicted yield)
28	ACMRNY06	NYFED (six year predicted yield)
29	ACMRNY07	NYFED (seven year predicted yield)
30	ACMRNY08	NYFED (eight year predicted yield)
31	ACMRNY09	NYFED (nine year predicted yield)
32	ACMRNY10	NYFED (ten year predicted yield)
*33	GPR_THREAT	Caldara and Iacoviello Index
*34	GPR_ACT	Caldara and Iacoviello Index
*35	dM2	1st difference of M2, FRED (St. Louis Fed)
36	Prod_Merc_Positions_Long_ALL	CFTC Commitments of Traders
37	Prod_Merc_Positions_Short_ALL	CFTC Commitments of Traders
38	Swap_Positions_Long_All	CFTC Commitments of Traders
39	Swap__Positions_Short_All	CFTC Commitments of Traders
40	Swap__Positions_Spread_All	CFTC Commitments of Traders
41	M_Money_Positions_Long_ALL	CFTC Commitments of Traders
42	M_Money_Positions_Short_ALL	CFTC Commitments of Traders
43	M_Money_Positions_Spread_ALL	CFTC Commitments of Traders
*44	IGREA	Kilian Index of Real Economic Activity (Dallas Fed)
45	log(US Storage Slack)	log (1-EIA storage utilization - 0.25)
46	log(Global Inventories)	log of global inventories from PIW, monthly issues
47	S&P500 returns	log Returns of S&P500, YAHOO Finance
*48	Dollar Index	Trade weighted, FRED (St. Louis Fed)
*49	Inflation	from CPI FRED (St. Louis Fed)
50	VIX	YAHOO Finance
*51	Industrial Prod Growth	1st diff of log of Industrial Production, FRED (St. Louis Fed)
*52	Credit Spread Corporate	FRED (St. Louis Fed)
*53	Chicago Fed National Activity Index	FRED (St. Louis Fed)
*54	US Economic Policy Uncertainty	FRED (St. Louis Fed)
*55	US Distillate Supply	EIA PET.WDIUPUS2.W
*56	US Refinery Utilization Rate	EIA PET.WPULEUS3.W

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The IAEE is pleased to announce that our leading publications exhibited strong performances in the latest 2021 Impact Factors as reported by Clarivate. The Energy Journal achieved an Impact Factor of 3.494 while Economics of Energy & Environmental Policy received an Impact factor of 1.800.

IAEE wishes to congratulate and thank all those involved including authors, editors, peer-reviewers, the editorial boards of both publications, and to you, our readers and researchers, for your invaluable contributions in making 2021 a strong year. We count on your continued support and future submission of papers to these leading publications.