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Examining the Impact of Energy Price Volatility on Commodity Prices from Energy Supply Chain Perspectives

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Abstract: Oil has historically been the most significant primary energy source for our daily lives and business activities. However, recent skyrocketing oil prices have been one of the greatest concerns among policymakers, business executives, and the general public due to their impacts on daily necessities, including food, clothing, and automobile transportation. As a result, fast-rising inflation on the global scale is attributed to mounting oil prices. Even though many countries have made a conscious effort to tame oil prices and the subsequent inflation, their efforts are often in vain due to some uncontrollable situations. These situations include the ongoing war between Ukraine and Russia, where Russia began weaponizing its oil resources and limiting oil supplies to its neighboring European countries. Faced with the current energy crisis, a growing number of policymakers and business executives have attempted to develop energy-induced risk mitigation strategies. With this in mind, the primary purpose of this paper is to investigate what may have caused oil price hikes and to determine how significantly oil prices influence commodity prices. This paper then proposes ways to mitigate energy-induced supply chain risks by analyzing four decades of secondary data obtained from multiple sources.

Keywords: energy price volatility; energy supply chain; commodity pricing; supply chain mapping; supply chain resilience; secondary data analysis; trend analysis

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1. Introduction

For the last two years, global oil prices have surged, with benchmark Brent crude jumping from an average of USD 41.96 per barrel at the peak of the COVID-19 pandemic in 2020 to USD 107.64 in July 2022 [1]. The International Energy Agency expects the current energy demand to increase by 37% in the next 25 years [2]. Similarly, the International Energy Outlook 2019 [3] predicts significant growth in worldwide energy demand over the 28 years from 2012 to 2040. Total global energy consumption is expected to grow from 549 quadrillion British thermal units (Btu) in 2012 to 629 quadrillion Btu in 2020 and eventually to 815 quadrillion Btu in 2040—a 48% increase from 2012 to 2040 [4]. In particular, U.S. gasoline and diesel inventories are running low, refining capacity is constrained, and oil demand remains strong due in part to the pent-up demand [5]. A massive increase in energy prices puts a heavy burden on every household, with soaring costs for electricity and mobility. Subsequently, rising energy (especially oil) prices have created unprecedented economic crises worldwide through superinflation. Energy price hikes are primarily caused by rapidly growing worldwide demand for oil in the wake of extreme weather conditions, a shortage of oil supply to the European Union (E.U.) from Russia, and a lack of investment in energy grid stability due to austerity government policies following the COVID-19-induced economic doldrums. In particular, the E.U. nations' dependency on the imports of fossil fuels from Russia, which is using oil as its geopolitical weapon, poses serious additional challenges in defusing the current energy crisis. Faced with these challenges, policymakers and business executives need to act immediately to change their energy conservation policies and strategies. These polices include oil rationing, energy supply diversity, and energy supply chain security. Another change in business strategies includes the overhaul of private-sector energy usage practices, such as industrial energy curtailment. Cases in point, the state of California has already issued electricity outage warnings and imposed restrictions on air conditioning usage. Texas, Illinois, and Missouri will likely develop energy policies (e.g., rolling blackouts) similar to those in California amid sweltering summer heat in 2022.

Petroleum (crude oil) is a fossil fuel that is a non-renewable source of energy. Although crude oil (oil hereafter) is a primary energy source for generating electricity, gasoline, and heating, oil is a significant culprit of air pollution and the subsequent greenhouse effect since burning oil emits carbon dioxide gas and contributes to climate change through global warming. To make matters worse, a vast majority of countries worldwide have imported oil from the Organization of the Petroleum Exporting Countries (OPEC) and Russia at increasingly high prices as worldwide oil reserves shrink. In particular, electricity generated from oil is costly compared to other fossil fuels, such as coal and gas.

2. Relevant Literature Review

Despite the inherent complexity and volatility of energy prices, an accurate forecast of energy prices and an understanding of energy price behaviors would help energy producers and consumers determine their energy production capacity, energy inventory level, and size of investments in energy generation and distribution. Such energy price forecast can help the energy user or energy developer select the most cost-efficient energy sources. Given the significance of energy pricing to economic activities, some scholars have attempted to capture energy pricing patterns and assess their impacts on economic activities. To elaborate, Asafu-Adjaye [6] was one of the first to estimate the causal relationships between energy consumption and income in India, Indonesia, the Philippines, and Thailand, using co-integration and error-correction modeling techniques. His study result indicates a causal relationship between energy prices and income. Finn [7] theorized that energy price shocks equivalent to adverse technology shocks could induce significant contractions in economic activity. Brown and Yücel [8] found that oil price shocks could affect aggregate economic activities. Thus, they argued that both monetary and energy policies should be developed based on energy price fluctuations.

Similarly, Papapetrou [9] observed that oil price changes affected actual economic activity and employment. Oil prices were found to be important in explaining stock price movements based on the empirical evidence obtained from a multivariate vector autoregression (VAR) approach. His study, however, was confined to Greece. Huang et al. [10] applied the multivariate threshold model to investigate the impacts of an oil price change and its volatility on economic activities (changes in industrial production and actual stock returns) and found that an oil price change or its volatility had a limited impact on the economies if the change was below threshold levels. If the change was above threshold levels, an oil price change or volatility affected economic activities more significantly than the real interest rate. Their data, however, were limited to monthly data from the US, Canada, and Japan from 1970 to 2002.

However, Olomola [11] found that oil price shocks did not affect economic output or inflation in Nigeria, while oil price shocks significantly influenced the actual exchange rates in Nigeria. Benkraiem et al. [12] investigated the relationship between S&P 500 prices as a U.S. economic barometer and a set of energy prices, including WTI crude oil prices. They observed that crude oil price shocks influenced short- and long-term U.S. stock market dynamics. Balashova and Serletis [13] discovered that oil price shocks had a positive and statistically significant impact on almost all types of Russian economic activity, including the economic output of manufacturing, mining, construction, transport, retail, and wholesale trade.

Similar to the above line of research examining the causality between oil price shocks and economic activity, Carfora et al. [14] recently examined the causal relationships among energy prices, income, and energy consumption in selected Asian countries (India, Indonesia, Thailand, and the Philippines). Although those relationships varied from one country to another, they found that, in the cases of India and Indonesia, a bidirectional relationship existed between energy prices and income. Dagoumas et al. [15] re-investigated the long-run relationship between energy prices and economic growth within the periphery of the European Union (E.U.) using the Variance Decomposition Analysis. Given that energy prices were strong drivers of inflation in the E.U., they examined how the energy prices (especially crude oil prices) affected economic growth within the E.U. periphery. They found that energy prices negatively affected Gross Domestic Product (GDP) growth rates in the E.U.

As this review of the prior literature on energy pricing reveals, most of the existing studies on energy pricing focused on the macroeconomic implications of energy pricing. Refocusing on the microeconomic implications of energy pricing, some pioneering works started to investigate how energy prices affected commodity prices sensitive to economic fluctuations and, thus, better reflect economic conditions. To elaborate, after recognizing an increase in the interconnections of agriculture and energy markets through the rise in new biofuel agribusinesses and oil–ethanol–corn linkages, Saghaian [16] reported a strong correlation between oil and commodity prices based on empirical results obtained from the contemporary time-series analysis and Granger causality. Following up, Koirala et al. [17] examined whether linear relationships exist between future energy prices and future prices of agricultural commodities, such as corn and soybeans. Their study results revealed that future agricultural commodity and energy prices were highly correlated; thus, an increase in energy prices increased the prices of corn and soybeans. Concerned about a surge in agricultural commodity prices in South Africa from 2004 to 2008, Fowowe [18] analyzed the relationship between oil prices and commodity prices and found no evidence that agricultural commodity prices in South Africa responded to oil prices. This finding contrasted with the prior findings of the earlier studies. López Cabrera and Schulz [19] investigated price and volatility risk originating in linkages between energy (especially biofuel) and agricultural commodity prices in Germany using an asymmetric dynamic conditional correlation GARCH model, as well as a multivariate multiplicative volatility model. Similar to Fowewe [18]'s study finding, they found that the long-run correlation between energy (biodiesel) prices and agricultural commodities (rapeseed) was relatively low and not significant. They also noted that biodiesel prices did not influence rapeseed and crude oil prices in the short run. In contrast, Wei et al. [20] confirmed a bidirectional positive causality between oil and agricultural commodity prices. These earlier studies focused on examining any causality between oil and agricultural commodity prices under the premise that oil price hikes would lead to a greater use of alternative energy (especially biofuel) extracted from agricultural commodities (e.g., corn and rapeseed) and to an increase in agricultural commodity and food prices.

Considering the shortcomings mentioned above and the paucity of earlier studies on energy pricing implications, this paper analyzes more than four decades of secondary data regarding global oil prices; gasoline prices; and beef, pork, cotton, gold, silver, iron ore, and coffee prices. Furthermore, this paper examines any functional connection between global oil price volatility and commodity prices. This paper also discusses various managerial or policy implications of energy price volatility from an energy supply chain perspective.

3. Sources of Energy Crisis

Given energy's direct impact on our costs of living, such as electricity and heating bills, many households and enterprises pay close attention to energy pricing and wonder why energy pricing is so volatile and thus difficult to predict. The volatility of energy prices is attributed to a multitude of complicated factors. In particular, since oil has been a primary energy source, I focus on identifying the main factors influencing oil price volatility. These factors include the following:

(1) <u>Demand for Crude Oil</u>: Volpe [21] recently reported that, based on the data available from the American Petroleum Institute (API), the prices of gasoline are often determined by the cost of global crude oil (61%), refining costs (14%), distribution and marketing costs (11%), and federal and state taxes (14%). Therefore, it is apparent that the price of a barrel of crude oil in open markets dictates the price of fuel that people consume every day. Due to the variety and different blends of crude oil, its

price depends on one of the four popular benchmarks: Brent Crude, West Texas Intermediate (WTI), Dubai Crude, and OPEC baskets. Brent Crude is the most widely used one and is typically sold on the spot market at London's International Petroleum Institute. At the same time, WTI is the U.S. benchmark for light sweet oil traded on the New York Mercantile Exchange (NYMEX) for gasoline. The Dubai Crude (called Fateh) represents a medium sour crude oil extracted from Dubai. Dubai Crude is used for pricing Persian Gulf crude oil exports to Asia [22]. The OPEC basket price is a weighted average of the prices of 13 regional oils from Algeria's Saharan Blend, Angola's Girassol, Ecuador's Oriente, Indonesia's Minas, Iran's Heavy, Iraq's Basra Light, Kuwait's Export, Libya's Es Sider, Nigeria's Bonny Light, Qatar's Marine Saudi Arabia's Light, the United Arab Emirates' Murban, and Venezuela's Merey [23]. To complicate oil pricing, the benchmark mentioned above can be determined through either the spot market or future prices. Two contrasting market situations can set future prices: (1) Backwardation, where market prices are expected to be lower in the future months than the present day, and (2) Contango, where market prices are expected to be higher in the future months than the present day.

(2) Government Policy, Regulations, and Laws: U.S. gasoline is subject to federal and state taxes. As of 2022, U.S. federal taxes consisted of excise taxes of USD 0.183 per gallon on gasoline, USD 0.243 per gallon on diesel fuel, and a leaking underground storage tank fee of USD 0.01 per gallon on both fuels [21]. This fact illustrates that fuel price is affected by the government's tax policy. In addition, since oil drilling and production can be regulated by state laws in the U.S., oil supplies and subsequent changes in oil market pricing controlled by the state government can affect oil pricing. The U.S. federal government regulates offshore oil exploration for the Outer Continental Shelf (a radius of 200 nautical miles offshore) and thus influences oil production and pricing. Furthermore, stricter government regulations (e.g., Environmental Protection Agency regulations) intended for environmental protection can hurt oil pricing. Not to mention the U.S. policies, the OPEC policies regarding its oil production tend to have a profound impact on global oil prices since OPEC accounts for 40% of the world crude oil production, and its oil exports represent about 60% of the total petroleum traded globally [24]. Another example is Venezuela and Nigeria's nationalization of oil fields, which led to global oil shortages and price increases soon after those countries' abrupt policy shifts.

(3) Political Instability, Unrest, Geopolitical Tension, and War: Historically, civil uprisings, changes in political power, border conflicts, and regional wars involving oil-producing countries disrupted oil supplies and created a ripple effect on oil prices. For instance, the Gulf War in the early 1990s, triggered by Iraq, caused a 9-month oil price hike and nearly doubled oil prices [25]. Similarly, the ongoing war between Ukraine and Russia has led to a series of import bans for Russian crude oil, liquefied natural gas, and coal by the U.S. and European Union (E.U.), subsequently increasing global oil prices in the year 2022. Indeed, the price of crude oil in the global market skyrocketed from approximately USD 76 per barrel at the start of January 2022 to over USD 110 per barrel in March 2022 due to Ukraine and Russia's border conflicts [26].

(4) Natural Calamities and Disasters: Natural disasters, such as hurricanes, tornadoes, flooding, earthquakes, and tsunamis, can wreak havoc on energy infrastructure, including oil refineries and power plants. For example, when Hurricane Katrina hit the U.S. Gulf Coast region, which accounted for 35% of oil production in 2005, U.S. oil prices soared by around 20% [27]. However, when a 9.0-magnitude earthquake rocked Japan in 2011 and then destroyed six oil refineries that accounted for 31% of Japan's oil output, many expected a temporary oil price drop since refinery closures would result in reduced crude oil imports [28].

(5) Trader's Speculative Investment in Oil: Generally, when crude oil supply is tight or it is considered valuable (premium), its price goes up, whereas if its demand is low or it is considered less valuable, its price decreases due to its discount. In the NYSE,

oil traders determine the volume of speculative crude oil purchases and thus affect the overall demand for crude oil and the subsequent future oil prices. To meet the U.S. Renewable Fuel Standard (RFS) program targets, the EPA also requires U.S. oil companies to have one Renewable Identification Number (RIN) for each gallon of ethanol blended into fuel [29]. To comply with this requirement, some oil producers that are RIN-short need to increase the purchase of RIN (e.g., biodiesel fuels). Thus, their oil trade volume can affect oil prices. Furthermore, some industries (e.g., airline and trucking sectors) participating in cooperative hedging programs against fuel price hikes can increase their speculative investments in crude oil and the subsequent oil price, especially when many companies speculate towards a continued upward pressure on oil prices.

(6) Grid Network, Power Generation, and Distribution: Tayeb [30] recently reported that U.S. power grid failures in most of Western and Central U.S. increased vulnerability to the energy supply chain and increased the risk of electricity shortfalls and disruptions. With rising demand for additional power generation, the U.S. government has been under growing pressure to expand the power grid. However, adding high-voltage transmission lines and switches to the grid usually takes much time. In contrast, replacement parts for turbines and other equipment needed for the power grid may not be readily available. In addition, power plant commissioning delays can aggravate the grid network problem. An obsolete and insufficient grid network can adversely affect oil prices.

(7) Alternative Energy Availability and Affordability: Recognizing the mounting cost of using fossil fuels and their contribution to global warming, a growing number of energy producers, including power plants, are exploring various sources of alternative energy. These include solar, wind, geothermal, biomass, hydrogen, tide/wave, natural gas, municipal waste, coal, and nuclear. All of these alternative energy sources, apart from coal, are clean or renewable energy sources. In particular, since renewable energy can derive power from natural sources, it can replenish itself without running out. Due to such benefits, the use of alternative energy has grown exponentially in recent years, accounting for 23.2% of all energy sources for power generation in 2020 [31]. The International Energy Agency (IEA) predicted that alternative energy sources would account for nearly half of the worldwide increase in power supply up to 2040 [32]. The increased use of alternative energy will decrease oil demand and lower oil prices.

(8) Energy Waste: According to the Energy Information Administration (EIA), two-thirds (66%) of the primary energy used to create electricity is wasted by the time the electricity arrives at the customer's meter. Generally, more than half (59%) of energy is lost in the power generation process due in part to waste heat released in the air and inefficient transformers and equipment, including pumps, fans, and industrial boilers [33]. If energy waste can be reduced, energy consumption will drop, thus decreasing oil prices.

As discussed above, there exists a host of factors influencing oil prices. Though not specified, other factors, such as inflation and currency fluctuations, can contribute to oil price volatility. Due to complicated oil price volatility, it is challenging to forecast oil prices and assess their impacts on our standard of living and daily business practices. Recognizing such a challenge, the primary purpose of this paper is to examine any functional relationship or link between oil price volatility and commodity pricing that shapes our daily lives and everyday business practices. This paper proposes a series of hypotheses and tests them using statistical data analyses, including a regression analysis and a trend analysis, predicated on more than four decades of various pricing data collected from secondary sources.

4. Propositions, Analyses, and Results

Due to the volatility and complexity of crude oil pricing, it is a daunting task for us to accurately predict future oil prices and to assess their potential impacts on commodity prices. To understand oil pricing dynamics and their ramifications for commodity markets, I experimented with multiple business analytic tools (e.g., a series of statistical data and forecasting analyses) with secondary data obtained from multiple public sources. These sources include IEA's Energy Statistics Data Browser, Nasdaq Data Link, Refinitiv Eikon-Commodities Data Catalogue, Internal Monetary Fund's Commodity Data Portal, World Bank Commodity Prices Database, and Wall Street Commodity Data. The following subsections provide details of those experimental results and their managerial implications.

4.1. Experimental Data

I collected monthly time-series data about the prices of popular energy sources, comprising crude oil, gasoline, diesel, and Austrian coal from the secondary data sources that I referred to earlier. I also compiled matching data about the prices of selected commodities: (1) metals, such as aluminum, gold, silver, and iron ore; (2) agricultural commodities, such as corn, cotton, coffee, and wheat; and (3) meats, such as beef and pork. The data set contained 449 monthly pricing records for 37 years, from March 1985 to July 2022. I compiled the collected data into formats of both Excel® and SPSS files for statistical data analyses.

4.2. Propositions

When the price of crude oil rises, people have to decide how often they should travel, how often they should go grocery shopping, or how much they should spend without going over their budgets since oil price hikes tend to impact people's mobility, heating/electricity bills, and subsequent daily spending. In particular, Americans' daily lives are heavily dependent on oil, as they are the biggest oil consumers in the world. The United States uses 20.54 million barrels of oil daily, accounting for approximately 20% of the 100.23 million barrels produced daily worldwide [34]. Although people have long felt the impact of oil prices on their livelihood, few scientific studies have examined the correlation between oil prices and the cost of living. With that in mind, I developed a series of propositions that test the validity of relationships between oil price volatility and the cost of living reflected in the prices of commodities that are essential for sustaining our daily lives. These commodities include wheat, corn, coffee, beef, and pork, which comprise ordinary people's daily food menu. In addition, I included other commodities, such as cotton, an essential material for clothing; aluminum and iron, which represent essential ingredients for many products (e.g., automobiles); and gold and silver, which represent popular investment targets as currency replacements. Furthermore, I added coal since it can be substituted for oil as an alternative energy source.

Proposition 1. *There is a positive relationship between oil and corn prices.*

Based on the premise that crude oil prices can increase conventional fossil fuel (e.g., gasoline) prices, I propose that oil price hikes will increase the demand for alternative energy, such as biofuel (e.g., ethanol), which can be created from corn, consequently increasing corn prices. As of 2009, corn use for ethanol accounted for approximately one-third of the total demand for U.S. corn [35]. However, corn processing for ethanol will continue to proliferate in the next few years with government mandates calling for increased ethanol use in the wake of sky-high oil prices. Such growth is likely to further increase corn prices. When this proposition is tested using a correlation analysis, corn price has a significant positive correlation with oil price with a Pearson correlation coefficient of 0.811 (p = 0.000). Figure 1 graphically shows the positive correlation between oil and corn prices for the last four decades. As expected, I also found that both gasoline and diesel prices have strong positive correlations with corn prices. Specifically, gasoline price significantly correlates with corn price with a Pearson correlation coefficient of 0.832. Likewise, diesel price significantly correlates with corn price with a Pearson correlation coefficient of 0.715. In addition, I performed a regression analysis to conduct an inference test with the corn price as the dependent variable and the crude oil price as the independent variable.

This test result also confirms that crude oil is a significantly good predictor of corn price (with a standardized β coefficient of 0.811 and an adjusted R-square value of 0.657).

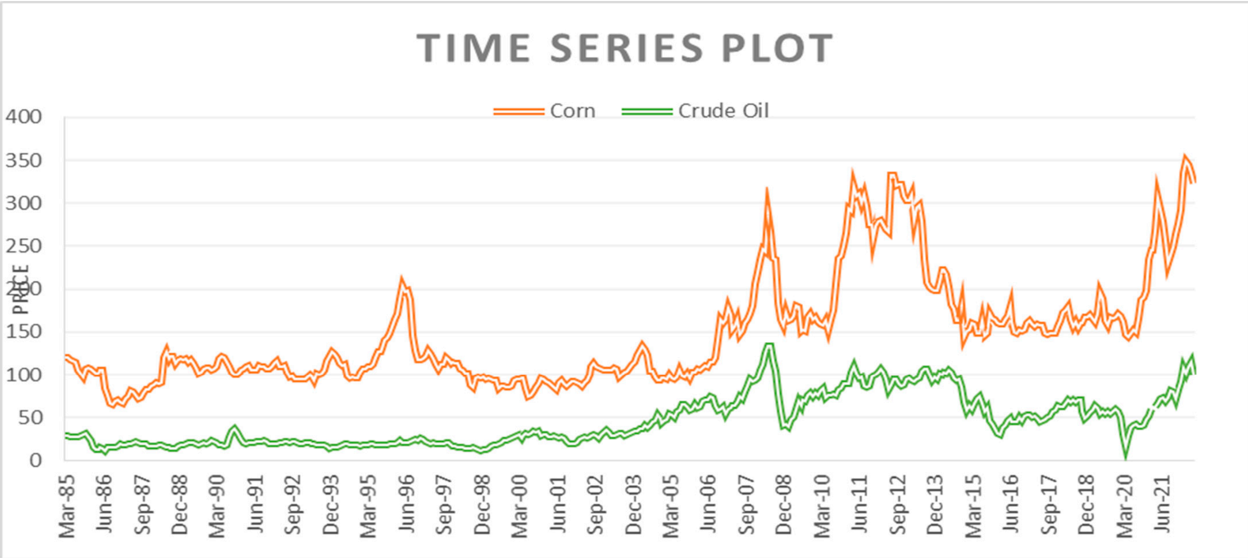


Figure 1. Time-Series Plot of Crude Oil and Corn Price Patterns.

Proposition 2. *There is a positive relationship between oil and coal prices.*

Using the logic similar to proposition 1, I hypothesize that oil price hikes will increase the demand for another alternative energy source, such as coal, thus increasing coal price. The test result of this proposition reveals that coal price is positively related to oil price, as illustrated in Figure 2. The correlation analysis shows that coal price has a strong positive correlation with oil price, with a Pearson correlation coefficient of 0.831 (p = 0.000). The inference test based on a bivariate regression analysis with the coal price as the dependent variable and the crude oil price as the independent variable shows that crude oil is a good predictor of coal price (with a standardized β coefficient of 0.831 and an adjusted R-square value of 0.690).

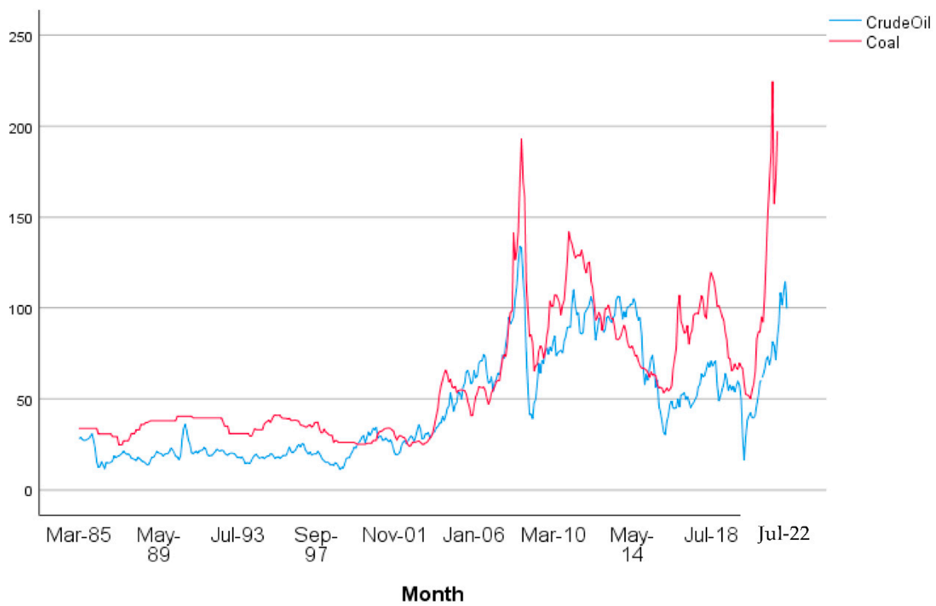


Figure 2. Time-Series Plot of Crude Oil and Coal Price Patterns.

Proposition 3. *There is a positive relationship between oil and iron ore prices.*

As the world's second most traded bulk commodity, iron ore is one of the essential minerals needed for producing industrial goods, such as machinery, tools, vehicles, aircraft, ships, building structures, and bridges. Iron ore production is dominated by Brazil and Australia, which accounts for 80% of iron ore supplies [36]. Since the world's largest iron ore consumer is China, importing iron ore from remotely located Brazil and Australia to China will likely involve bulk shipping affected by fuel cost. Since fuel cost is dictated by oil price, the rising oil price will lead to higher iron ore prices. Under such a premise, I posit a hypothesis that iron ore price is directly related to oil price. This hypothesis is validated in that iron ore price has a strong positive correlation with oil price, with a Pearson correlation coefficient of 0.787 (p = 0.000). Figure 3 graphically displays the matching pricing patterns of crude oil and iron ore. The regression analysis result with the iron ore price as the dependent variable and the crude oil price as the independent variable shows that crude oil is a good predictor of iron ore price (with a standardized β coefficient of 0.787 and an adjusted R-square value of 0.619).

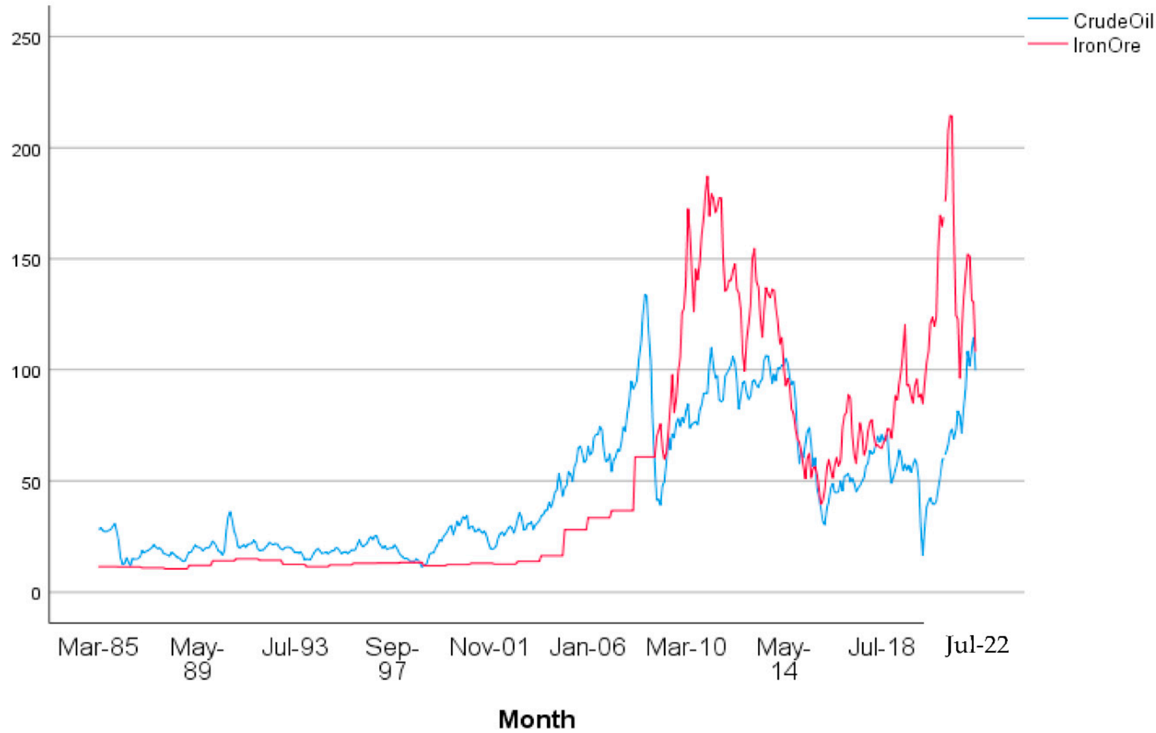
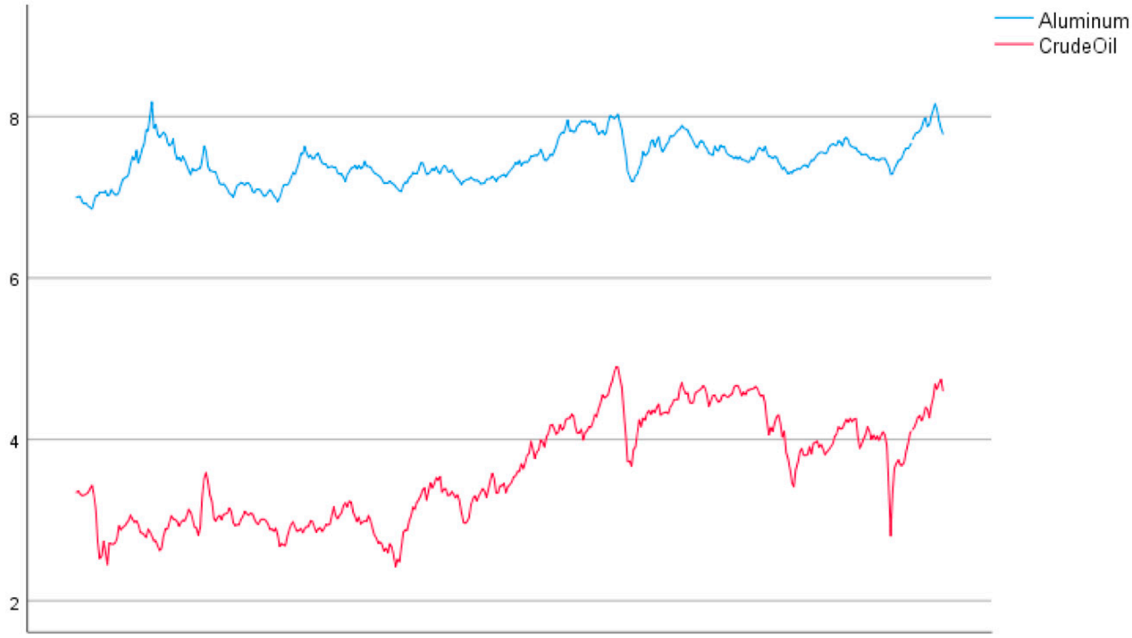


Figure 3. Time-Series Plot of Crude Oil and Iron Ore Price Patterns.

Proposition 4. *There is a positive relationship between oil and aluminum prices.*

The aluminum price reached USD 2830 per metric ton (M.T.) in May 2022, the highest price since the two-year high in 2018 [37]. A constant rise in aluminum prices is a cause for concern due to its impact on the cost of production of industrial goods. Kumar [38] recently observed that the hike in aluminum price was attributed to a substantial increase in energy costs, growing demand, a decline in China's production capacity, a reduction in global inventories, and the impact of COVID-19. He also noted that the cost of electricity powered by oil comprised approximately one-third (38%) of aluminum production cost. Therefore, I hypothesize that oil price affects aluminum price. As expected, aluminum price positively correlates with oil price, with a Pearson correlation coefficient of 0.657. Considering that the unit of measurement for aluminum price is substantially higher than that for crude oil price, I transformed the price scales of aluminum and crude oil into logarithmic price scales to represent equivalent price fluctuations on the same vertical scale. This transformation intends to reduce the variance in price scales by making the data conform to the lognormal law of error for inferential purposes [39]. Figure 4 shows the similar time-series patterns of the logarithmic price scales of aluminum and crude oil. The regression analysis result with aluminum price as the dependent variable and crude oil price as the independent variable confirms that crude oil is a good predictor of aluminum price (with a standardized β coefficient of 0.657 and an adjusted R-square value of 0.430).



Mar-85 May-89 July 93 Sept-97 Nov-1 Jan-6 Mar-10 May-14 Jul 18 Jul 22

Figure 4. Time-Series (Logarithmic) Plot of Crude Oil and Aluminum Price Patterns.

Proposition 5. *There is a positive relationship between oil and gold prices.*

Over the last half-century, oil prices seemingly fluctuated in parallel to gold prices. Indeed, gold prices rose along with oil prices in the 1970s and 2000s, while both prices dropped simultaneously in the 1980s and 1990s. Based on this observation, some suggest that oil price may drive gold's price, whereas others discount the relationship since the inflationary trend may raise both prices simultaneously [40,41]. To complicate the gold and oil relationship myth, gold is often regarded as a monetary asset (or currency) rather than a typical commodity. Although gold price may be influenced by many dynamic factors, such as inflation, interest rate, and currency (e.g., dollar) valuation, I still found a positive correlation between gold and oil price fluctuations, with a Pearson correlation coefficient of 0.748 (p = 0.000). The regression analysis result with gold price as the dependent variable and crude oil price as the independent variable reaffirms that crude oil is a good predictor of gold price (with a standardized β coefficient of 0.748 and an adjusted R-square value of 0.559).

Even though oil price may be slightly more volatile than gold price as shown in Figure 5, Figure 5 indicates a similar movement pattern for both prices (especially in the 2000s and 2010s). In addition, when I made a similar premise for a potential relationship between silver and oil prices, I still found a significant relationship between oil and silver prices, with a Pearson correlation coefficient of 0.640. That is, gold, silver, and oil prices tended to move together most of the time during the last four decades, and, thus, oil prices can be a predictor of both gold and silver prices.

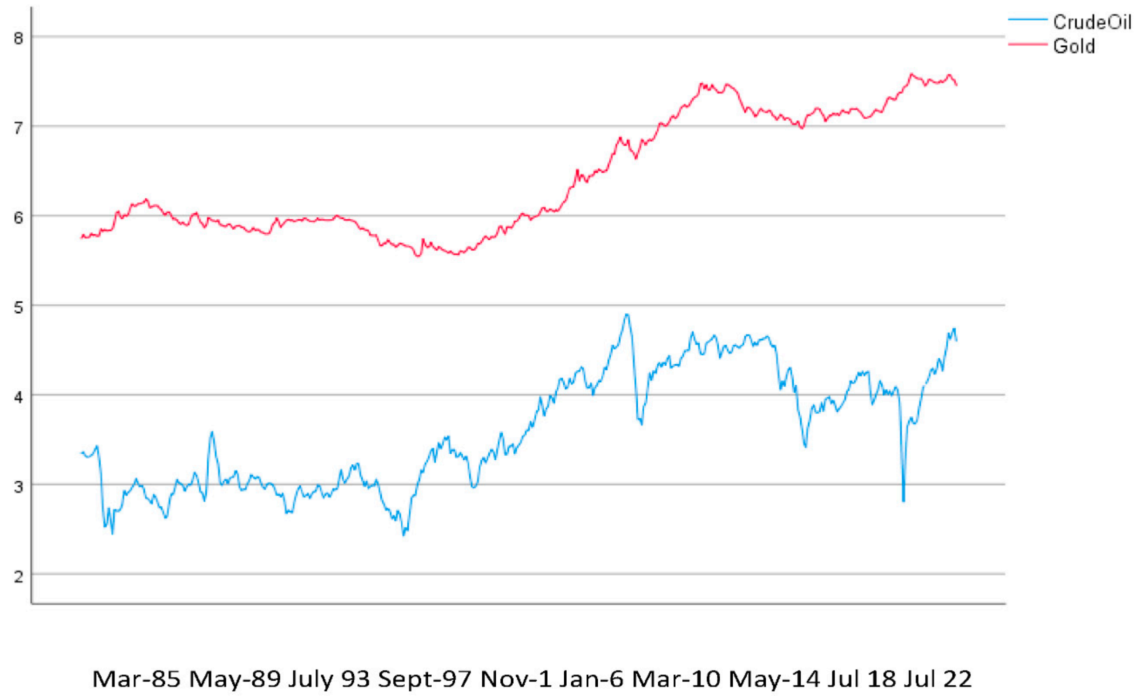


Figure 5. Time-Series (Logarithmic) Plot of Crude Oil and Gold Price Patterns.

Proposition 6. *There is a positive relationship between oil and wheat prices.*

Baffes [42] estimated that grain prices increased 0.18 percent for every 1 percent increase in the price of oil. Cartwright and Riabko [43] discovered that future wheat and oil prices were correlated but not causally related. However, Reboredo [44] found weak oil–food dependence and no extreme market dependence between oil and food prices, including wheat prices, based on a weekly data analysis from January 1998 to April 2011. Given that fuel created by oil is required to run agricultural equipment and process, store, and transport agricultural commodities (such as wheat), crude oil is a critical input to agricultural production. Therefore, I surmise that wheat price may increase with oil price. This premise turns out to be true since wheat price has a strong positive correlation with oil price, with a Pearson correlation coefficient of 0.814 (p = 0.000). Although wheat price looks more volatile than oil price, Figure 6 shows a similar price pattern for both wheat and oil prices. The regression analysis result with wheat price as the dependent variable and crude oil price as the independent variable reaffirms that crude oil is a good predictor of wheat price (with a standardized β coefficient of 0.814 and an adjusted R-square value of 0.662).

Proposition 7. *There is a positive relationship between oil and coffee prices.*

Coffee is a tropical commodity that the Commodity-Dependent Developing Countries (CDCs) located in sub-Saharan Africa, South Asia (e.g., India), and Latin America (e.g., Brazil and Columbia) mainly produce. These CDCs are vulnerable to oil price hikes and subsequent supply chain disruptions due to an inadequate transportation infrastructure. Thus, conventional wisdom indicates that the volatility of coffee prices would parallel that of oil prices. Maurice and Davis [45] found a long-run causality between oil and coffee prices. However, Vijayakumar [46] did not find any concrete evidence indicating a correlation between oil and Indian coffee prices. Congruent with the finding of Vijayakumar [46], I found no significant correlation between oil and coffee (especially Robusta Coffee) prices for the last four decades, as shown in Figure 7. In particular, except for in the early 2000s, coffee and oil prices rarely moved in the same direction.

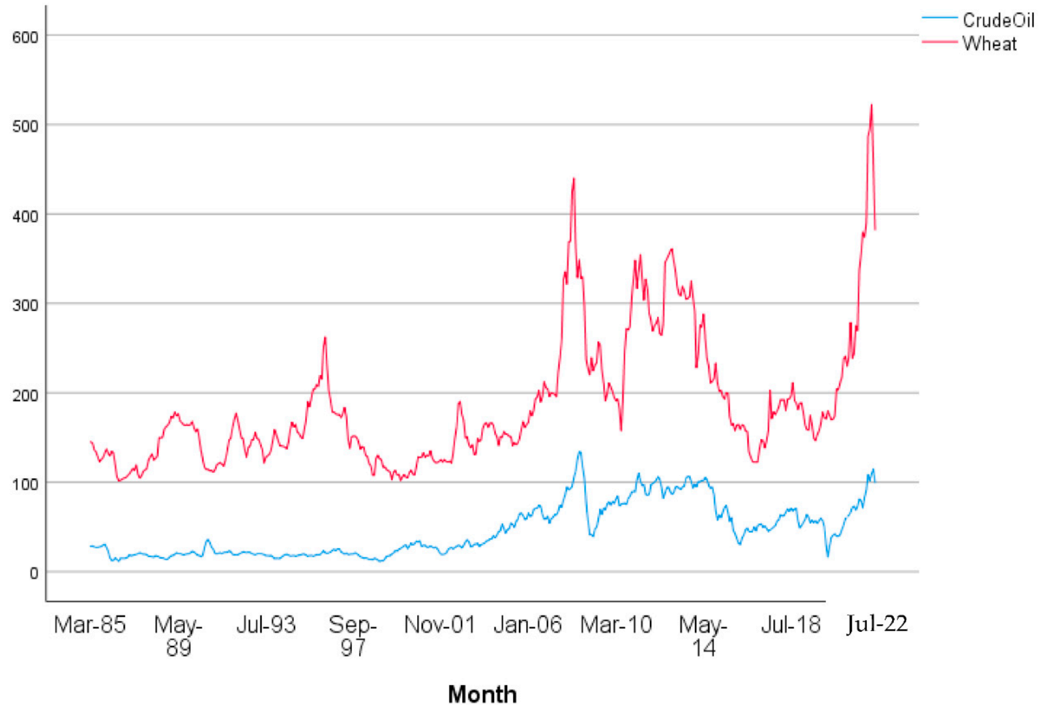


Figure 6. Time-Series Plot of Crude Oil and Wheat Price Patterns.

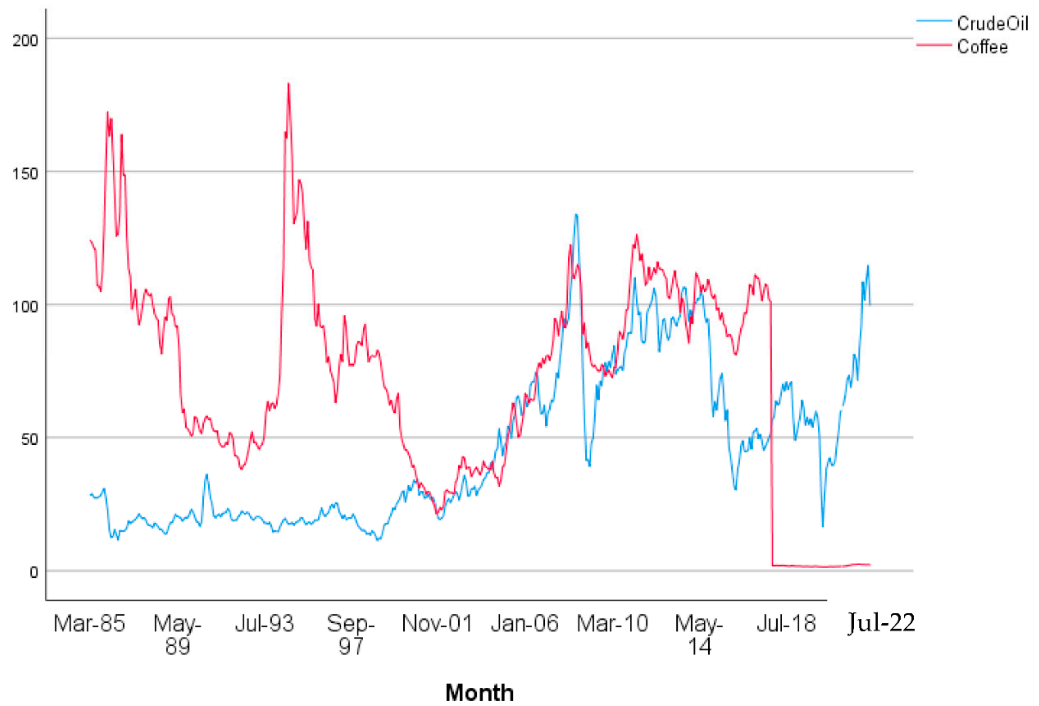


Figure 7. Time-Series Plot of Crude Oil and Coffee Price Patterns.

Proposition 8. *There is a positive relationship between oil and beef prices.*

The recent skyrocketing food prices have raised hyperinflation fears across the world. Coincidentally or not, since fast-rising food prices have accompanied the recent oil price hikes, many wonder if oil price has any bearing on food prices. In contrast with the finding of Onour [47], indicating no evidence of shared trends or cycles between oil and food (including beef) prices, I found a relatively strong correlation between oil and beef prices, with a Pearson correlation coefficient of 0.670. Figure 8 shows similar price trend patterns, even though oil prices look more volatile than beef prices. The regression analysis result with beef price as the dependent variable and crude oil price as the independent variable reaffirms that crude oil is a good predictor of beef price (with a standardized β coefficient of 0.670 and an adjusted R-square value of 0.447). However, I found that the oil and pork price relationship was not as strong as the oil and beef price relationship.

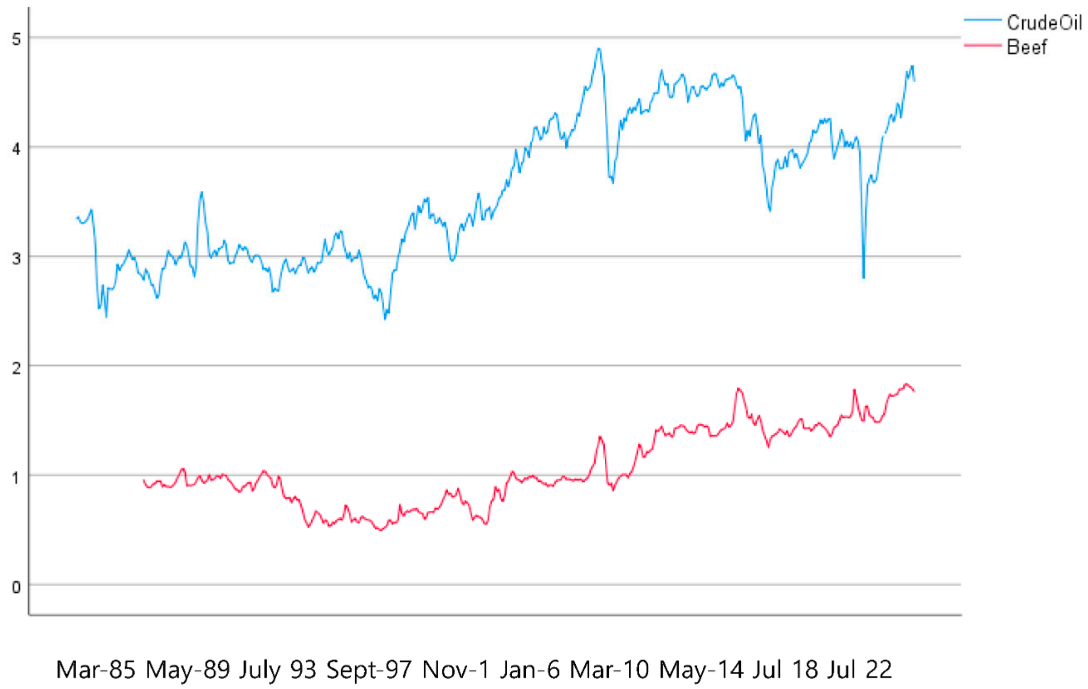


Figure 8. Time-Series (Logarithmic) Plot of Crude Oil and Beef Price Patterns.

5. Managerial Implications

So far, I have learned that crude oil price volatility tends to parallel the price volatility of many commodities, but not that of coffee. Primarily, I found that rising demand for alternative energy sources (especially biofuel) resulting from mounting oil prices created a new link between oil prices and the price volatility of agricultural commodities (especially corn) that can be transformed into biofuel materials. For a similar reason, I discovered that coal, as an alternative fossil fuel source, tends to have co-movement pricing patterns with oil. In a nutshell, oil price appears to have a profound impact on the prices of various commodities essential for everyday lives and industrial activities. Considering the critical role of oil in sustaining our standard of living, government policymakers and business decision makers should ensure the long-term stability of oil prices regardless of rapid environmental, social, economic, and geopolitical changes. Since such stability cannot be guaranteed without preventing or mitigating the risk of oil/gasoline supply chain disruptions, government policies and/or business strategies that can enhance resilience from supply chain disruptions should be developed. With that in mind, this paper also creates an oil/gasoline supply chain map that will allow political and business leaders to identify the vulnerability and potential bottlenecks of the oil/gasoline supply chain. Figure 9 graphically displays this map.

For example, if Russia's weaponization of its oil resources in response to the E.U.'s economic sanctions against Russia is the biggest culprit of worldwide oil supply shortages, a borderline between the upstream (refinery storage) and downstream (oil pipeline) levels of the oil supply chain is considered the most vulnerable chokepoint with the highest supply chain risk.

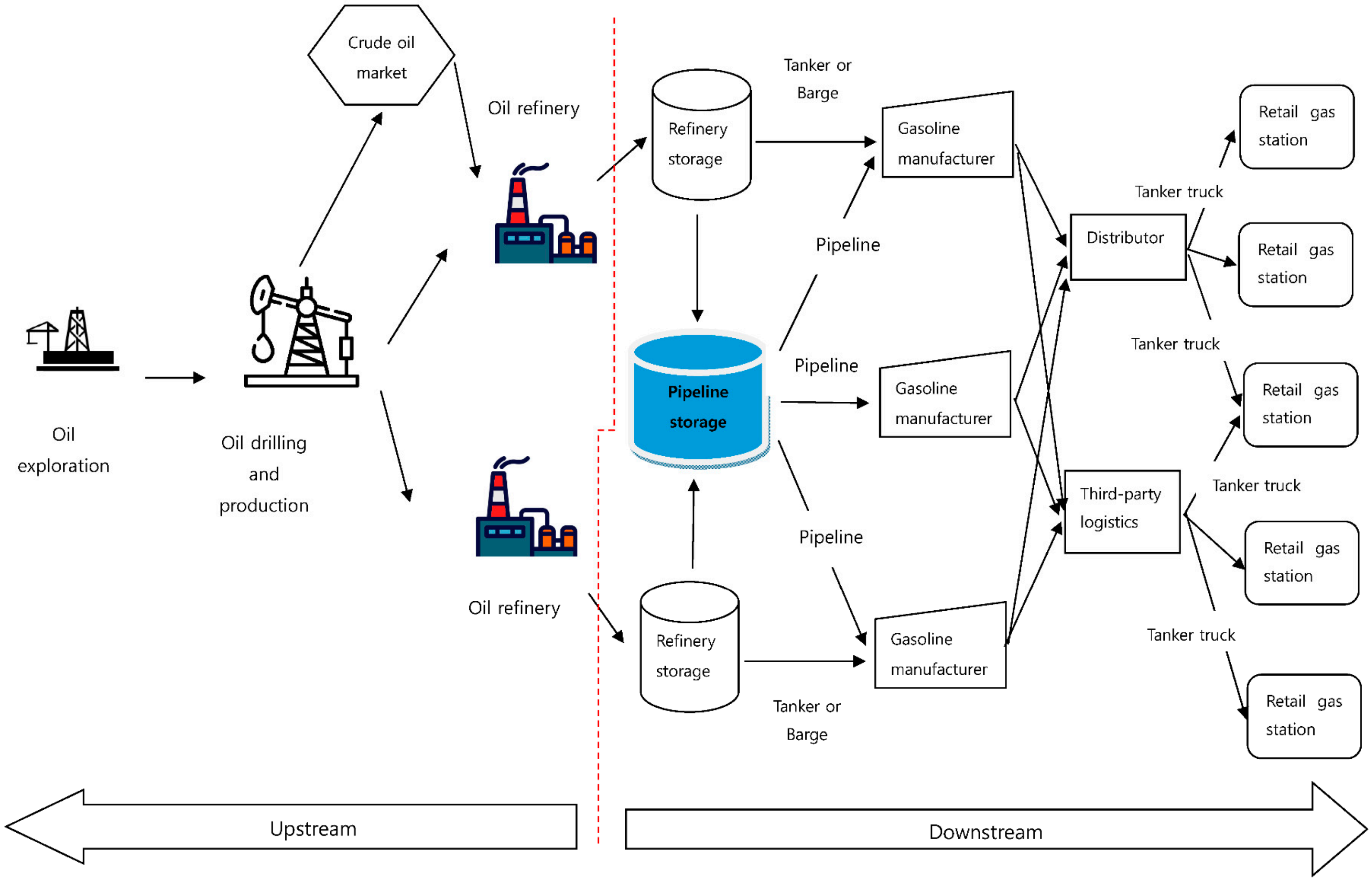


Figure 9. Oil/Gasoline Supply Chain.

6. A Summary and Concluding Remarks

In the era of worldwide energy and inflation crises created by the lingering COVID-19 pandemic, a series of natural disasters (e.g., flooding in Europe, East Asia, and the U.S.), and the prolonged war between Russia and Ukraine, the entire world has been swept into unprecedented economic turmoil. Volatile oil prices across the globe have further magnified this turmoil. This paper is one of the few attempts to investigate the functional relationship between the prices of crude oil and various types of commodities. In addition, this paper not only identifies a multitude of factors that can influence oil price and its volatility, but it also develops an oil/gasoline supply chain map that can visualize the weak points of an oil/gasoline supply chain vulnerable to disruptions. Through a series of experimental data analyses of four decades of primary energy sources (crude oil, coal, gasoline, and diesel) and commodities in high demand (corn, wheat, coffee, iron ore, aluminum, gold, silver, beef, and pork), I discovered the co-movement of crude oil and many commodities' pricing trend patterns. In particular, I found strong evidence indicating that oil price can be a good predictor of corn price, which, in turn, may influence food price. This finding implies that failure to stabilize oil price may substantially increase the cost of living and business expenditures. Although this paper did not present a clear causality between oil price and all the commodities, it reminds us of the crucial role of oil in sustaining our standard of living.

From a practical standpoint, this paper aids government policymakers and business executives in developing effective energy conservation policies and in strengthening the energy supply chain with enhanced resilience from various risks and uncertainties. In today's world, where many countries (developed or developing) are experiencing unprecedented energy crises and subsequent economic turmoil, establishing a more resilient energy supply chain helps humans better prepare for future energy crises. This paper also contributes to the existing body of energy literature by developing key propositions/hypotheses that raise future open research questions and by theorizing dynamic relationships between oil and daily necessities in the global commodity market. Despite these contributions, this paper is far from perfect in its current form. One of the major limitations of this paper includes a lack of scientific evidence indicating a clear causal relationship between crude oil prices and ongoing worldwide superinflation. As such, one of the fruitful areas of future research includes the examination of causal relationships between crude oil prices and consumer price indexes (CPIs) in both advanced and developing economies across the world. Another fruitful line of future research is the development of resilient energy supply chain strategies targeting specific countries or regions (e.g., E.U. nations) vulnerable to energy supply chain disruptions.

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