Institute for New Economic Thinking
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Betting on black gold: Oil speculation and U.S. inflation (2020-2022)

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Working Paper No. 208

June 6th, 2023

Abstract

Sharp increases in systemically important crude oil prices have been a major cause of the recent surge in the inflation rate in the U.S. This paper investigates the extent to which the increase in oil prices can be attributed to excessive speculation in the oil futures market. Our analysis suggests that excessive speculation in the crude oil market has been responsible for 24%-48% of the increase in the WTI crude oil price during October 2020-June 2022. These estimates translate into an oil price increase of around \$18-\$36 per barrel and an increase in the U.S. PCE inflation rate by circa 0.75 to 1.5 percentage points during the same period. We complement the analysis with an empirical investigation of the crude oil market which shows that (speculative) long non-commercial open-interest positions in oil futures have increased considerably relative to short non-commercial positions. We further find that higher futures prices for crude oil 'Granger-cause' oil spot prices, the futures prices of corn and soybeans and the fertilizer price. These econometric results show that oil speculators have to be held accountable for not just raising oil prices, but also driving up food

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The authors thank Thomas Ferguson and an anonymous referee for extended comments and suggestions.

commodity prices. We finally discuss measures to clamp down on excessive speculation in oil in order to eliminate its systemically adverse consequences for the U.S. economy.

https://doi.org/10.36687/inetwp208

JEL codes: E0; E5; E6; E62; O23; I12; J08.

Key words: inflation; oil prices; oil majors; spot and futures prices; speculation; Granger causality; Working's T-index; speculative pressure; commercial and non-commercial traders; open interest; index investor.

… buyers and sellers of oil and other commodities are outnumbered something like 10 to one by Wall Street traders, none of whom have a genuine buyer's incentive to keep prices low, because few of them ever actually buy it; they mostly bet on it. Because deregulated traders dramatically outnumber them, genuine buyers and sellers are virtually irrelevant now when it comes to setting prices. That, Greenberger says, is what's causing Ukraine and other supply issues to create disproportionately large impacts on prices: Wall Street is amplifying spikes ….

—*The Young Turks*, June 14, 2022.
https://tyt.com/reports/4vZLCHuQrYE4uKagy0oyMA/e1018f2cc10fa8316

I. Introduction

Of all the drivers behind the dramatic surge in U.S. inflation in the past two years, one of the most significant is the rise in energy prices. The price of crude oil rose from around $40 per barrel in the second half of 2020 to a peak of $115 in June 2022. During the same period, the U.S. Personal Consumption Expenditure (PCE) price index for energy increased by more than 70%. Prices of oil, gas and electricity are unusually important because American consumers pay close attention to them (after all, energy's share of consumer spending is around 5%) and energy is a critical input into the production of most other goods and services. The macroeconomic significance of energy prices is underscored by the findings of a recent input-output analysis for the U.S. economy (2000-2019) by Weber, Jauregui, Teixeira and Nassif Pires (2022), who show that energy prices (notably petroleum and coal prices) are *systemic*ally important to overall price stability in the U.S.

High prices for fuel and electricity have continued to put pressure on inflation during 2022, in response to which the Federal Reserve decided to drastically tighten monetary policy, raising interest rates from near zero during the second half of 2021 to 4.83% in April 2023. The drastic monetary tightening is lowering demand and slowing economic growth.

Since energy prices are systemically important to the overall price level and the cost of living, it is important to understand the origins of the recent hike in energy prices. A number of observers have pointed fingers at the growing flow of money into financial instruments tied to oil (Meyer 2018; Larsen 2022; Verleger 2022; EIA 2023). These money flows, they argue, have pushed the oil price up and away from its 'fundamental' value. It is well known that hedge funds are very active in the oil market and their activity, along with other speculators, has raised the volume of oil transactions far above the volume warranted by ordinary commercial transactions (Eckaus 2008). However, some observers are skeptical that the oil price spike during 2020-2022 was speculative, arguing that the underlying (geopolitical) fundamentals of oil supply and demand changed significantly during this period (Foreman 2022; EIA 2023). Hence, and specifically focusing on the U.S. oil market, we ask the question whether the sharp increases in prices during 2020-2022 were due to fundamental shifts in supply and demand or whether they must be attributed (at least partly) to excessive market speculation.

To answer this question, we apply the analytical framework proposed by Knittel and Pindyck (2016) to recent data for the years 2020-2022 in order to determine whether speculation as a factor driving recent oil price increases is "consistent with the data on production, consumption, inventory changes, and spot and futures prices, given reasonable assumptions about elasticities of supply and demand" (Knittel and Pindyck 2016, p. 88).

According to the model analysis, excessive speculation in the crude oil market has been responsible for 24%-48% of the increase in the WTI crude price during October 2020-June 2022. These estimates would translate into an oil price increase of around $18-$36 per barrel and an increase in the U.S. PCE inflation rate by circa 0.75 to 1.5 percentage points during October 2020-June 2022. We complement our model analysis by an empirical investigation, based on monthly data for the period January 2004-January 2023. We show that (speculative) long non-commercial open-interest positions in oil futures have increased considerably relative to short non-commercial positions, signaling a sustained and significant increase in speculative pressure in the oil market. And using Granger causality tests, we explore the potential impacts of higher prices for crude oil on the futures prices of corn and soybeans (which are major food commodities) and the price of fertilizers (a major agricultural input). Our econometric results show that oil speculators have to be held accountable for driving up food commodity prices as well—and by doing so, oil speculators have further fueled U.S. consumer price inflation, while increasing food insecurity and food poverty in the U.S. itself as well as abroad.

Our paper is organized as follows. In the next section, we discuss the empirical record on the recent surge in U.S. inflation, the rise in (crude) oil and energy prices, and the contribution of energy inflation to overall consumer price inflation. In **Section III**, we briefly discuss the 'simple' model of Knittel and Pindyck (2016) and next present our empirical evidence, which separates the effects on oil prices of speculative activity from the effects of shifts in fundamental drivers of supply and demand. In **Section IV**, we present additional evidence on speculative activity in the oil market based on Working's T-index and a measure of speculative pressure (Algieri 2016). **Section V** presents evidence on the (causal) impacts of higher oil prices on the prices of key food commodities and fertilizers. **Section VI** concludes.

II. Higher energy prices and U.S. inflation

In the first two decades of the new millennium, the average annual rate of PCE inflation in the U.S. was low—2.1% per year during 2000-2010 and only 1.5% per year during 2010-2020.[1] But then the U.S. inflation rate began to accelerate to around 4% in the middle of 2021 and further up to a peak of almost 7% in June 2022. The surge in U.S. inflation has been attributed to a number of supply-side causes (Ferguson and Storm 2023; Storm 2022), namely: (*1*) higher import prices; (*2*) higher energy prices; (*3*) higher corporate profit margins; and (*4*) the impact of COVID19 on wages in (mostly) low-wage occupations that had previously been considered safe. In addition, as Ferguson and Storm (2023) show, U.S. inflation has increased in response to the recovery of aggregate U.S. consumption expenditure during mid-2021 and end-2022, caused by unprecedented gains in household wealth, particularly for the richest 10% of American households.

Our focus here is on the impact of higher energy prices and oil prices, in particular on the PCE inflation rate during January 2020 – February 2023. During these 38 months, the PCE price index rose by 13.8%, while the PCE price index for energy goods & services increased by 43.1%. Since energy is a major item of consumer expenditure, the sharp increase in energy prices did raise the PCE inflation rate. Direct evidence on the contribution of the energy price inflation to the PCE inflation rate during January 2020 – February 2023 is presented in **Figure 1**.

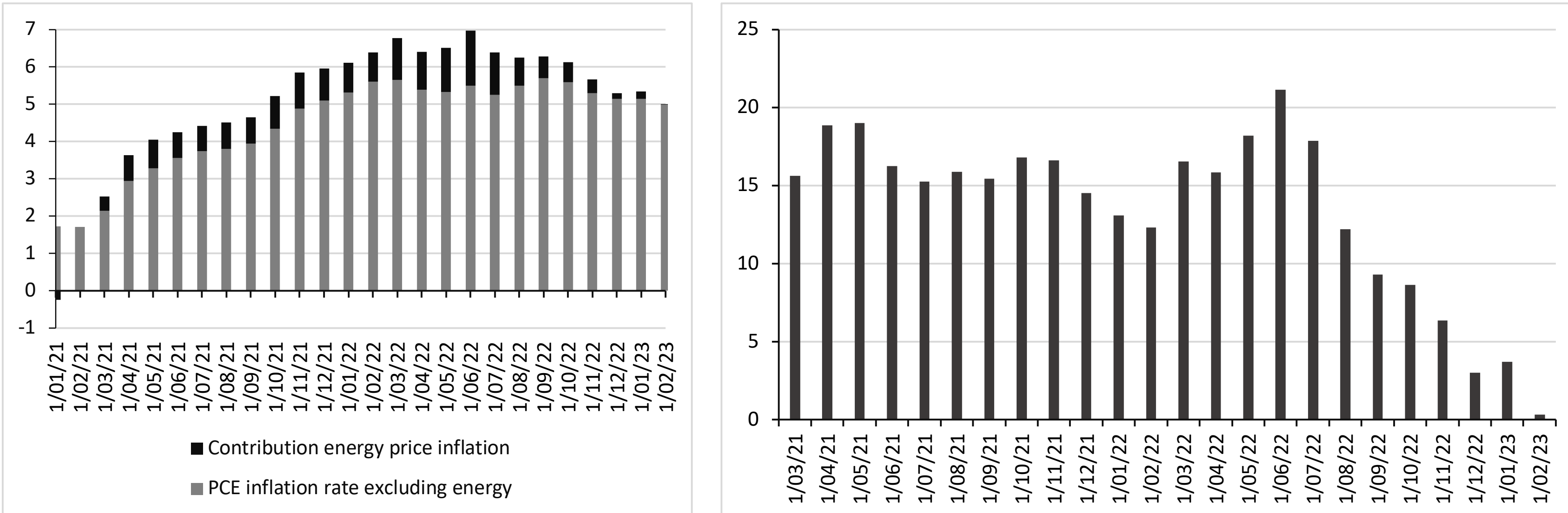
It can be seen that the monthly PCE inflation rate (calculated over a period of 12 months) increased from 1.5% in January 2021 to 7% in June 2022; thereafter, the PCE inflation rate declined to 5% in February 2023. Energy price inflation was a *direct* driver of consumer price inflation (*panel b*, **Figure 1**). During March 2021 – June 2022, higher energy prices accounted for an average of 16% of the accelerating PCE inflation rate; and in June 2022, energy inflation alone was responsible for more than 21% of PCE inflation.

As consumers faced soaring oil (and energy) prices and struggled with fuel, heating and electricity bills, the world's biggest oil corporations broke company records for (annual) profits (**Figure 2**). Seven of the largest energy firms—ExxonMobil, Chevron, BP, Shell, Total Energies, Eni and Saudi Aramco—made almost $200 billion in 2021 and $376 billion in 2022. These windfall profits are good news for the shareholders of these corporations. To illustrate, under pressure from shareholders, led by Wall Street firms such as BlackRock, ExxonMobil is planning to spend $30 billion on share repurchases in 2023 and another $50 billion in 2024. Chevron pledged a massive $75 billion share buyback in the coming years and is raising its dividend.

[1] We begin with a look at the course of U.S. inflation during January 2021-February 2023. We follow the Federal Reserve's Federal Open Market Committee (FOMC) and focus on the Personal Consumption Expenditures price index (PCE) from the Bureau of Economic Analysis. The alternative measure of consumer price inflation is the consumer price index (CPI) from the U.S. Bureau of Labor Statistics. The PCE price index includes a more comprehensive coverage of goods and services than the CPI; the 'narrower' CPI tends to show 'more' inflation than the PCE price index.

Figure 1

The contribution of energy price inflation to the PCE inflation rate, January 2020-February 2023

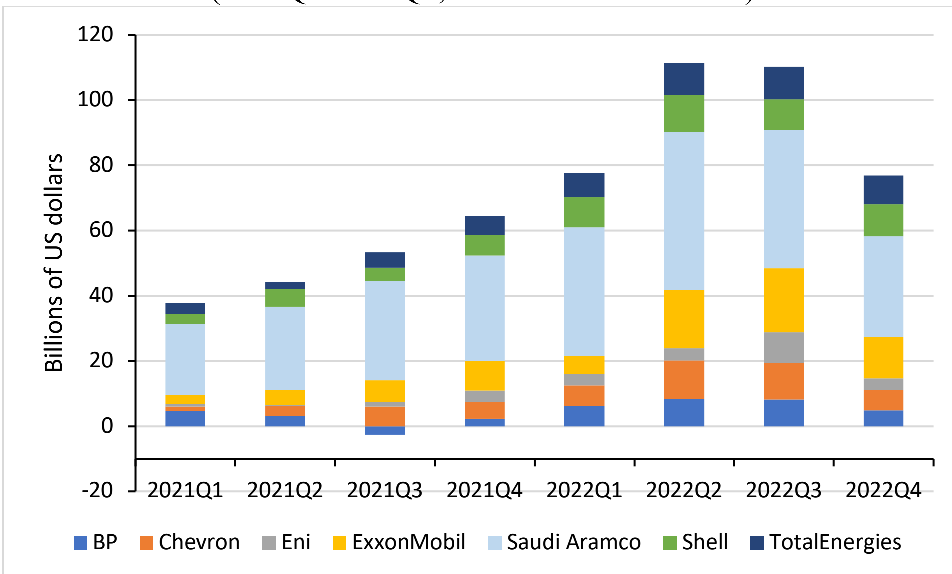


Panel a: The monthly PCE inflation rate, decomposed into energy price inflation (black bar) and all other sources of inflation (grey bar).

Panel b: The contribution (per cent) of energy price rises to the PCE inflation rate.

Source: Authors' calculations based on BEA, Table 2.4.4U. Price Indexes for Personal Consumption Expenditures by Type of Product. *Note*: The monthly inflation rates are calculated as the percentage increase in the respective price indices over the preceding 12 months.

Figure 2
Net profits of seven major oil corporations
(2021Q1-2022Q4; billions of U.S. dollars)



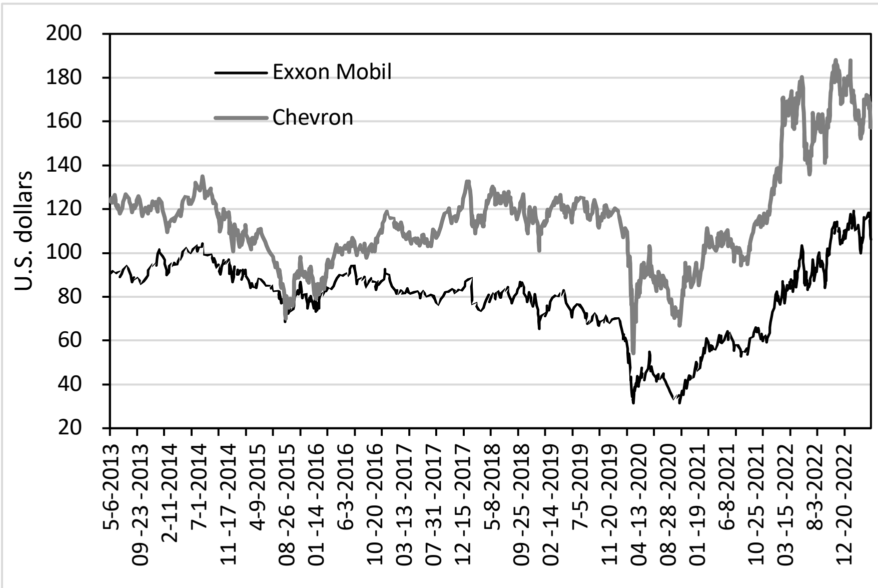
Source: Annual reports.

As a result, and as shown in **Figure 3**, the share prices of the oil majors have increased considerably during the period October 2020 – June 2022 (and beyond). In fact, the stock price of ExxonMobil and Chevron increased by 168% and 107%, respectively, while the share price of Shell plc rose by 142% during this period. The resulting wealth gains for shareholders did reinforce the wealth impact on personal consumption spending and demand, which contributed to rising inflation from the demand side (Ferguson and Storm 2023). From the cost side, rising (oil) profit margins have played a significant role in the acceleration of consumer price inflation, as is explicitly recognized, for the European Union, by economists from the European Central Bank (Arce, Hahn and Koester 2023)**.**

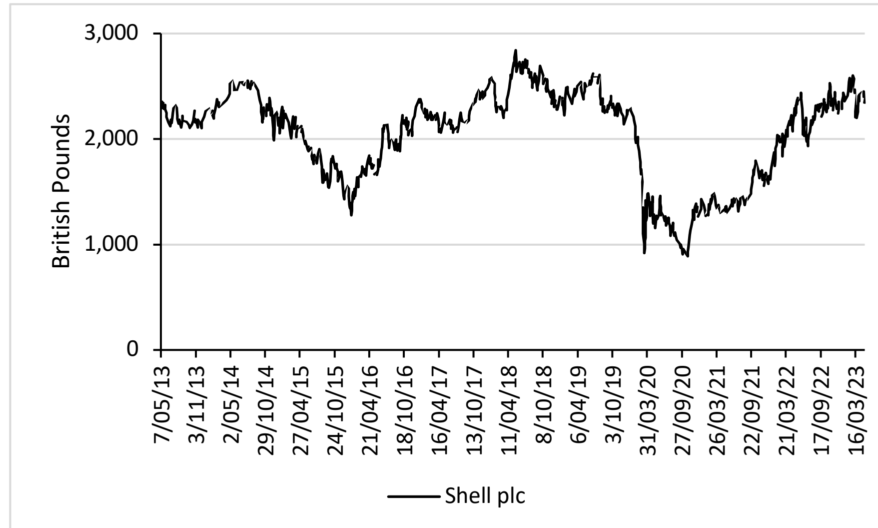
According to Federal Reserve chair Jerome Powell, the Fed estimates as a rule of thumb that every \$10 increase in the price of oil adds 0.2 percentage point to the inflation rate (Dunsmuir 2022). Federal Reserve data in **Figure 4** show that the West Texas Intermediate (WTI) crude oil price rose by \$75 from \$39.4 per barrel in October 2020 to \$114.8 per barrel in June 2022.[2] Using Powell's rule of thumb, a back-of-the-envelope calculation suggests that the higher crude oil price raised the U.S. PCE inflation rate by 1.5 percentage points during October 2020-June 2022—which explains more than one fifth of the recent surge in the U.S. consumer price level.

[2] We note that absent the policy responses by U.S. Treasury Secretary Janet Yellen, the oil price would very likely have increased by even more. In particular, as argued by Verleger (2023), the large strategic reserve oil release announced in March 2022, of more than two hundred million barrels over 12 months, and the price cap on Russian crude oil that she convinced G7 nations to adopt, lowered global oil price pressures.

Figure 3
The (daily) share prices of ExxonMobil, Chevron and Shell (June 2013-May 2023)



Panel a: The share prices of ExxonMobil and Chevron by 168% and 107%, respectively, during October 2020-June 2022.

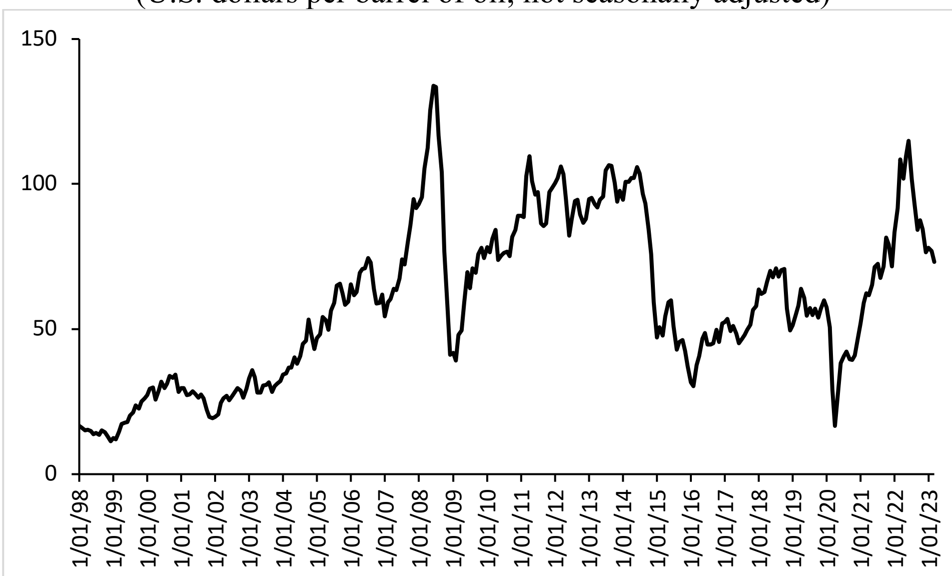


Panel b: The share price of Royal Dutch Shell (in GBP) rose by 142% during October 2020-June 2022.

Sources: NASDAQ and Royal Dutch Shell.

Recent econometric estimates by Kilian and Zhou (2022) indicate that an increase of $10 in the price of oil adds, directly and indirectly, 0.4 percentage points per year to the PCE inflation rate. Based on their estimate, higher oil prices raised the PCE inflation by 3 percentage points during October 2020-June 2022. Input-output analysis by Weber *et al*. (2022) confirms that the indirect (upstream) price effects of an increase in energy prices are substantial, often around half as large as its direct effects. The macroeconomic significance of energy prices is such that Weber *et al.* (2022) consider them of *systemic* importance to overall price stability in the U.S.

Figure 4
Monthly spot price of West Texas Intermediate (WTI) crude oil, 1998-2023
(U.S. dollars per barrel of oil; not seasonally adjusted)



Source: FRED database (*series* DCOILWTICO).

However, our aim is not to explain the exact pass-through effect of higher oil prices on U.S. inflation, but rather to determine whether financial speculation was a significant driver of the sharp increase in oil prices during 2020-2022. Or is the sharp oil price increase during 2020-2022 fully due to fundamental shifts in oil supply and demand? To answer this question, we use the model of supply and demand in the cash (or 'spot') market for oil, the storage market and the futures-spot price spread, developed by Knittel and Pindyck (2016).

III. Estimating the degree of oil price speculation (2020-2022)

Knittel and Pindyck (2016) model the impacts on the oil price of fundamental shifts in supply, demand and inventories. Considering the spot market for oil, they assume that oil supply $S = k_S P^{\eta_S}$ and demand $D = k_D P^{\eta_D}$, where k_S and k_D are parameters incorporating market fundamentals on the supply and the demand side, respectively; these market fundamentals include real incomes and technological progress.[3] η_S and η_D are the price elasticities of supply and demand. Oil supply is further assumed to include imports, and domestic production and imports are perfect substitutes. Oil demand includes exports.

Using these (isoelastic) equations, the change in oil inventories ΔN_t can be expressed as follows:

$$(1) \qquad \Delta N_t = S_t - D_t = k_S P_t^{\eta_S} - k_D P_t^{\eta_D}$$

Dividing equation (1) by D_t, we obtain $\frac{\Delta N_t}{D_t} = \frac{S_t}{D_t} - 1 = \frac{k_S}{k_D} P_t^{\eta_S - \eta_D} - 1$. Next taking logs and then first differences of both sides of the equation, gives, after rearranging:

$$(2) \qquad \Delta \ln P_t = \frac{1}{(\eta_S - \eta_D)} [\Delta \ln k_D - \Delta \ln k_S] + \frac{1}{(\eta_S - \eta_D)} \Delta \ln \left(\frac{S_t}{D_t}\right)$$

Equation (2) is useful. Following the assumptions made, any change in market fundamentals must be reflected in changes in k_S and k_D, and, hence, any non-zero change in oil prices resulting from the term $\frac{1}{(\eta_S - \eta_D)} \Delta \ln \left(\frac{S_t}{D_t}\right)$ must be due to speculation.

Knittel and Pindyck highlight one key implication of equation (2). Suppose that for a period of time, say t = 0 to t = T, there are no changes in fundamentals, or $\Delta k_S = \Delta k_D = 0$ and further suppose that we observe that the oil price is nevertheless increasing ($\Delta \ln P_t > 0$), then we must observe a continuing increase in inventories, since $\Delta \ln \left(\frac{S_t}{D_t}\right) > 0$.

Considering the inverse demand function for inventories, Knittel and Pindyck (2016) adopt the following standard specification:

$$(3) \qquad \Delta \ln \psi_t = \Delta \ln k_N + \Delta \ln P_t - \left({}^{1}/{}_{\eta_N}\right) \Delta \ln N_t$$

where ψ_t = the (capitalised) flow of marginal convenience yield from holding a unit of inventory from t to t + T. The price elasticity of the demand for storage $\eta_N \approx 1$ (in accordance with the empirical evidence). Any change in market fundamentals concerning the demand for storage is reflected in a change in k_N. Equation (3) shows that $\psi_t$will increase if the spot price for oil P_t increases. Substituting eq. (2) into eq. (3) to eliminate the spot price gives:

$$(4) \quad \Delta \ln \psi_t = \Delta \ln k_N + \frac{1}{(\eta_S - \eta_D)} [\Delta \ln k_D - \Delta \ln k_S] + \frac{1}{(\eta_S - \eta_D)} \Delta \ln \left(\frac{S_t}{D_t}\right) - \left({}^{1}/{}_{\eta_N}\right) \Delta \ln N_t$$

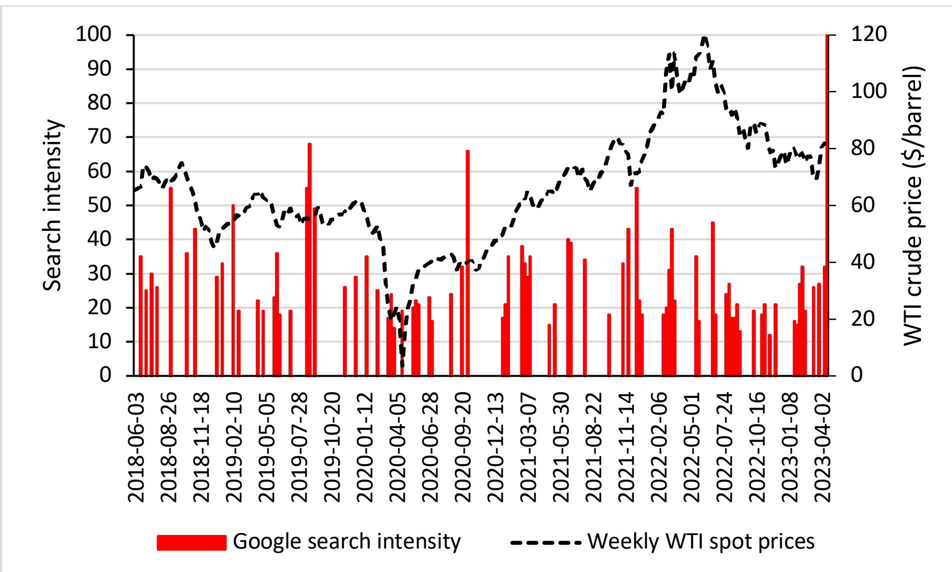
[3] We agree with Roncaglia (2014, p. 163) that references to the 'fundamentals' are in fact rather vague: "Agents active in the oil markets or newspaper commentators are thus able, when commenting on the day-to-day events in the market, to explain price levels and movements by quoting the most disparate pieces of news, once the halt to production in Libya, once the slowing down of the Chinese economy, and so on." The notion of 'fundamentals' is so elastic that it can be made to include any factor that could possible 'explain' a movement in the oil price—which makes the proposition that fundamentals determine the oil price non-falsifiable.

Again, changes in k_N, k_S, and k_D indicate changes in market fundamentals and the speculative component of changes in the convenience yield of oil inventories is given by the term $\frac{1}{(\eta_S - \eta_D)} \Delta \ln\left(\frac{S_t}{D_t}\right) - \left(1/\eta_N\right) \Delta \ln N_t$.

We use equations (2) and (4) and employ reasonable empirical values for the price elasticities η_S, η_D and η_N, to estimate the speculative components of the oil spot price and the convenience yield. We focus on specific time periods ('epochs') during which oil prices increased sharply and there also was clear public concern over oil price speculation. **Figure 5** plots WTI spot prices and Google search intensity for the term 'oil speculation'.[4]

Figure 5

Weekly WTI crude oil spot prices and Google search intensity for 'oil speculation'
(June 2018 – April 2023)



Source: FRED database (*series* DCOILWTICO) and Google Trends.

We analyze the following three (overlapping) epochs:

- *epoch (1)*: October 2020 – October 2021: the crude oil spot price more than doubled, increasing from $39.40 per barrel in October 2020 to $81.48 per barrel in October 2021.
- *epoch (2)*: October 2020 – June 2022: the oil spot price increased by more than 190% from $39.40 per barrel in October 2020 to $114.84 per barrel in June 2022; and

[4] Google Trends allows one to track the intensity of internet search for a particular term. The week with the maximum search is normalised at 100, and all other weeks are a percentage of 100. In **Figure 5**, the maximum occurs in the week of April 16, 2023.

- *epoch (3)*: December 2021 – June 2022: the spot price increased by 60% from $71.71 in December 2021 to $114.84 per barrel in June 2022.

These epochs also featured heightened Google search intensity for 'oil speculation' (**Figure 5**). Search intensity rises in October 2020, June 2021, December 2021, February-March 2022 (following Russia's invasion of Ukraine) and May-June 2022. (We note that public concern over oil speculation peaks in April 2023 which is outside our period of analysis.)

Following Knittel and Pindyck (2016) we calculate the cumulative change in the speculative component of price and convenience yield over the period of analysis t to $t + T$. In the **Appendix**, we discuss the data (sources) used in the empirical analysis. The **Appendix** also presents the results of our replication of Knittel and Pindyck's results for four epochs of oil price increases during January 2007 and April 2011. From the replication, it became clear that the values of the (short-run) price elasticities of oil supply and demand are of critical importance to the numerical outcomes. Choosing reasonable elasticity values is no sinecure.

Even though there is a consensus in the empirical literature on oil markets that the short-run (and longer-run) price responsiveness of both crude oil supply and demand is rather low, oil market experts are strongly divided over the 'true' magnitude of these price elasticities. These differences in empirical findings are not easily resolvable, because they are due to differences in econometric approaches, the use of microeconomic versus global, regional or country-level data, differences in time-periods of analysis, differences in how to account for exogenous shocks to the oil market (such as the Gulf war, the financial crisis of 2008-09, the corona crisis of 2020-21 and recent monetary tightening) and disagreements about the use of prior (external) information in the estimation procedure (Kilian 2022; Caldara *et al*. 2019).

However, for the purpose of this paper, it is possible to define empirically plausible scenarios concerning 'reasonable' price elasticities of oil supply and demand. We first note that the longest epoch considered in the analysis (*epoch* 2) lasts 21 months, whereas *epoch* 1 and *epoch* 3 last only 12 months and 7 months, respectively. We are, therefore, considering short-run price responsiveness of oil supply and demand. Nevertheless, the length of the period of analysis still matters, because oil supply tends to be more price-inelastic in the very short run than in the medium run (for obvious reasons concerning physical constraints on existing oil wells).

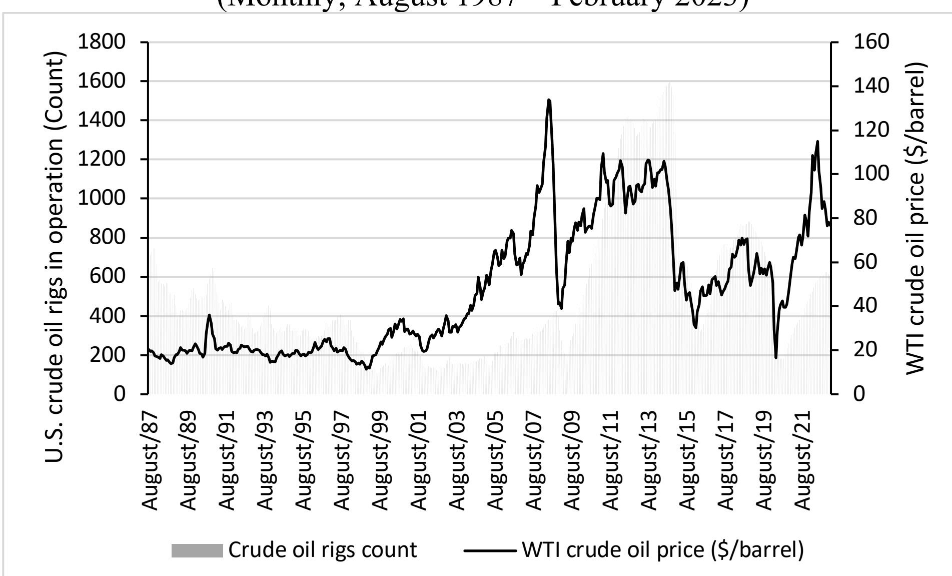
For example, Anderson *et al*. (2018) and Kilian (2022) find that the *one-month* price elasticity of oil supply is close to zero.[5] Newell and Prest (2019) obtain an estimate of the *one-quarter* price elasticity η_S of oil supply for conventional crude of only 0.017. Caldara *et al*. (2019) obtain estimates of the short-run price elasticity of oil supply ranging from 0.021 to 0.11, and Baumeister and Hamilton (2019) report a much higher short-run price elasticity of oil supply of 0.15 (which appears to make sense only over a longer period of analysis than 12 months).

[5] The justification for this result is given by the high operational costs for conventional oil producers, operating existing wells. The authors report a pronounced positive correlation between higher oil prices and new drilling activity.

We must account for the fact that crude oil supply tends to become more price-inelastic during price booms. One reason for this is that oil price booms usually happen after periods of low investments (Gilbert 2010). This appears to be the case presently. **Figure 6** shows the number of (rotary) crude oil rigs[6] in operation in the U.S. The active rig count is used as an indicator of the future demand for oil, because it measures physical investment in oil production.[7] The rig count peaked at 1593 in October 2015, right when WTI crude oil was selling at $100 per barrel. The number of active rigs then steadily declined to 663 in March 2020. This decline coincided with battles between Saudi Arabia and Russia on how to respond to the demand shock from the spreading coronavirus in Spring 2020. Since 2016, Saudi Arabia has relied on other countries outside of the OPEC cartel, notably Russia, to help it influence the global oil market. When in March 2020 Russia refused to join in production cuts (following the COVID19 shock), Saudi Arabia launched a price war, boosting its own output and selling crude at a discount. This way, Riyadh tried to bring Russia around to cartel pricing, while at the same time undermining (smaller-scale) U.S. shale producers, many of whom had accumulated dangerous levels of debt (Financial Times 2020).

Figure 6

U.S. Crude Oil Rigs in Operation (Count) and the WTI crude oil price
(Monthly; August 1987 – February 2023)



Sources: U.S. Energy Information Administration and FRED database.

During the extraordinary circumstances of the COVID19 crisis, the lockdowns and the consequent drop in the oil price to $40 per barrel, the number of active oil rigs dropped to a mere 180 in August-September 2020. This is a clear sign that, by the end of 2020, oil producers did not have much faith

[6] A rotary rig is the machinery that rotates the drill pipe from the surface to drill a new well (or side-tracking an existing one) to explore for, develop and produce oil.

[7] Note that due to advancements in technology and improvements in the efficiency of extraction, oil production can be raised even when rig counts fall.

in a rapid recovery of oil demand. However, as the economy started to recover and oil prices began to go up during 2021-22, more rigs were brought back into use (**Figure 6**); the number of active rigs is 604 in February 2023, which is still far below the number of active rigs during most of the period 2011-2019. We note that the U.S. (shale) oil industry has been reluctant to increase productive capacity since its clash with the Saudis in Spring 2020.

According to the *Dallas Fed Energy Survey* published by the Federal Reserve Bank of Dallas (2022), fifty-nine percent of oil executives responded that investor pressure from Wall Street to return cash to shareholders through dividends and stock buybacks is the primary reason why oil companies are not investing in badly needed supply. "Institutional investors, led by BlackRock Inc., have convinced virtually every oil executive to keep spending under control. Pierre Breber, the chief financial officer at Chevron, put it this way: "We're not really paid for growth by the market." Instead, they are channeling the profits into dividends and share buy backs"" (Blas 2022). Blas (2022) adds that "today, the pressure from shareholders to remain frugal is so strong and uniform across the industry that from the outside it almost looks like a cartel. And the result is cartel-like: Big Oil is collectively underinvesting by a lot."

Another 11% of oil executives (in the Dallas Fed Energy Survey) pointed to environmental, social and governance (ESG) issues, which have motivated many financial investors to move away from fossil fuel companies in favor of 'greener' energy ones.[8,9] In addition, multiple executives surveyed expressed significant concern about the policy message coming from Washington, DC, which is that oil is a dying industry and needs to abandoned—as part of the transition towards renewable energy that is imperative to eliminate carbon emissions. Higher interest rates are a final factor underlying the oil industry's sluggish supply response to the oil price hike.

As a result of the reasons mentioned above, the oil majors have been reluctant to invest and instead prefer to continue to maximize revenues for shareholders from their decaying, sun-setting assets. Or, as oil analyst Javier Blas (2023) writes,

> "No matter how high oil prices go above that level—say $100 a barrel—the industry will no longer add rigs to sop up market share. Rather, it will stay put and go into harvest mode with existing wells—that's exactly what happened in 2022, much to the consternation of the White House, which urged shale companies to drill more."

[8] However, as Ferguson, Jorgensen and Chen (2021, p. 59) observe, large international oil majors respond to 'green' investor pressures by selling off shale oil holdings to smaller oil firms. These smaller oil firms are well aware that those holdings can yield a steady stream of profits for a long time, especially if firms protect their investments by deploying political money on a large scale.

[9] Following the Ukraine war and the rise in energy prices, the oil majors are no longer much bothered about climate change. For example, at the Shell 2023 Annual General Meeting (AGM) on 23 May, Shell's board made clear that renewable energy is not profitable enough to increase value for its shareholders and that oil and gas are better investments. Eighty percent of Shell's shareholders rejected a shareholders resolution demanding the company lower its greenhouse gas emissions in line with the targets set by the Paris Climate Agreement. And an even higher proportion of shareholders gave approval for Shell to continue repurchasing up to 10% of Shell's shares into 2024. We note that by mid-April 2023, BlackRock held 10.6% of Shell's publicly traded stock, while Vanguard held 3.4% of Shell's shares; it is not disclosed how BlackRock and Vanguard voted in the AGM. Source: Vander Stichele (2023).

Blas predicts that "Wall Street is going to profit at the expense of Washington and Main Street. The consequences are likely to be higher oil prices — and inflation …." Oil companies, in harvesting mode, thus contributed to the sharp oil price increases during 2020-2022 by reducing production from existing wells and delaying the development of new, undeveloped reserves.[10] Furthermore, the recent surge in inflation and supply-chain disruptions rates have raised the production costs of (shale) oil firms which is holding back new drilling. The go-slow is a business reality, and the drastic curtailment of rig utilization—and capital destruction in the oil shale industry in earlier years—have been key factors constraining the already low price-responsiveness of oil supply during 2020-2022.[11]

For what concerns the short-run price elasticity of oil demand, it can also be assumed to be quite low—Caldara *et al*. (2019) report values ranging from -0.017 to -0.14. Kilian (2022) argues that the price elasticity of oil demand takes a value of -0.18.[12] Given the uncertainty surrounding the price elasticities of oil supply and demand, we use the model of Knittel and Pindyck (2016) to evaluate three empirically plausible scenarios, namely:

- Scenario A: $\eta_S = 0.02$ and $\eta_D = -0.08$ (relatively price-inelastic supply and demand)
- Scenario B: $\eta_S = 0.07$ and $\eta_D = -0.13$ (moderately inelastic supply and demand)
- Scenario C: $\eta_S = 0.12$ and $\eta_D = -0.18$ (relatively price-elastic supply and demand)

The numerical assumptions underlying our analysis are given in the **Appendix**. The results of the epoch analysis appear in **Table 1**.

For each of the three epochs we find that speculation drove up the price of crude oil, and quite considerably so. If we consider scenario A (which we deem the most plausible one), we find that speculation has been responsible for 47.6% of the oil price increase during October 2020 – June 2022 (*epoch 2*). Note that this translates into an oil price increase of almost $36 per barrel. Using the oil-price-pass-through estimate of Kilian and Zhou (2022) in a back-of-the-envelope calculation, we conclude that oil price speculators have driven up the U.S. PCE inflation by 1.5 percentage points (or around one quarter of the recent rise in the U.S. consumer price level). These effects for *epoch 2* are halved in scenario B (with moderately price-inelastic supply and demand).

Table 1 shows that the net effect of speculation on convenience yields has been positive in epochs (1), (2) and (3). Higher convenience yields mean that speculation made it more costly to store crude oil. This appears realistic, because prior to 2021, investment by oil companies was depressed

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[10] As Blas (2023) reports in April 2023: "Driving across the Permian, which stretches from West Texas into southeast New Mexico, signs of the slowdown are everywhere. In one place, half-a-dozen unused rigs are stacked up in a yard waiting for better days; in another, a once-bustling man camp is half empty. If it's a great day to drill an oil well, no one seems to be in a hurry to get the work done."

[11] The situation is changing following the war in Ukraine: small (shale oil) producers in the U.S., which purchased shale oil holdings from the oil majors, are now increasing their investments and supply. See Ferguson, Jorgensen and Chen (2021).

[12] Hamilton (2009) argues that, as a rule of thumb, the price elasticity of oil demand should be approximately half as large as the price elasticity of gasoline demand, given the 50% cost share of oil in producing gasoline. State-of-the-art estimates for the U.S. agree that the elasticity of gasoline demand is around —0.36 (Kilian 2021), which gives a price elasticity of oil demand of —0.18.

(**Figure 6**)—and furthermore, global oil supply declined following the Ukraine war and the ban on Russian crude oil and petroleum products by the U.S., the U.K. and the E.U., driving crude oil prices up in 2022. However, at the same time, speculative inventory accumulation must have pushed down convenience yields. The net result in this case has been significantly higher convenience yields. Speculation has thus driven up oil prices and the (opportunity) cost of oil storage, even when oil inventories decreased (**Table 1**).

According to Knittel and Pindyck (2016), and based on equation (2), declining inventories are unlikely to be consistent with speculation—and, therefore, our results for the price effect and the impact on convenience yield appear to be contradictory. We beg to disagree, however. In fact, the observed decrease in oil inventories can be the *net* result of two opposing forces: on the one hand, the strong increase in global demand during 2021-2022 (coupled with stagnant supply, see **Figure 6**) has been driving inventories down, but on the other hand, speculation has motivated an increase in storage. The net effect of these contrasting tendencies was a decline in crude oil inventories (as captured by our data).

We thus find, using the simple oil market model of Knittel and Pindyck (2016), that speculation has been a significant driver of spot prices in oil markets during the period October 2020 – June 2022. Speculation (across the three scenarios) 'explains' between 16% to 48% of the crude oil price increase during this period and has been a significant systemic factor contributing to the recent surge in the U.S. inflation rate.

Table 1
Epoch Analysis

	(1)	(2)	(3)
Period of analysis (epoch):	2020:10- 2021:10	2020:10-2022:6	2021:12-2022:6
Beginning price (P_0)	\$39.40	\$39.40	\$71.71
Ending price (P_T)	\$81.48	\$114.84	\$114.84
Beginning futures prices price for delivery of oil at $t + T$ ($F_{t,T}$)	\$40.19	\$40.19	\$71.20
Ending futures prices price for delivery of oil at $t + T$ ($F_{t,T}$)	\$79.50	\$109.20	\$109.20
Beginning supply (S_0)	461719	461719	520023
Beginning demand (D_0)	474058	474058	521431
Ending supply (S_T)	524699	505161	505161
Ending demand (D_T)	516999	494553	494553
Cumulative change in log price due to speculation ($\Delta \ln P_T^S$)			
- Scenario A	41.2%	47.6%	23.9%
- Scenario B	20.6%	23.8%	12.0%
- Scenario C	13.7%	15.9%	8.0%
Beginning inventories (N_0), de-seasonalised	496101	496101	434061
Ending inventories (N_T)	438759	411197	411197
Actual inventory build-up over entire epoch (ΔN_T)	—57342	—84904	—22864
Beginning convenience yield (ψ_0)	\$3.72	\$3.72	\$5.10
Ending convenience yield (ψ_T)	\$6.49	\$10.57	\$10.57
Change in log convenience yield due to speculation ($\Delta \psi_T$)			
- Scenario A	53.4%	66.4%	29.3%
- Scenario B	32.9%	42.6%	17.4%
- Scenario C	26.0%	34.6%	13.4%

Notes: $\Delta \ln P_T^S = \ln P_T^S - P_0 = \sum_{t=0}^{T} \Delta \ln P_T^S$ is the cumulative change in the oil spot price; $\Delta \ln \psi_T^S = \ln \psi_T^S - \psi_0 = \sum_{t=0}^{T} \Delta \ln \psi_T^S$ is the cumulative change in the convenience yield of oil inventories over the period of analysis. *Source*: authors' calculations.

Our estimates are plausible.[13] A recent econometric analysis for 1938Q1-2018Q3 by Kaufman and Connelly (2020) shows that oil prices repeatedly strayed from the levels implied by market fundamentals during these eight decades, including during the periods 2007Q4–2008Q3 and 2010Q1–2011Q1. We find that it happened again during 2020-2022—which does not come as a surprise to industry observers.

“Fundamentals do not matter to a new breed of oil speculator”, writes Gregory Meyer (2018). A new class of prominent ‘macro speculators’, mostly Wall Street money managers, is not necessarily reacting to news about supply and demand, but instead may be buying and selling oil futures based on moves in currencies, interest rates or the price of oil itself. Veteran oil analyst Philip K. Verleger (2022) agrees, arguing that “oil prices in 2022 are being driven not by fundamentals but by those betting that prices will soon exceed \$125, \$150, or \$200/bbl”. And as pointed out by Domenica Tropeano (2023), “most increases in the price of futures that […] affect spot prices are due to an excess demand for futures that in turn depend on hedging strategies by financial and nonfinancial firms.”[14]

We finally note that the oil price spike during October 2020-June 2022 generated ample profit-making opportunities for the commodity trading divisions of (European) oil corporations (Wilson 2023). For instance, Shell’s trading division earned \$16.6 billion in earnings before interest, tax, depreciation and amortization, while the trading divisions of Total Energies and BP made \$11.5 billion and \$8.4 billion, respectively. The trading divisions of the oil companies made unprecedented profits, outperforming the four biggest (specialized) private energy traders—Vitol, Trafigura, Mercuria and Gunvor—which made combined energy trading profits last year of about \$34 billion. The private energy traders were also making historic returns: Vitol, the world’s largest private energy trader, made a record net profit in 2022 of almost \$15 billion, equal to its combined earnings for the prior six years (Wilson 2023). We consider additional indicators of speculative activity in the oil market next.

[13] This is true in a general sense, because “there is nearly nobody left who believes in the theory of efficient financial markets (Fama, 1970), according to which prices of financial assets reflect at every moment the so-called fundamentals, namely the elements underlying supply and demand.” (Roncaglia 2014, p. 172).

[14] Tropeano (2023) gives the following illustration: “the chief financial officer of a big Italian electricity producer [….] recently revealed that the firm has to follow its risk-averse guidelines and hedge in advance all the planned production by selling futures on the market. During the crises [of 2021-2022], those derivative positions fell heavily in value and the firm was asked to pay immediately in cash enormous margin calls […] to the clearinghouse that in turn is owned by the largest international banks. If borrowing to pay the calls was not available or too expensive, firms then rushed to get rid of the short exposures by building a long position, which means buying new futures. The latter move increased the already high demand for futures and the price of energy goods. [….] So, most agricultural prices and energy prices did not increase out of excess demand in the market for goods.”

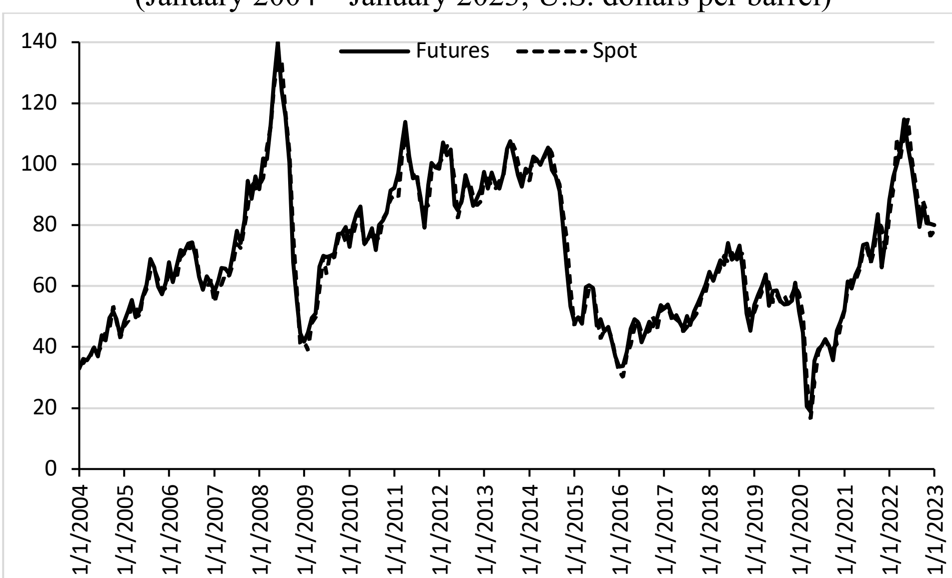
IV. Further evidence of speculation in oil markets

There are other ways to estimate the presence and the degree of speculative activity in the U.S. oil market. We present evidence on the financialization of, and excessive speculation in, the oil market (**Section IV.1**) and next discuss two specific indicators of speculative activity (**Section IV.2**).

IV.1. The financialization of the oil market

Figure 7 shows that futures and spot prices of WTI crude oil are highly correlated and that there is an information flow between spot and futures markets. We note that the WTI crude oil market has often been in backwardation[15], as futures prices tend to be lower than spot prices. The cost of storing oil above the ground is high and as a result, at least historically, the term structure of oil prices is usually backwardated.

Figure 7
Monthly spot and futures (first contract) prices for WTI crude oil
(January 2004 – January 2023; U.S. dollars per barrel)



Source: Energy Information Administration (EIA).

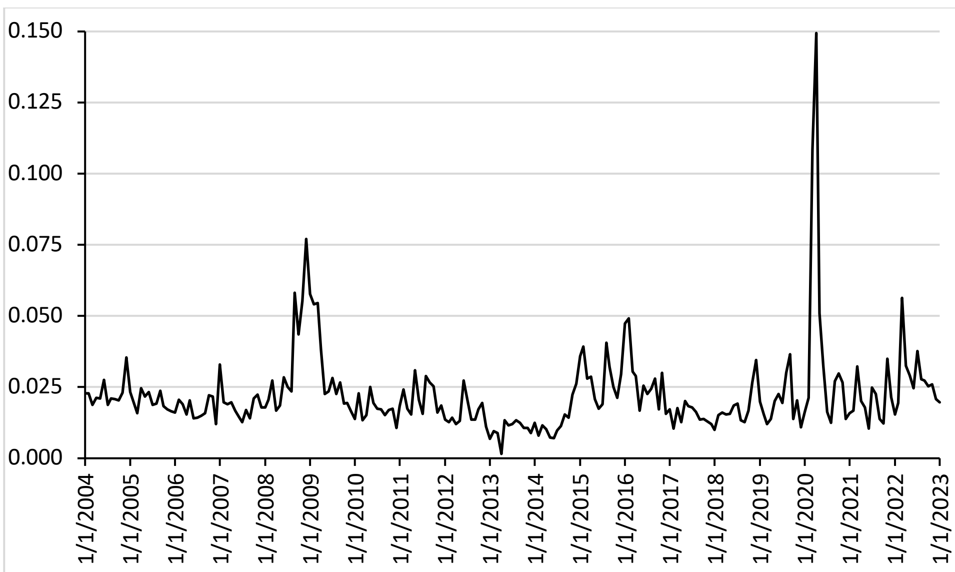
Figure 8 presents the monthly volatility of futures returns of crude oil during January 2004 and February 2023. Volatility peaks during the final months of 2008, in the wake of the global financial crisis, and again in April 2020, following the onset of the corona crisis. However, excluding exceptional periods with volatility peaks, it can be seen that the futures returns of WTI crude oil

[15] Backwardation occurs when the future price is less than the spot price plus the cost of carry/storage. In a state of backwardation, futures contract prices include compensation for the positive risk transferred from the underlying asset holder to the purchaser of the futures contract. This means that the expected spot price on expiry is higher than the price of the futures contract.

have become more volatile in the recent times—which must have negatively affected the price discovery function of the oil futures market.

The increase in price volatility is also delaying increased investment expenditures by oil corporations because oil companies have less confidence in price forecasts. The increase in monthly volatility of futures returns is—we argue—related to the financialization of the oil market. A first piece of empirical evidence on this financialization appears in **Figure 9**: a steady increase in the total open interest contracts by non-commercial traders for WTI crude oil.

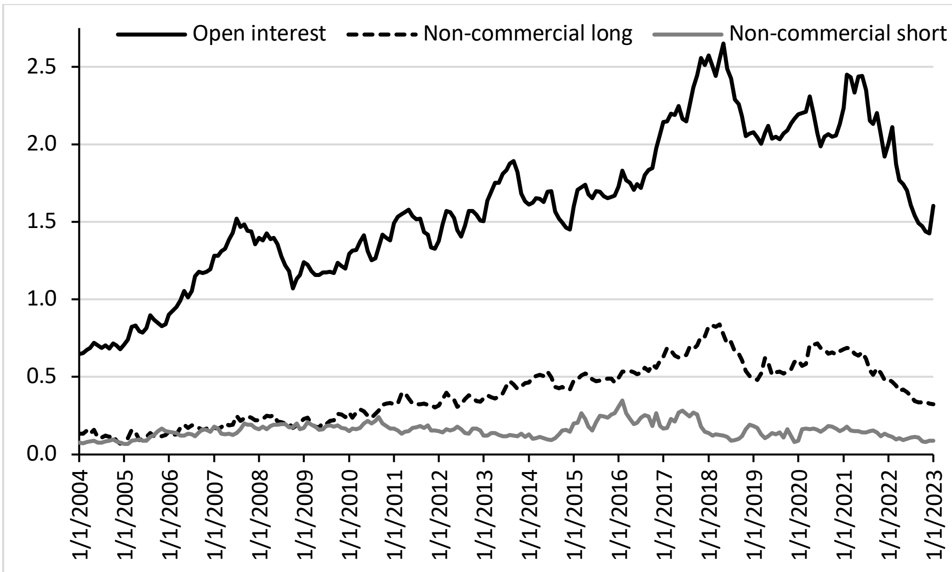
Figure 8
WTI crude oil: volatility of futures' returns
(January 2004 – January 2023; U.S. dollars per barrel)



Source: data on futures prices from EIA. Volatility of futures returns is computed by the authors.

One metric to consider is the total number of open interest or the total number of open (long and short) positions in oil futures contracts for a commodity which still carry market risk. Open interest contracts are bets, with someone being on the long side of the bet and someone else being on the short side. As is clear from **Figure 9**, the number of open interest contracts exhibits a rising trend during January 2004-June 2021. Actually, total open interest in futures rose from over 350,000 contracts in mid-1995 to more than 1.28 contracts in July 2008—and further to 2.44 million contracts in June 2021 (**Figure 9**). Open interest declined sharply, especially after February 2022, as market uncertainty increased following the Ukraine war. Price volatility increased (see **Figure 8**) following an exodus of banks, hedge funds and other speculators.

Figure 9
WTI crude oil futures:
Open interest and (short and long) non-commercial positions,
Millions of contracts (January 2004 – January 2023)



Source: *Commitments of Traders Reports*, Commodities Futures Trading Commission.

A futures contract is for 1,000 barrels of oil, so this is a rise from 350 million barrels in mid-1995 to 2.44 billion barrels in June 2021, or almost 8% per year. As is shown in **Figure 10**, the share of barrels of oil traded in the oil futures market to global crude oil production rose from 1.4% in 2006 to 3.3% in February 2021. Multiplying the open interest measured in barrels by the price of oil per barrel shows that the value of open interest in futures rose from $6.2 billion in mid-1995 to $159 billion in July 2008 and to $179 billion in June 2021.

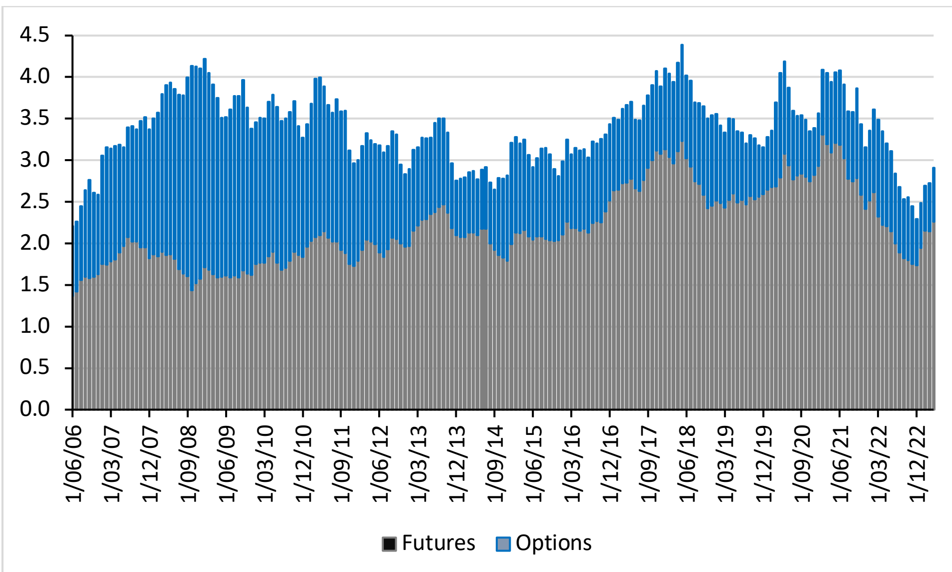
In addition to future positions, traders can hold option positions on oil. Adding oil option contracts (for 1,000 barrels of oil per contract) increases total open interest exposure by more than 50%—as is shown in **Figure 10**. The share of barrels of oil traded in the oil futures and option markets to global crude oil production rose from around 2.5% in 2006 to 4.1% in February 2021.

There are other financial bets on the oil price that never come to the futures market. In particular, swap dealers can privately negotiate (*Over-The-Counter* or OTC) tailored contracts with clients that look in most regards similar to oil futures or option contracts; these OTC contracts are not generally subject to reporting to the Commodity Futures Trading Commission (CFTC) and data on the volume and terms of these swap deals are not public information. The numbers shown in **Figure 9** and **Figure 10**, therefore, considerably underestimate the true size of the total stock of bets on crude oil, because they exclude off-exchange derivative transactions.

The CFTC publishes weekly data on open interest positions in its *Commitment of Traders* report. This report breaks down open interest according to commercial and non-commercial traders and also outlines whether they are holding long or short positions.[16] Commercial traders (*i.e.*, institutional traders) are defined by the CFTC as traders who trade in the futures market to primarily hedge core business activities on behalf of a business or institution.[17] Commercial traders make up around two-thirds of the total open interest contracts.

Figure 10

Average daily open interest in WTI crude oil futures and options as a percentage of average daily global crude production (Millions of barrels per day) (June 2006 – April 2023)



Sources: *Commitments of Traders Reports*, Commodities Futures Trading Commission and U.S. Energy Information Administration.

Non-commercial traders, mostly hedge funds and large financial firms (operating index funds), are defined by the CFTC as traders who have no business activities related to a particular commodity (such as oil) in which they have a position in the futures markets. In other words, non-commercial traders take speculative market positions only to profit from price shifts in the market—they do not

[16] Originally, the distinction between commercial and non-commercial dealers roughly corresponded to the distinction between financial and non-financial traders, or speculators and hedgers. However, over time, the CFTC, under political pressure, allowed the meaning of the two categories to become blurred by reclassifying swap dealers, whose positions are mostly speculative, as hedgers or 'commercials'. This blurring of categories happened, not coincidentally, exactly when purely financial investments in oil began their inexorable increase.

[17] For instance, an oil trader, employed by an airline, who hedges against expected kerosine price increases, is an example of a commercial trader. See: https://www.cftc.gov/MarketReports/CommitmentsofTraders/AbouttheCOTReports/index.htm

intend to take delivery of a commodity or hedge costs related to a commodity-related business. As shown in **Figure 9**, the number of open interest contracts held by non-commercial traders has grown considerably during 2004-2023 — from 31.7% during 2004-2015 to 37.8% during 2016-2021.

As is indicated in *panel a* of **Figure 11**, merchants/producers of oil are outnumbered by Wall Street traders. The ratio of oil producers/merchants to Wall Street traders rose from 3.6 in June 2006 to 13 in October 2008 and peaked again at a level of 10 in Spring 2016; the ratio was around 5 in October 2020 and 3.8 in October 2022. The other panel (*panel b*) of **Figure 11** highlights recent trends in inflows in commodity index funds. (We note that energy commodities comprise around one-third of most commodity index funds, with crude oil comprising around 15 percent.) It can be seen that money flows to commodity index funds increased sharply during 2021Q1 and 2022Q2; in cumulative terms, the value of assets under the management of commodity index funds grew by more than 300% on a year-to-year basis during these six quarters.

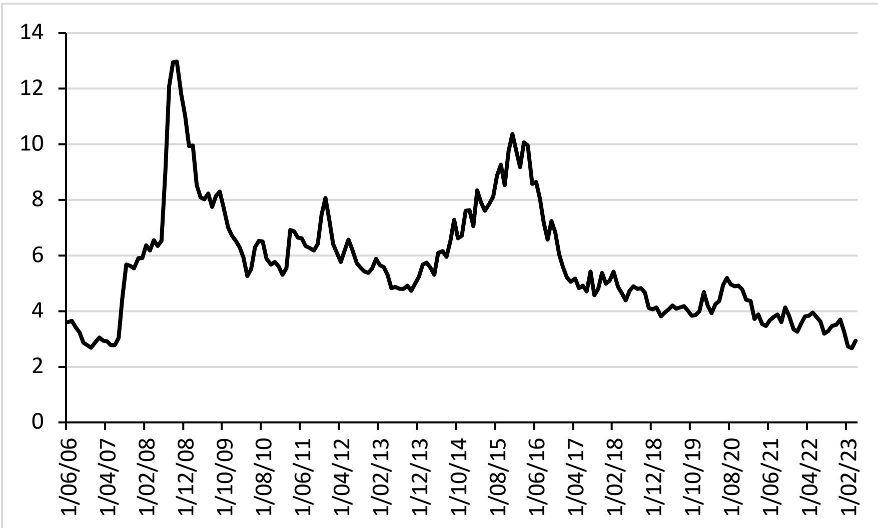
Short positions by non-commercial traders (as a proportion of total open interest) declined over time, while their long positions increased significantly (**Figure 12**). The ratio of long non-commercial positions to long commercial positions rose from around 30% during 2004-2009 to almost 108% in July 2020; subsequently, this ratio declined to around 62% during 2022 (**Figure 13**). When more non-commercial traders are betting long (*i.e.*, expecting that the oil price will rise), it is usually a strong bullish signal. This strong growth of long non-commercial positions is related to the growing importance of 'long only' index funds (**Figure 11**; see also Masters and White 2008; Sanders and Irwin 2010; Sanders *et al*. 2010), while hedgers (mostly commercials) are mainly found in the short market.

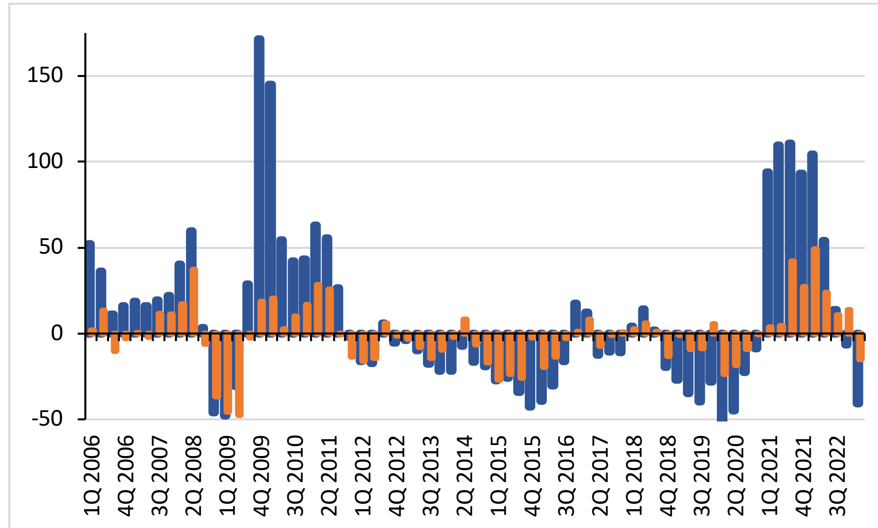
Normally, for every long position there is an opposite short position, and a good balance between long and short positions is beneficial for the (oil) market's liquidity. However, commodity index investors, as Masters and White (2008) explain, "lean only in one direction—long—and they lean with all their weight." Investors in such instruments expect commodity prices to rise; money is lost if the values of the underlying commodities in the index decrease. In effect, the share of non-commercial short positions in total open interest declined from 12.8% in 2004 to 6.7% in 2020, while the share of non-commercial long positions in total open interest increased from 17.6% in 2004 to 31% in 2020 (**Figure 12**). As a result, the oil market has become more financialized and, arguably, more speculative.

The ratio of non-commercial positions to total open interest positions is widely interpreted as the ratio of speculative activity relative to hedging activity (Robles *et al*. 2009). Non-commercial traders in the oil market mostly hold long positions, which means that they are betting that the oil price will rise. Their activity may drive up futures prices of oil (as part of a self-fulling process) and higher futures may drive up oil spot prices. We know from **Figure 7** that futures and spot prices are closely correlated ($r = 0.95$; t-value $= 47.1$), but correlation does not mean 'causation'. Visual inspection of the figure does not tell us whether futures prices are leading spot prices or whether it is the other way around.

Figure 11

Producers/merchants and commodity index funds (2006-2022/23)



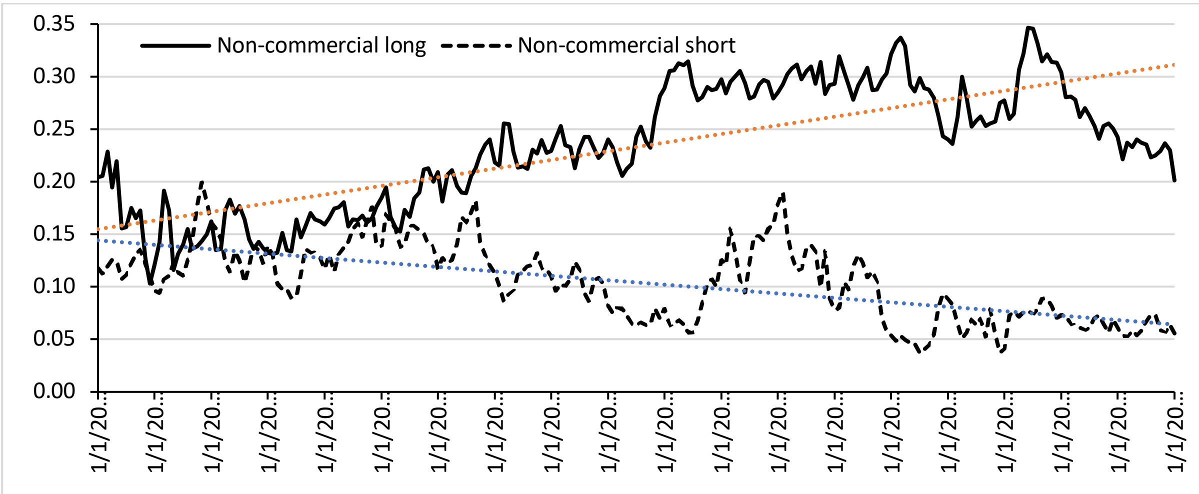


Panel a: WTI crude oil futures: The ratio of producers/merchants relative to Wall Street traders (*Monthly* data for June 2006 – April 2023).

Panel b: Year-on-year percentage change in commodity index assets under management (4 largest public U.S. commodity index funds). These changes are compared to year-on-year percentage changes in the Bloomberg commodity price index level. When the growth rate of assets under management (blue bars) is greater (resp. more negative) than the growth rate of the price index (orange bars), this indicates a net inflow (resp. outflow) of index investment.

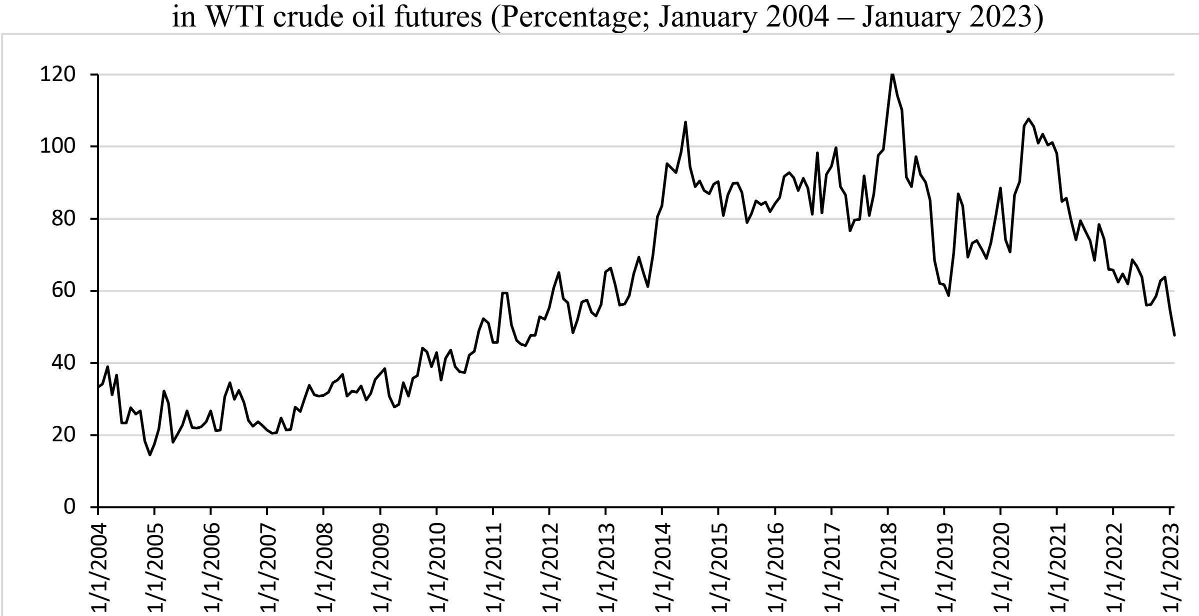
Sources: *Disaggregated Commitments of Traders Reports*, CFTC and U.S. EIA. *Note*: Wall Street traders include swap dealers, managed money dealers, other reportable positions and non-reporting dealers. For **panel b**: see https://www.eia.gov/finance/markets/crudeoil/financial_markets.php

Figure 12
WTI crude oil futures: short and long non-commercial positions
(As percentage of total open interest; January 2004 – January 2023)



Source: *Commitments of Traders Reports*, Commodities Futures Trading Commission.

Figure 13
Long non-commercial positions as a ratio of long commercial positions in WTI crude oil futures (Percentage; January 2004 – January 2023)



Source: *Commitments of Traders Reports*, Commodities Futures Trading Commission.

We employed linear Granger causality tests to check whether knowing the time-path of futures oil prices helps to improve the forecast of the time path of oil spot prices (and *vice versa*). Specifically, we test the following Null Hypotheses (H_0): (A) 'futures oil prices do not Granger-cause spot oil prices'; and (B) 'spot oil prices do not Granger-cause futures oil prices.' Since the test results are sensitive to the selected lag length, it is important to choose the appropriate lag length to ensure that the residuals have no serial correlation and no conditional heteroskedasticity. To find the optimal lag used in the estimation, we employ the Akaike information criteria (AIC) which suggests a lag length of 3 months. We tested the Null Hypotheses for different lag lengths varying from 1 to 12 months. Standard Granger causality tests require variables to be stationary. Compounded returns (*i.e.*, changes in consecutive logarithmical prices) of futures and spot prices of oil have been computed to transform the time-series of futures and spot prices into stationary series. The results of the Granger causality tests appear in **Table 2**.

Table 2
Granger causality tests: Spot and futures prices of WTI crude oil
(Monthly data; January 2004-January 2023)

	H0: spot prices do not Granger cause futures prices	H0: futures prices do not Granger cause spot prices
No. of Lags	p values of *F*-test	P values of *F*-test
1	0.6392	0.0000***
2	0.0935*	0.0000***
3	0.1244	0.0000***
4	0.3111	0.0000***
5	0.4347	0.0000***
6	0.4661	0.0000***
7	0.5823	0.0000***
8	0.5751	0.0000***
9	0.7678	0.0000***
10	0.8448	0.0000***
11	0.6702	0.0000***
12	0.8493	0.0000***

Source: Estimations by authors. *Notes*: *p*-values: * = reject Null Hypothesis at 10% significance; ** = reject Null Hypothesis at 5% significance; and *** = reject Null Hypothesis at 1% significance. The number of observations is 229. The time-series of spot and futures prices of WTI crude oil are non-stationary. Compounded returns (*i.e.*, changes in consecutive logarithmical prices) of futures and spot prices of oil have been computed to respect the stationarity requirement of the test. For each test, the optimal number of lags was selected through the Akaike Information Criterion (AIC); the shaded row indicates the optimal lag length.

Concerning hypothesis (A), the Granger causality results in **Table 2** suggest that we must reject H_0 (at 1% significance) for the optimal lag length of 3 months and for all lag lengths from 1 to 12 months. These findings imply that there is a unidirectional effect of futures oil prices on spot oil prices (during 2004-2023). This result falsifies the ‘fundamentalist’ claim concerning the oil market that spot oil prices are fully determined by economic fundamentals, and, hence, there is no way in which futures prices—and excessive speculation—can affect spot prices. The proposition that futures oil prices ‘Granger-cause’ spot oil prices has been rejected for earlier periods by Alquist and Gervais (2013), Kilian and Murphy (2014), Irwin *et al*. (2009) and Büyükşahin and Harris (2011). Krugman (2008) prominently echoed ‘fundamentalist’ opinion, stating that “a futures contract is a bet about the futures price. It has no, zero, nada direct effect on the spot (physical) price.” Our findings in **Table 2** are not consistent with the ‘fundamentalist’ consensus.

On the other hand, we cannot reject hypothesis (B) that ‘spot oil prices do not Granger-cause futures oil prices.’ The test is not significant (at 10%) for all lag lengths (except for a lag of 2 months). In other words, the exchange of information between spot oil and futures oil markets runs in only one direction: from the futures market, dominated by (speculative) non-commercial traders to the spot market, populated mostly by commercial traders. The close correlation between spot and futures prices for crude oil in **Figure 7** is, therefore, the result of (speculative) futures prices leading the spot market. Merchants/producers are, in other words, followers of price trends initiated by non-commercial traders.

Following Masters and White (2008), an increase of demand for long positions in the futures market can influence the oil spot price in the following way. If a large number of financial investors (such as hedge funds) enter the oil futures market in the expectation of an oil price increase, the demand for long positions rises which tends to increase the futures price. Merchants/producers notice the increase in the futures price (‘price discovery’) and update their expectations, predicting an increase in the spot price. As a result, these actors tend to increase inventories or reduce production, either of which reduces the supply of crude oil in the physical market and thus increases the spot price. Because agents are heterogeneous, differences in expectations lead market participants to overreact to the futures price signal and this exacerbates higher-order moments such as the volatility of prices in the futures market.

IV.2 Measures of speculation

A widely use measure of the degree of speculation in the oil futures market is Holbrook Working’s T-index (Working 1962). Working’s T-index is a ratio measuring the degree of *excess speculation* over hedging needs. Excessive speculation could cause prices to deviate from the supply and demand fundamentals. A level of speculation that is larger than the need to satisfy net hedging transactions and market liquidity, is called excessive, because the excess may distort price dynamics. The T-index is defined as follows:

(5) $$T = 1 + \frac{SS}{HL+HS} \text{ if } HS \geq HL$$

or $$T = 1 + \frac{SL}{HL+HS} \text{ if } HS < HL$$

where SS (SL) defines the number of short (long) positions held by speculators, while HS (HL) represents the number of short (long) positions held by hedgers. The denominator ($HL + HS$) is the total number of futures open interest contracts due to hedging activity. If the number of short hedging contracts is greater than the amount of long hedging, then speculative long contracts SS are needed to balance the market; and technically, speculative shorts are not required by hedgers. Any surplus of speculative short positions would thereby need to be balanced by additional speculative long positions. Technically, then the speculative short positions would appear to be superfluous or "excessive."

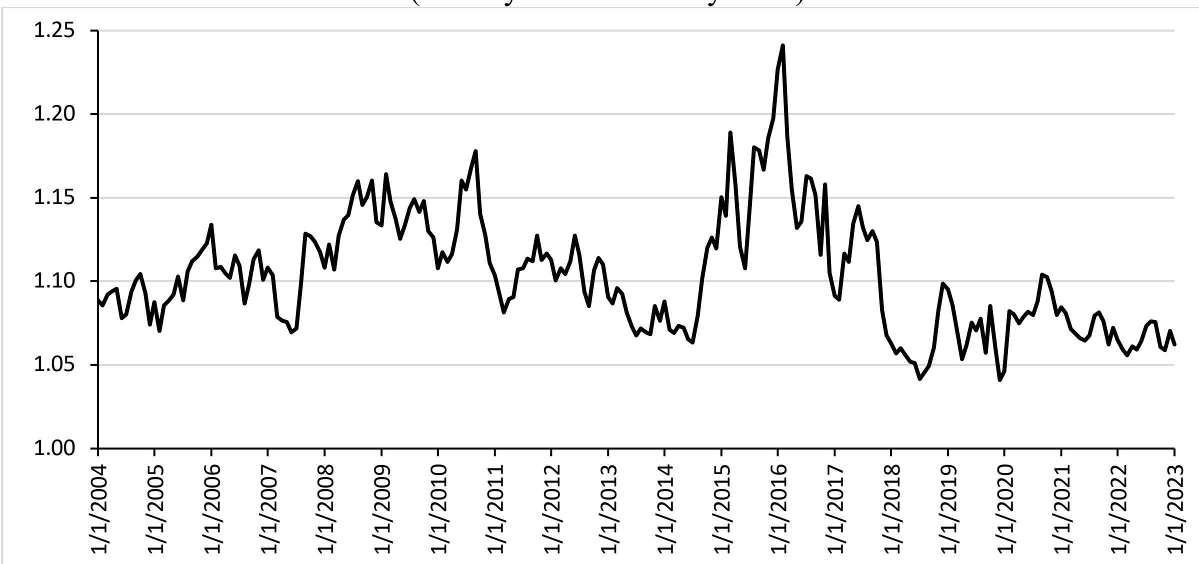
Working's T-index thus measures the excess of speculative positions beyond what is technically needed to balance commercial needs, and this excess is measured relative to commercial open interest. Accordingly, the index can be interpreted as follows (Irwin *et al*. 2009):

- If $HS \geq HL$ (*i.e*., the increase in short hedging exceeds the increase in long speculation): long speculators (as a group) are trading with short hedgers, and this is beneficial for the overall market performance, as speculators provide liquidity and risk–bearing capacity for hedgers (Working 1962).
- If $HS < HL$ (*i.e*., the increase in short hedging is less than the increase in long speculation): the increase in long speculation is absorbed by an increase in short speculation. This distorts market performance and we can speak of 'excessive speculation' (Working 1962).

As is shown in **Figure 14**, Working's T-index for crude oil futures has an average value of 1.11 during January 2004-Jannuary 2023; this means that almost 11% of open interest contracts in crude oil were not beneficial for providing short-term liquidity and hedging, but rather constituted speculative excess. The T-index peaked at 1.18 in 2016, indicating a speculative excess of almost 18% of all activities, when crude oil prices were down (**Figure 7**). This peak falls well within historical norms (Büyüksahin and Harris 2011). Speculative activity during April 2020 – January 2023 hovered around 7.5% of total activity. Hence, according to Working's T-index, a considerable degree of excess speculation is characteristic of the crude oil market; however, the T-index does not signal a significant *increase* in the degree of excess speculation in the oil market in recent years.

A limitation of the Working index is that it does not include non-reportable positions and non-reportable positions can be held by speculators or hedgers (Algieri 2016). In addition, the official distinction in speculators and commercials can be biased, because traders may have an incentive to be classified as commercials, due to the speculative position limits placed on non-commercials (Algieri 2016). Working's T-index does, in other words, underestimate the degree of excessive speculation.

Figure 14
Working's T-index: TWI crude oil
(January 2004 – January 2023)



Source: *Commitments of Traders Reports*, Commodities Futures Trading Commission. The T-index was computed by the authors.

An alternative measure of speculative activity considers the extent of speculative pressure in a market versus the extent of hedging pressure (Algieri 2016), or:

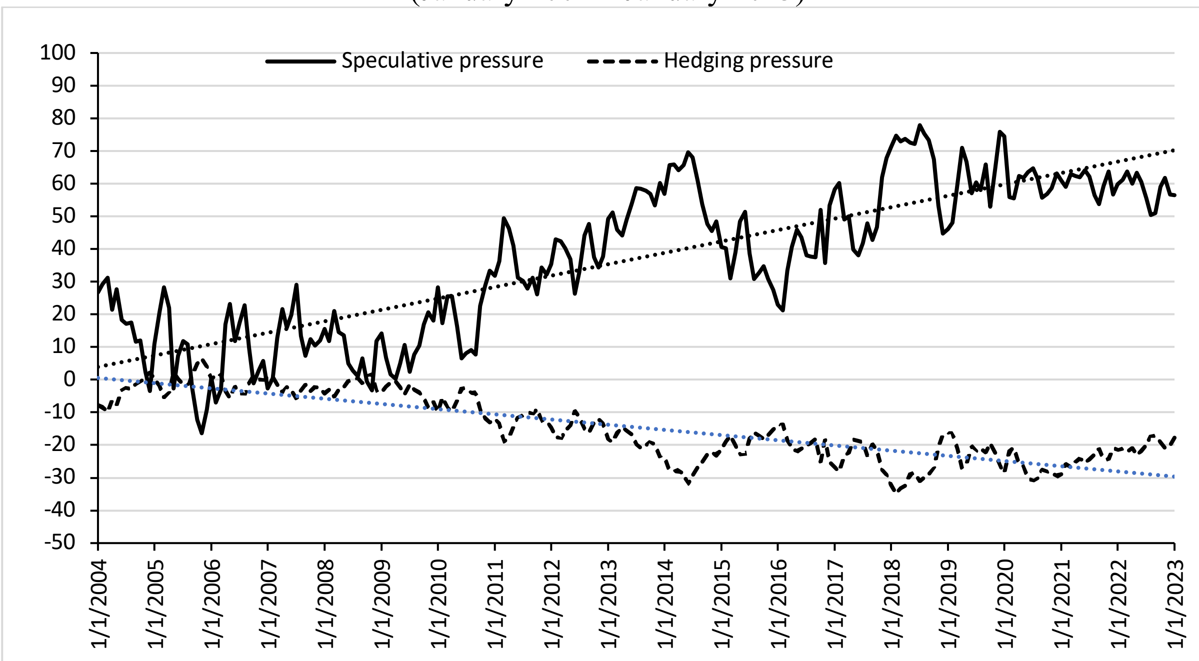
(6) $$speculative\ pressure = \frac{SL-SS}{SL+SS} \quad \text{versus} \quad hedging\ pressure = \frac{HL-HS}{HL+HS}$$

Hedging (speculative) pressure is defined as the difference in commercial (non-commercial) short and commercial (non-commercial) long positions divided by total commercial (non-commercial) positions. Each index represents the net long position held by the hedgers (speculators) normalized as a percentage of the total size of their positions.

As is shown in **Figure 15**, hedging pressure in the oil futures market declined throughout the period 2004-2023 and has been negative for most months. Negative values of hedging pressure means that commercial actors take short rather than long positions ($HL < HS$). This is reasonable if we think about the role of commercial actors within futures markets: usually (non-commercial) speculators are the ones taking mostly long positions.

In contrast, the measure of speculative pressure is (mostly) positive and shows a clear upward trend. A positive measure of speculative pressure indicates that the oil market is a speculative market. The mean value for speculative pressure during January 2004-Janaury 2023 is 37.1 (with standard deviation = 23.0). The fact that the measure of speculative pressure more than doubles during 2004-2023 signals that the crude oil market under analysis has become more speculative over time as long non-commercial positions have increased considerably relative to short non-commercial positions (Algieri 2016).

Figure 15
Hedging and speculative pressure: TWI crude oil
(January 2004 – January 2023)



Source: *Commitments of Traders Reports*, Commodities Futures Trading Commission. Computed by the authors based on Algieri (2016).

The evidence on the financialization of the U.S. oil market reviewed in **Section IV** underscores the significant role played by (non-commercial) speculators in the futures oil market, which is consistent with our estimates of the impact of speculation on spot oil prices during 2020-2022 in **Section III**, based on the model of Knittel and Pindyck (2016). In the next section we consider the impacts of higher oil prices on the prices of key (food) commodities.

V. Oil price, fertilizer price and the prices of food commodities

Speculation has been driving up oil prices, and higher oil prices, in turn, have pushed up the inflation rate, because oil is an essential intermediate input into most other goods and services (Weber *et al*. 2022). Here we focus on the impact of higher oil prices on the prices of key food commodities (corn and soybeans)—and of fertilizers (which themselves are a critical input agricultural production). We want to assess—using statistical analysis—whether higher oil prices do indeed matter for key food commodity prices. Higher food prices accounted for 7% of the PCE inflation rate in the U.S. in 2021, and for more than 12% of PCE inflation in 2022. In addition, due to rising food prices, the number of people facing acute food insecurity worldwide has increased from 135 million in 2019 to 349 million at the end of 2022 (IPES-Food 2022). Food commodity prices are therefore of systemic importance to the functioning of the U.S. and the global economy.

However, we have a deeper—analytical—motivation for our focus on food commodity prices. There is evidence that food prices have reflected financial market sentiment rather than grain market fundamentals, as commodity speculators have been found to have exacerbated recent price shocks in global grain markets (IPES-Food 2022). Specifically, speculative activity forced food commodity prices away from their equilibrium levels determined by market fundamentals. Importantly, the (crude) oil price is generally considered to be one of the 'grain market fundamentals'. However, given the evidence (presented above) that speculative activity in the crude oil market has been driving up the oil price and assuming that higher oil prices have (directly or indirectly) raised food commodity prices, it follows that 'market fundamentals' in food commodity markets do include a significant speculative element. If this is the case, oil speculators are not just distorting the crude oil market but are responsible for driving up food commodity prices as well.

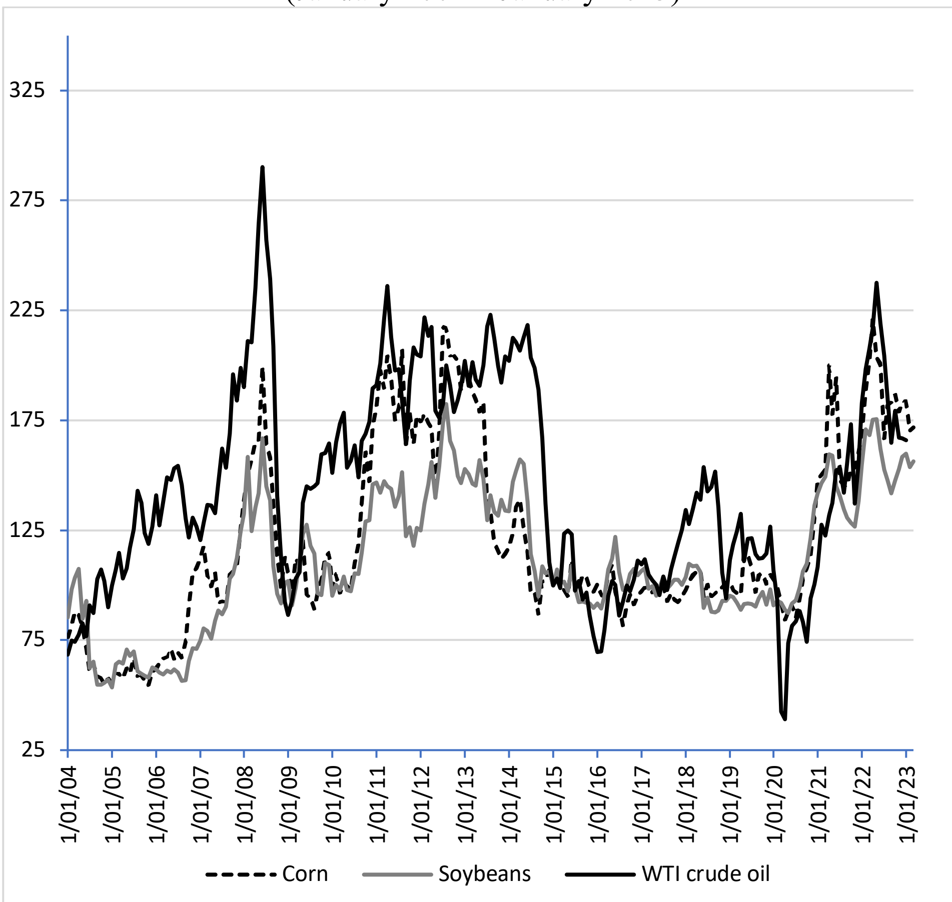
Crude oil is a critical input, both directly and indirectly, into agricultural production, which means that higher oil prices raise agricultural production costs and prices, as farmers may pass higher costs onto consumers. Petroleum is used to power farm equipment and to transport products; on average, fuel used for operating farm equipment accounts for around 8% of production costs of corn and soybean in the U.S. (Hitaj and Suttles 2016). Crude oil is also indirectly used through energy-intensive inputs including pesticides and fertilizer. Fertilizers account for an additional 16% and 18% of production costs for soybeans and corn, respectively (Hitaj and Suttles 2016).

Higher oil prices therefore likely lead to higher prices of corn, soybeans and other food commodities. **Figure 16** shows that the futures prices of corn and soybeans are co-moving with the futures price of WTI crude oil. **Figure 17** shows a similarly strong (contemporaneous) co-movement between the S&P GSCI[18] and the IMF Global Food Price Index, on the one hand, and the futures price of crude oil, on the other hand. We performed Granger causality tests using these monthly data for the period January 2004-January 2023. Based on the results, we could not reject the hypothesis that "the futures price of WTI crude oil does not Granger cause the futures prices of corn and soybeans".[19]

[18] The Standard & Poor's Goldman Sachs Commodity Index (S&P GSCI) invests in an array of different futures including energy, industrial and precious metals, and agricultural commodities and livestock. The index has been heavily weighted toward energy and specifically crude oil (circa 38% in 2022). Customers can buy into the index as they would buy into a mutual fund.

[19] The results of these tests appear in **Table A.4** in the **Appendix**.

Figure 16
Futures prices of corn, soybeans and WTI crude oil
(January 2004 – January 2023)



Sources: EIA for oil futures prices; and investing.com for futures prices of corn and soybeans.

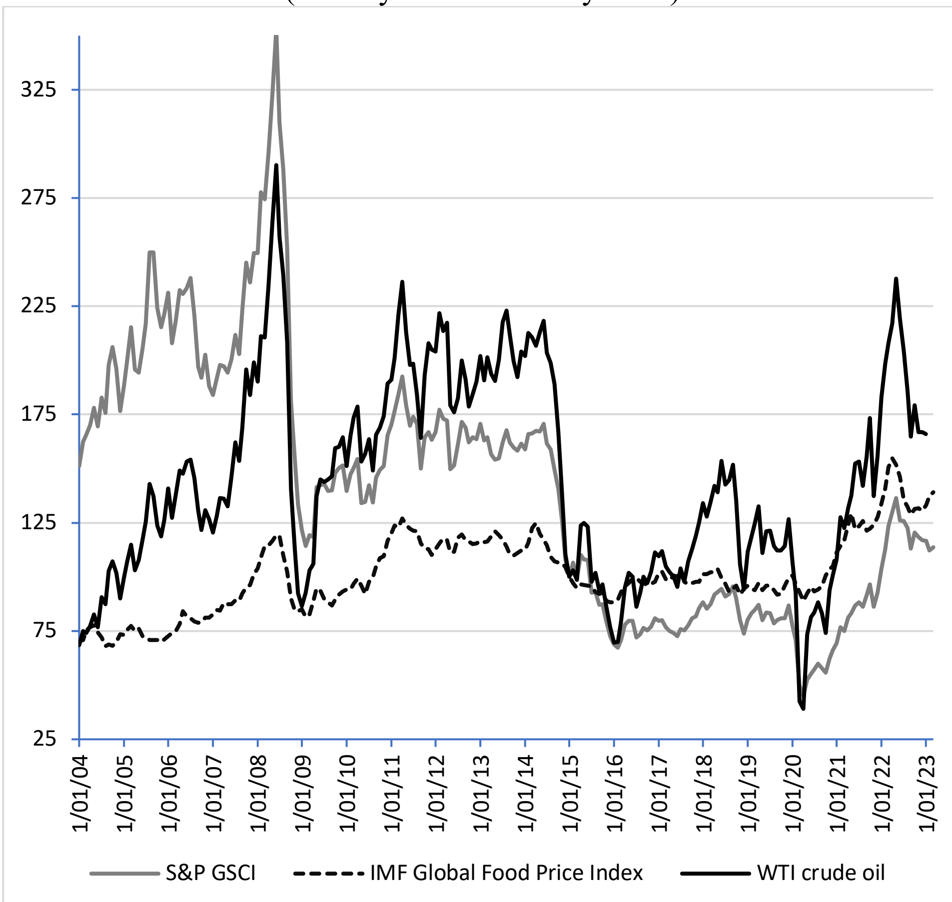
Hence, notwithstanding the fact that higher oil prices raise farm production costs and likely increase crop prices, we do not find statistical support for the claim that the (speculative) futures price of oil is a *direct* Granger-type 'predictor' of corn and soybean prices. Rather, what we find is that oil, corn and soybeans prices move together under the 'simultaneous' effects of index investments and inter-market information flows.

However, we also considered the *indirect* impact of higher crude oil prices—via fertilizer use—on the prices of corn and soybean. The fertilizers price index and the futures prices of WTI crude oil are plotted in **Figure 18**. From a graphical inspection, it can be seen that fertilizer prices show a trend which is similar to that of the oil price. Furthermore, it also appears as if fertilizer prices respond to changes in the oil price, as the price peaks of oil precede the peaks in the fertilizer price.

Using linear Granger causality tests and monthly data for January 2004-January 2023, we proceed by testing the following two (null) hypotheses:

1. WTI crude oil futures prices do not Granger-cause fertilizer prices.
2. Fertilizer prices do not Granger-cause the futures prices of corn and soybeans.

Figure 17
S&P GSCI, IMF Global Food Price Index and the futures prices of WTI crude oil
(January 2004 – January 2023)



Sources: EIA for oil futures prices; investing.com for S&P GSCI; the International Monetary Fund (IMF) for the IMF Global Food Price Index.

The estimations results appear in **Table 3**.

The (first) null hypothesis that prices of oil do not Granger-cause fertilizer prices can be rejected at 1% significance. This means that higher futures oil prices do indeed raise the fertilizer price (**Figure 18**).

Table 3
Granger causality tests: Futures prices of WTI crude oil, corn and soybeans and the fertilizer price (Monthly data; January 2004-January 2023)

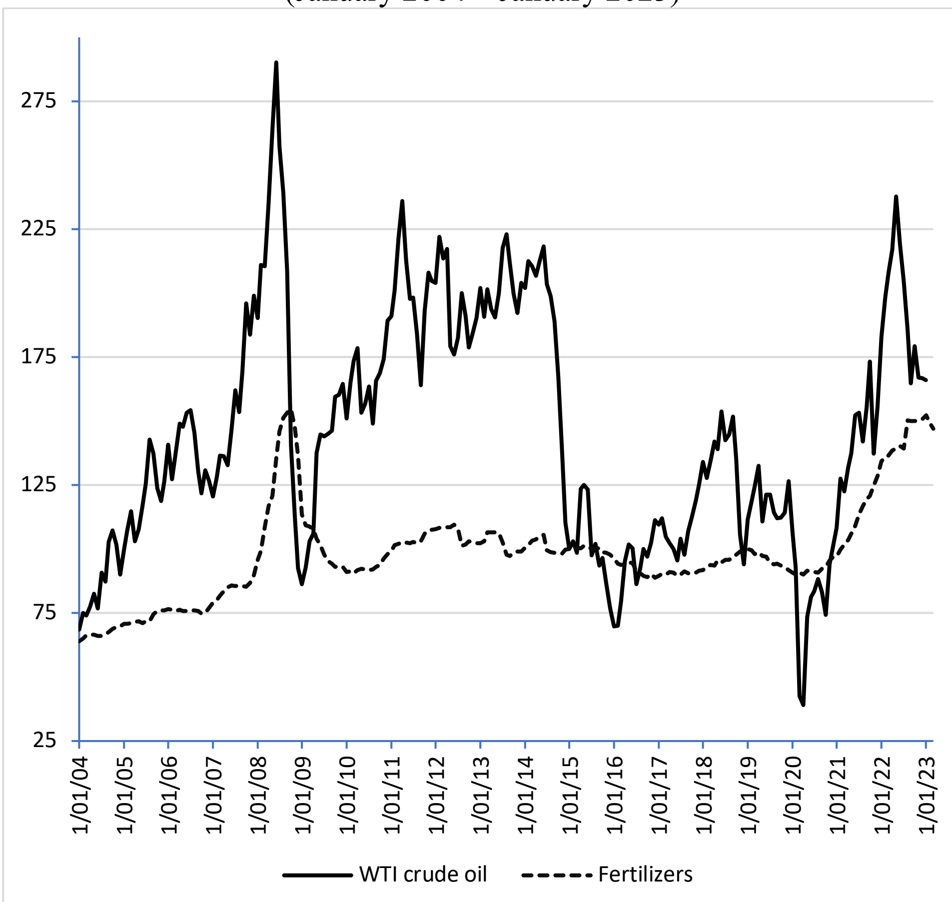
Null Hypothesis	Lags (AIC)	*F*-test (*p*-value)	Decision
Future returns of crude oil do not Granger cause fertilizer prices	4	0.0045***	Reject
Fertilizer prices do not Granger cause corn prices	5	0.0022***	Reject
Fertilizer prices do not Granger cause soybean prices	5	0.0016***	Reject
Memo:			
Fertilizer prices do not Granger cause future returns of crude oil	4	0.1282	Do not reject
Corn prices do not Granger cause fertilizer prices	5	0.0031***	Reject
Soybean prices do not Granger cause fertilizer prices	5	0.1135	Do not reject

Source: Estimations by authors. *Notes*: See *Notes* to **Table 2**.

The (second) null hypothesis also has to be rejected (at 1% statistical significance): as is shown in **Table 3**, fertilizer prices Granger-cause corn prices as well as soybeans prices.[20] Taken together, this implies that higher oil prices have indirectly raised the prices of corn and soybeans by their impact on fertilizer costs and prices. Oil speculators have been responsible, therefore, for driving up food commodity prices as well—and by doing so, oil speculators have provided further fuel to U.S. consumer price inflation, while increasing food insecurity and food poverty in the U.S. itself as well as abroad.

[20] For corn prices, bidirectional Granger causality is found; we also have to reject the (null) hypothesis that corn prices do not Granger-cause fertilizer prices (**Table 3**). Corn is intensively used as biofuel feedstock in the U.S. Hence, if biofuel demand increases, corn production and prices will rise and the demand of fertilizers will increase; as a result, fertilizer prices will increase in response.

Figure 18
Fertilizers price index and the futures prices of WTI crude oil
(January 2004 – January 2023)



Sources: EIA for WTI crude oil price; and FRED database for the price index for fertilizers.

VI. Conclusions

Higher energy prices have been a major driver of the surge in the U.S. PCE inflation, accounting for 21% of (annualized) PCE inflation in June 2022. Under reasonable empirical assumptions (concerning the short-run price elasticities of oil supply and oil demand) and using the recent model of Knittel and Pindyck (2016), the present analysis has shown that speculative activity in the crude oil market has been responsible for 24%-48% of the increase in the WTI crude price during October 2020-June 2022. A back-of-the-envelope calculation suggests that these estimates translate into an oil price increase of around $18-$36 per barrel and an increase in the U.S. PCE inflation rate by circa 0.75 to 1.5 percentage points during October 2020-June 2022.

The higher oil prices are also found to have raised the price of fertilizers. The higher fertilizer price, in turn, has led to higher prices of major food commodities (corn and soybeans). Oil speculators have been responsible, therefore, for driving up food commodity prices as well—and by doing so, oil speculators have further fueled U.S. consumer price inflation, while increasing food insecurity and food poverty in the U.S. itself as well as abroad. Higher oil prices squeeze real incomes, and disproportionately hit lower- and middle-income households (as these are spending a larger proportion of their budgets on energy and food than the richer households).

Our estimations of the extent by which speculative activity in the oil market has driven up oil prices, are supplemented by direct evidence of the degree of speculative activity in the WTI crude oil market. Long non-commercial open-interest positions in oil futures have increased considerably relative to short non-commercial positions, signaling a sustained and significant increase in speculative pressure in the oil market. Working's T-index, while not increasing, indicates that almost 11% of open interest contracts in crude oil were not beneficial for providing short-term liquidity and hedging, but rather constituted speculative excess (throughout the period January 2004-January 2023).

If all this speculation is pushing oil prices higher and leading to higher (energy and food) price inflation, with adverse societal consequences, then what can be done to eliminate excessive oil speculation? There are quick solutions. First, the CFTC can establish speculative oil position limits equal to the position accountability levels that have been in place at the New York Mercantile Exchange since 2001. Second, the CFTC can raise the margin requirements on speculative oil trading so that non-commercial traders (often Wall Street investment banks and hedge funds) back their bets with real capital. By raising the 'down payment' on oil futures contracts, obliging speculators to put up more money when they buy futures contracts, buyers who are just there to place bets, will exit the market. And finally, financial firms including Goldman Sachs, Morgan Stanley, and other Wall Street investment banks engaged in proprietary oil (swap) trading should be classified as speculators, instead of bona-fide hedgers. To increase the transparency of the crude oil market all transactions, including oil swaps and options, should be brought under the purview of the CFTC and their positions should be limited according to the market's need for liquidity. These are not difficult steps to take—and it would be wise to take them. However, there is a catch: when these remedies are taken only by the U.S., they will not work, because speculators will move offshore. Remedies need to be internationally coordinated and should also involve central banks which could impose high bars on loans for speculative purposes. Growing geopolitical tensions in a belligerent multipolar world further complicate the matter.

However, clamping down on excessive speculation in the oil market will also be beneficial for the functioning of food commodity markets—as our research implies. Eliminating the speculative elements from the oil price will eliminate a significant distortion in the market fundamentals in the corn and soybean markets. It is a boon that everyone but a few special interests ought to agree on.

References

Algieri, B. 2016. 'Conditional price volatility, speculation, and excessive speculation in commodity markets: sheep or shepherd behaviour?' I*nternational Review of Applied Economics* 30 (2): 210-237.

Alquist, R. and O. Gervais. 2013. 'The role of financial speculation in driving the price of crude oil.' *The Energy Journal* 34 (3): 35-54.

Anderson, S., R. Kellogg and S. Salant. 2018. 'Hotelling under pressure.' *Journal of Political Economy* 126 (3): 984-1026.

Arce, Ó., E. Hahn and G. Koester. 2023. 'How tit-for-tat inflation can make everyone poorer.' *The ECB Blog*, March 30. Link: https://www.ecb.europa.eu/press/blog/date/2023/html/ecb.blog.230330~00e522ecb5.en.html

Baumeister, C. and Hamilton, J.D. 2019. 'Structural interpretation of vector autoregressions with incomplete identification: Revisiting the role of oil supply and oil demand shocks.' *American Economic Review* 109: 1873-1910. https://doi.org/10.1257/aer.20151569

Blas, J. 2022. 'We told Big Oil not to invest. Don't complain now.' *The Washington Post*, November 3.

Blas, J. 2023. 'Wall Street Is Finally Going to Make Money Off the Permian.' *Bloomberg.com*, April 25. Link: https://www.bloomberg.com/opinion/articles/2023-04-24/higher-oil-prices-means-wall-street-s-shale-investments-will-finally-pay-off?leadSource=uverify%20wall

Bornstein, G., Krusell, P. and S. Rebelo 2019. 'Lags, costs, and shocks: An equilibrium model of the oil industry.' *Manuscript*, Northwestern University.

Bos, J. W. and van der Molen, M. 2012. 'A bitter brew? futures speculation and commodity prices.' *Futures Speculation and Commodity Prices* (August 29).

Büyükşahin, B. and J.H. Harris. 2011. 'Do speculators drive crude oil futures prices?' *The Energy Journal* 32 (2): 167-202.

Caldara, D., Cavallo, M. & Iacoviello, M. 2019. 'Oil price elasticities and oil price fluctuations.' *Journal of Monetary Economics* 103: 1–20.

Dunsmuir, L. 2022. 'No inflation relief in sight for U.S. as impact of Ukraine war intensifies.' *Reuters.com*, March 7. Link; https://www.reuters.com/markets/europe/us-inflation-set-heat-up-further-impact-ukraine-war-intensifies-2022-03-07/

Eckaus, R. 2008. 'The oil price really is a speculative bubble.' *MIT Centre for Energy and Environmental Policy Research Working Paper 08-007*. Cambridge, Mass.: MIT Sloan School of Management.

EIA. 2023. 'What drives crude oil prices? An analysis of 7 factors that influence oil markets, with chart data updated monthly and quarterly.' U.S. Energy Information Administration. Link: https://www.eia.gov/finance/markets/crudeoil/financial_markets.php

Fama, E. 1970. 'Efficient capital markets: A review of theory and empirical work.' *The Journal of Finance* 25 (2): 383-417.

Federal Reserve Bank of Kansas. 2022. *Dallas Fed Energy Survey March 2022*. Link: https://www.dallasfed.org/research/surveys/des/2022/2201#tab-report

Ferguson, T., P. Jorgensen and J. Chen. 2021. 'The knife edge election of 2020: American politics between Washington, Kabul, and Weimar.' *INET Working Paper No. 169*. New York: Institute for New Economic Thinking.

Ferguson, T. and S. Storm. 2023. 'Myth and reality in the Great Inflation Debate: Supply shocks and wealth effects in a multipolar world economy.' *International Journal of Political Economy 52* (1): 1-44. https://doi/full/10.1080/08911916.2023.2191421

Financial Times. 2020. 'Saudi Arabia puts the squeeze on US shale producers.' The FT View, *The Financial Times*, March 9.

Foreman, D. 2022. 'Analyzing how geopolitical events have impacted crude oil markets.' Blog for American Petroleum Institute. Link: https://www.api.org/news-policy-and-issues/blog/2022/05/13/analyzing-how-geopolitical-events-have-impacted-crude-oil-markets

Gilbert, C. L. (2010) 'How to understand high food prices.' *Journal of Agricultural Economics* 61 (2): 398–425.

Hamilton, J. D. 2009. 'Causes and consequences of the oil shock of 2007-08.' *Brookings Papers on Economic Activity* 40: 215-283.

Hitaj, C. and S. Suttles. 2016. *Trends in U.S. Agriculture's Consumption and Production of Energy: Renewable Power, Shale Energy, and Cellulosic Biomass*. Washington, D.C. United States Department of Agriculture.

IPES-Food. 2022. 'Another perfect storm? How the failure to reform food systems has allowed the war in Ukraine to spark a third global food price crisis in 15 years, and what can be done to prevent the next one.' Report of the International Panel of Experts on Sustainable Food Systems. Retrieved from https://ipes-food.org/_img/upload/files/AnotherPerfectStorm.pdf

Irwin, S. H., D.R. Sanders and R.P. Merrin. 2009. 'Devil or angel? The role of speculation in the recent commodity price boom (and bust)'. *Journal of Agricultural and Applied Economics* 41 (2): 377–391.

Juvenal, L. and I. Petrella. 2015. 'Speculation in the oil market.' *Journal of Applied Econometrics* 30 (4): 621–649.

Kaufman, R.K. and C. Connelly. 2020. 'Oil price regimes and their role in price diversions from market fundamentals.' *Nature Energy* 5: 141-149. Link: https://www.nature.com/articles/s41560-020-0549-1

Kilian, L. 2022. 'Understanding the estimation of oil demand and oil supply elasticities.' *Energy Economics* 107.

Kilian, L. and D.P. Murphy. 2014. 'The role of inventories and speculative trading in the global market for crude oil.' *Journal of Applied Econometrics* 29 (3): 454–478.

Kilian, L. and X. Zhou. 2022. 'The impact of rising oil prices on U.S. inflation and inflation expectations in 2020–23.' *Energy Economics* 113 (106228).

Knittel, C. R. and Pindyck, R. S. 2016. 'The simple economics of commodity price speculation.' *American Economic Journal: Macroeconomics* 8 (2): 85–110.

Krugman, P. 2008. 'Speculative nonsense, once again.' *The New York Times*, June 23. Retrieved from: https://archive.nytimes.com/krugman.blogs.nytimes.com/2008/06/23/speculative-nonsense-once-again/

Larsen, J. 2022. 'Democrats eye Wall Street rule to fight inflation.' TYT, June 14. Link: https://tyt.com/reports/4vZLCHuQrYE4uKagy0oyMA/e1018f2cc10fa8316

Masters, M. W. and A.K. White. 2008. *The Accidental Hunt Brothers. How Institutional Investors Are Driving Up Food And Energy Prices*. Retrieved from https://www.loe.org/images/content/080919/Act1.pdf

Meyer, G. 2018. 'Fundamentals do not matter to new breed of oil speculator.' *Financial Times*, February 27.

Newell, R.G. and B.C. Prest. 2019. 'The unconventional oil supply boom: Aggregate price response from microdata.' *NBER Working Paper No. 23973*. Cambridge, Mass.: National Bureau of Economic Research. Link: https://www.nber.org/papers/w23973

Rezitis, A. N. and Sassi, M. 2013. 'Commodity food prices: review and empirics.' Economics Research International.

Robles, M., M. Torero and J. Von Braun. 2009. *When Speculation Matters*. IFPRI Issue Brief 57. Washington, D.C.: International Food Policy Research Institute.

Roncaglia, A. 2014. 'Oil and its markets.' *PSL Quarterly Review* 68 (273): 151-175.

Sanders, D. R. and S.H. Irwin. 2010. 'A speculative bubble in commodity futures prices? Cross-sectional evidence.' *Agricultural Economics* 41 (1): 25–32.

Sanders, D. R., S.H. Irwin and R.P. Merrin. 2010. 'The adequacy of speculation in agricultural futures markets: too much of a good thing? '*Applied Economic Perspectives and Policy* .32 (1): 77–94

Smith, J. L. 2009. 'World oil: market or mayhem?' *Journal of Economic Perspectives* 23 (3): 145–64.

Storm, S. 2022. 'Inflation in the time of corona and war.' *INET Working Paper No. 185*. New York: Institute for New Economic Thinking. Link: https://doi.org/10.36687/inetwp185

Tang, K. & Xiong, W. 2012. 'Index investment and the financialization of commodities.' *Financial Analysts Journal* 68 (6): 54–74.

Tropeano, D. 2023. 'Inflation: neither supply nor demand determined.' *Monetary Policy Institute Blog*, February 27. Link: https://medium.com/@monetarypolicyinstitute/inflation-neither-supply-nor-demand-determined-44fbadafcd92

Vander Stichele, M. 2023. 'Shell's AGM: back to fossil fuel business as usual.' SOMO Newsletter, May 31. Amsterdam: Centre for Research on Multinational Corporations (SOMO). Link: https://www.somo.nl/shells-agm-back-to-fossil-fuel-business-as-usual/

Verleger, P.K. 2022. ‘The oil casino: AI stacks the odds.’ *Energy Intelligence*, March 16. Link: https://www.energyintel.com/0000017f-92be-df49-abff-96fffe420000

Verleger, P.K. 2023. ‘Did Yellen break OPEC?’ *The International Economy*, Winter: 60-63.

Von Witzke, H. and S. Noleppa, S. 2011. ‘The economics of Rumpelstiltskin. Why speculation is not the prime cause of high and volatile international agricultural commodity prices: An economic analysis of the 2007–08 price spike.’

Weber, I., J.L. Jauregui, L. Teixeira and L. Nassif Pires. 2022. ‘Inflation in Times of Overlapping Emergencies: Systemically Significant Prices from an Input-output Perspective.’ *Economics Department Working Paper Series 340*. Amherst: University of Massachusetts at Amherst. Link: https://doi.org/10.7275/0c5b-6a92

Wilson, T. 2023. ‘Shell, BP and Total out-trade Vitol, Trafigura, Mercuria and Gunvor.’ *The Financial Times*, May 3. Link: https://www.ft.com/content/a82327a7-8ff7-4671-baac-cdeaeae135df

Working, H. 1962. ‘New concepts concerning futures markets and prices.’ *American Economic Review* 52 (3): 431-459.

Wright, B. D. 2012. ‘International grain reserves and other instruments to address volatility in grain markets.’ *The World Bank Research Observer* 27 (2): 222–260.

Appendix

A. Data

Following Knittel and Pindyck (2016), we collected monthly data from the Energy Information Administration (EIA) on U.S. oil production, commercial stocks, imports, and exports for two periods of time: January 2007 – December 2011; and January 2020 – December 2022. The data for the years 2007-11 were used to replicate Knittel and Pindyck's results. We constructed time-series data for our variables S_t, D_t and N_t. To eliminate seasonality in oil demand, we de-seasonalized stocks. Monthly average data on the WTI crude oil spot and future prices are from the EIA. To calculate the gross convenience yield, we use the following definition of ψ_t provided by Knittel and Pindyck (2016): $\psi_t = (1 + r_T)P_t - F_{t,T} + k_T$, where P_t is the spot price at time *t*; r_T is the risk-free *T*-period interest rate; $F_{t,T}$ is the futures prices price for delivery of oil at *t* + *T*; and k_T is the *T*-period per-unit cost of physical storage which is estimated to equal $1.50 per barrel of oil (see **Table A.1**). We use the T3-Bill rate to operationalize r_T and the price of 3-months futures contracts is used to measure $F_{t,T}$. The value for the price elasticity of demand for storage η_N is set at 1.0 (Knittel and Pindyck 2016).

Table A.1

Values of variables and price elasticities

Price elasticity of oil storage demand	$\eta_N = 1$
The *T*-period per-unit cost of physical storage	$k_t = 1.5$
Market fundamentals in the market for storage	$k_N = 1$

B. Replication of Knittel and Pindyck's (2016) epoch analysis

To check the validity of our approach and numbers we used the model framework to replicate the results for epochs during 2007-2011 obtained by Knittel and Pindyck (2016). The key numerical assumptions made by these authors are listed in **Table A.2**.

Table A.2

Knittel and Pindyck (2016): Values of variables and price elasticities

Long-run price elasticity of oil supply	$\eta_S = 0.2$
Long-run price elasticity of oil demand	$\eta_D = -0.2$
Short-run price elasticity of oil supply	$\eta_S = 0.1$
Short-run price elasticity of oil demand	$\eta_D = -0.1$
Price elasticity of oil storage demand	$\eta_N = 1$
The *T*-period per-unit cost of physical storage	$k_t = 1.5$
Market fundamentals in the market for storage	$k_N = 1$

Our replication results appear in **Table A.3** along with the findings of Knittel and Pindyck (2016). Our replication results are similar to the original results. We note that small differences in the numbers used in the analysis lead to larger differences in terms of the log values of the outcomes. The observed numerical differences are due to the fact that we used a different method to deseasonalize the stocks of crude oil than Knittel and Pindyck (2016). We note that the short-run price elasticities of oil supply and oil demand used by Knittel and Pindyck are relatively high (in absolute terms) compared to the short-run price elasticities reported in the literature. Choosing relatively high values (in absolute terms) for these elasticities directly diminishes the degree of (excessive) speculation observed in the model.

Table A.3

Epoch analysis 2007-2011

	2007:1-2008:7	2009:2-2011:4	2009:2-2010:4	2010:9-2011:4
Change in log price due to speculation				
- Knittel and Pindyck (2016)	-0.31%	-1.19%	-2.27%	-10.43%
- Replication	0.07%	-0.92%	-1.76%	-9.77%
Change in log convenience yield due to speculation				
- Knittel and Pindyck (2016)	12.05%	0.95%	0.82%	-4.56%
- Replication	13.01%	3.03%	2.74%	-2.70%

Sources: Knittel and Pindyck (2016) and authors' calculations. For epochs 1, 2 and 3, the authors assume that $\eta_S - \eta_D = 0.4$, but for epoch 4, they assume that $\eta_S - \eta_D = 0.2$.

C. Granger causality tests

Table A.4 reports the results of the Granger causality tests that tested the relationships between futures prices of crude oil (on the one hand) and the futures prices of corn and soybean (on the other hand).

Table A.4

Granger causality tests: Futures prices of WTI crude oil, corn and soybeans
(Monthly data; January 2004-January 2023)

Null Hypothesis:	Lags (AIC)	F-test (p-value)	Decision
Future returns of crude oil do not Granger cause:			
• future returns of corn	3	0.5247	Do not reject
• future returns of soybeans	2	0.4141	Do not reject
Future returns of corn do not Granger cause future returns of WTI crude oil	3	0.1236	Do not reject
Future returns of soybeans do not Granger cause future returns of WTI crude oil	2	0.1174	Do not reject

Source: Estimations by authors. *Notes*: p-values: * = reject Null Hypothesis at 10% significance; ** = reject Null Hypothesis at 5% significance; and *** = reject Null Hypothesis at 1% significance. The number of observations is 229. The time-series of the (price) indices are non-stationary. Compounded returns (*i.e.*, changes in consecutive logarithmical prices) have been computed to respect the stationarity requirement of the test. For each test, the optimal number of lags was selected through the AIC.