EVALUATING FUTURES-BASED HEDGING STRATEGIES: ASSESSING EFFECTIVENESS AND COST EFFICIENCY DURING CRUDE OIL PRICE SHOCKS

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Submitted in partial fulfillment of the requirements for Departmental Honors in the Department of Finance
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Fort Worth, Texas

May 5, 2025

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ABSTRACT

This study evaluates the performance and cost efficiency of short futures-based hedging strategies for crude oil producers during major price shocks, using a comparative back testing framework across varying contract maturities (3-month, 6-month, and 12-month) and hedge ratio methodologies (static vs. dynamic). By analyzing both supply and demand driven shocks including the 1990 Gulf War, 2008 Financial Crisis, 2014 OPEC Price War, 2020 COVID-19 Pandemic, and the 2022 Russian invasion of Ukraine, this study identifies strategy effectiveness based on shock direction, duration, and cause. The findings show that the 6-month static hedge delivers the most consistently balanced performance across scenarios, offering both strong downside protection and manageable rollover and margin costs. These insights offer a practical framework for producers seeking adaptable yet cost-conscious hedging strategies amidst uncertain oil market conditions.

1. Introduction

Crude Oil is the fuel of the global economy, influencing nearly every industry and financial market. However, its price is notoriously volatile particularly during periods of economic uncertainty, geopolitical conflict, and supply chain disruption. These fluctuations pose significant risk to firms with large exposures to crude oil like energy producers, manufacturers, airlines, and financial institutions with large positions in crude oil potentially destabilizing revenues, earnings, and investment plans.

In response firms adopt hedging strategies in order to stabilize cash flows and limit exposure to adverse price movements. Futures contracts remain one of the most widely used and accessible instruments for managing crude oil price risk. A futures contract is a standardized agreement to buy or sell an asset (in this case crude oil) at a predetermined price on a future date. Traders or firms can take either a long position (agreeing to buy) or a short position (agreeing to sell). Short futures hedges are commonly employed by oil producers seeking to protect the value of physical inventories or future sales against declining market prices. While the principles of hedging are straightforward, the effectiveness of such strategies varies widely depending on how the hedge is structured particularly in regard to contract maturities (3-month, 6-month, and 12-month) and hedge ratio methodologies (static vs. dynamic).

These structural choices determine not only how much risk is mitigated but also how costly the hedge becomes especially under extreme market volatility when rollover frequency and margin call risk escalate. This study aims to evaluate how different hedging structures can perform across a range of oil price shocks. By examining both supply driven and demand driven disruptions, the goal is to identify which strategies best balance risk reduction with cost efficiency, helping practitioners make more informed decisions when navigating uncertain market conditions.

This analysis applies a historical back testing approach to evaluate the performance of short futures-based hedging strategies across five major oil price shocks from the past three decades including the 1990 Gulf War, the 2008 Financial Crisis, the 2014 OPEC Price War, and the 2022 Russian invasion of Ukraine. Each strategy is tested assuming a standardized physical inventory exposure of 10,000 barrels to ensure comparability across different scenarios. By varying both the contract length and hedge ratio methodology, the study assesses strategy effectiveness in terms of portfolio value preservation, cost efficiency, and responsiveness to market volatility. Key performance metrics include profit/loss analysis, comparing hedged portfolio values to the unhedged portfolio value, and net margin profit/loss.

The results demonstrate that shorter-duration contracts such as 3-month futures tend to be more responsive to rapid price movements and shifting market conditions. However, this adaptability comes at the cost of increased rollover frequency, higher margin exposure, and greater liquidity demands. Similarly, while dynamic hedge strategies offer the potential for more precise adjustments over time, they can also expose firms to elevated risk when sudden or unexpected shocks occur particularly if the hedge ratio is poorly timed. A strategy that performs well in one type of shock may prove overly costly or ineffective in another. Given that many oil price shocks are unforeseen and vary significantly in direction and duration, the goal of this study is to identify which hedging strategy provides the most robust and cost-efficient protection across a wide range of scenarios. For firms aiming to maintain operational stability during periods of uncertainty, selecting a hedge that balances adaptability, downside protection, and capital efficiency is essential.

2. Literature Review

2.1. Introduction

Given the globalized nature of the world, economic shocks significantly impact commodity prices, and oil is no exception. Economic shocks such as geopolitical conflicts, supply chain disruptions, and financial crises can amplify these risks and increase volatility further. Energy markets have faced extreme price shocks during recent geopolitical crises such as the Russo-Ukrainian war, which triggered the largest energy price surge since the 1973 oil crisis, with Brent crude oil increasing by 35% within weeks of the invasion (Zaid and Khan 2023). Firms with long exposure to crude oil such as upstream producers and inventory holders face significant financial risk when oil prices decline as these price drops directly reduce revenue and asset value. Managing this volatility is critical for stabilizing cash flows and maintaining profitability. As the energy market has become more influenced by macroeconomic factors and geo-political events, the complexity of managing this risk has become ever more important. It is therefore essential for firms with substantial downside risk in crude oil to continuously adapt to changing oil prices and implement innovative strategies as the last 30 years has demonstrated the need to remain prepared for unforeseen developments.

To mitigate downside risks, many firms with long physical exposure hedge using short crude oil futures contracts, which allow them to lock in a future selling price and protect against falling market prices. In this structure, the firm takes a short position in the futures market, which gains value when crude oil prices decline, offsetting losses in the value of their physical inventory. Profit or loss on a short futures position is calculated by subtracting the exit price from the entry price for shorts and vice versa for longs. This profit/loss is then multiplied by the number of contracts and the contract size which is standardized based on the underlying. For crude oil, one futures contract protects 1000 barrels of crude oil making it a scalable and standardized hedging instrument. Conversely, if spot prices rise, the firm benefits from stronger physical sales but incurs a loss on the futures position. By shorting crude oil futures, firms can effectively stabilize revenue and cash flows during periods of market decline. While a given hedge strategy may be valuable in protecting downside portfolio risk, it is important to take into account the cost of such a hedge. However, during these volatile periods, price direction can switch rapidly, leaving firms over hedged when protecting their downside risk.

In most cases, crude oil futures are cash-settled via margin accounts rather than through physical delivery. To enter a position, the trader must deposit an initial margin typically 5-10% of the total contract value. Each day the margin account is adjusted based on the mark-to-market (MTM) process where gain/losses from futures price movements are settled daily. The maintenance margin represents the minimum account balance required to keep the position open (typically 70-80% of the initial margin) and if the margin account balance falls below the maintenance margin the holder of that position will receive a margin call (margin account balance < maintenance margin). When a margin call occurs, the trader must deposit more funds to restore the margin account balance to the maintenance margin. For example, if the maintenance margin is $6,000 and the margin account value falls to $5,500 then the trader will receive a margin call requiring them to deposit $500 into their margin account to keep the futures position open. These mechanics add operational risk, especially during market turbulence and must be factored into any analysis of hedge performance.

2.2. Hedging Tradeoffs and Contract Maturities

While short crude oil futures positions offer valuable downside protection for firms with long physical exposure, they do not come without tradeoffs. The daily mark-to-market nature of futures contracts means that traders and hedgers must maintain margin accounts that are constantly adjusted to reflect gains or losses. When futures prices move sharply, these adjustments can trigger frequent and sizable margin calls, forcing these firms to tie up liquidity to cover these costs. During. periods of high volatility, these margin calls can escalate rapidly, straining liquidity and capital reserves. This can be particularly problematic for smaller firms with limited access to short-term financing, as they may be forced to post additional collateral when markets are most turbulent**.** Liquidity risk arising from margin calls not only imposes short-term capital strain but also reduces the optimal hedge ratio, as firms anticipate the cost of raising funds during adverse market moves (Adam-Müller & Panaretou, 2009). Because the short futures position locks in a selling price, hedgers forgo upside participation when markets rise. This opportunity cost becomes more pronounced during unexpected price recoveries where the hedged position can be overexposed and very costly. Recent findings further emphasize market depth as a significant positive contributor to hedge efficiency, underscoring the importance of liquidity in futures-based strategies (Magalhães et al., 2022). In illiquid markets, even well-timed hedges can become inefficient due to pricing distortions or execution challenges. However, the absence of a significant risk premium in the NYMEX crude oil futures market means that risk transfer through futures does not typically require paying a hidden cost to speculators, enhancing the appeal of futures hedging from a cost efficiency standpoint (Deaves and Krinsky 1991).

Another key consideration in futures-based hedging is contract maturity, which significantly influences hedge responsiveness, transaction frequency, and cost efficiency. Shorter-term contracts like 3-month maturities allow for more frequent re-evaluations of market conditions and are subsequently more reactive to spot changes. This responsiveness makes them attractive during periods of rapid or uncertain change. However, short-term contracts must be rolled over more often, which introduces transaction costs, execution timing risks, and basis risks. This is especially true if liquidity conditions deteriorate near expiry or slippage occurs when entering into a new position. In contrast, longer dated contracts, such as 12-month maturities, reduce the need for frequent rollover and can simplify hedging. These longer-term contracts are less adaptive to rapidly changing market conditions, making them potentially less effective during sudden or unexpected price shifts. The choice of contract length also depends heavily on the firm's operational objectives. For instance, whether they are planning to sell inventory at regular intervals or hold it over a longer period for strategic or accounting reasons. A producer looking to monetize inventory on a rolling quarterly basis may benefit from shorter term contracts, while firms aiming to preserve asset value over an annual cycle may find longer maturities more aligned with their operational objectives.

2.3. Static vs. Dynamic Hedge Ratios

Beyond contract maturity, the hedge ratio significantly influences a futures-based hedging strategy's performance. A static hedge ratio remains fixed throughout the hedge period and is often based on the historical averages between the relationship of spot and futures returns. Its main advantage lies in its' simplicity as it requires no recalibration and reduces transaction costs. For firms with stable exposure levels and longer-term planning horizons, a static hedge ratio can provide baseline risk reduction with minimal overhead. Static hedging assumes a stable correlation between spot and futures prices, which breaks down during periods of market stress.

As a result, the hedge may become ineffective or even counterproductive if volatility spikes, potentially leaving the firm underhedged or overexposed.

A dynamic hedge ratio adjusts over time to reflect changing market conditions. This approach commonly employs the Minimum Variance Hedge Ratio (MVHR), calculated as the covariance between spot and futures returns divided by the variance of futures returns. This formula reflects how closely futures prices track movements in the spot market. When the covariance between spot and futures returns strengthens, the hedge ratio increases to capitalize on the futures' improved ability to offset spot price risk. Conversely when the variance of futures prices rises, signaling greater noise in the futures market, the hedge ratio decreases to reduce exposure to potentially destabilizing futures. When calculating this ratio, you can use an Exponentially Weighted Moving Average (EWMA), which gives greater weight to recent data while still factoring in longer term returns' trends. Dynamic hedging allows for more responsive and theoretically more accurate risk coverage especially in volatile environments.

Studies have found that hedge performance significantly improves when hedge ratios are calibrated using models that account for error sensitivity and market structure (Lautier and Galli 2010). However, its adaptability is a double-edged sword. If the market shifts quickly, dynamic hedging can amplify losses by increasing exposure at inopportune moments. Studies show that using EMWA based estimators when calculating the minimum variance hedge ratio can significantly reduce the volatility of the hedge ratio, by as much as 70%, thereby lowering transaction costs while preserving strong risk reduction performance (Harris and Shen 2003). Thus, the choice between static and dynamic hedging ultimately depends on the a firm's tolerance for complexity and its ability to react to changing market dynamics.

2.4. The Futures Curve: Contango vs Backwardation

The structure of the futures curve is another important element to consider when hedging using futures. The futures curve is a graphical representation showing the price of crude oil futures contracts with different maturities at a single point in time. It reflects how the market anticipates prices will move over the short and long term. The shape of the curve provides valuable insight into market expectations, storage conditions, and supply-demand dynamics.

The most common curve structures are contango and backwardation. In a contango market, longer-dated futures contracts are priced higher than the current spot price. This usually occurs when supply exceeds demand, inventories are elevated, or storage costs are high. Contango often signals that the market expects prices to rise in the future. However, for hedges in a short futures position, contango presents a cost. As contracts near expiration are rolled into the next maturity, the new contracts are more expensive to enter, resulting in roll loses that erode hedge performance. Conversely, in backwardation, futures prices are lower than the spot price, typically reflecting tight supply conditions, low inventories, or short-term disruptions. This structure benefits short hedgers by producing roll gains as they replace expiring contracts with cheaper ones. Backwardation can indicate that the market anticipates declining prices or temporary imbalances in supply and demand.

Importantly, the futures curve is not static, it shifts over time and can steepen or flatten depending on whether the spot market is appreciating or depreciating. For instance, during sharp price increases, the curve may flatten or move into backwardation, reflecting expectations of future price moderation. During prolonged selloffs, contango can steepen as the market anticipates eventual recovery. Empirical results comparing shorter term and longer-term contracts confirm that shorter term futures provide significantly higher hedge effectiveness due to their stronger correlation with spot prices (Ripple and Moosa 2007). Simulation-based analysis has shown that under widening backwardation, short futures hedges can produce negative hedge efficiency, meaning hedging actually increases risk compared to unhedged positions. This highlights the importance of forecasting time structure dynamics when designing futures-based hedge strategies (Horsnell, Brindle, and Greaves 1995). Therefore, the effectiveness and cost-efficiency of a hedge can vary widely depending on when and how a position is rolled.

2.5. Price Shock Cause and Duration

Major price shocks are generally categorized as supply-driven, demand-driven, or a combination of the two market forces. Supply-side shocks often stem from geopolitical conflict, production cuts, or infrastructure disruptions which tend to result in appreciative scenarios where prices surge due to fears of constrained supply. However not all supply shocks are upward moving, as seen during the 2014 OPEC Price War. The shock began as a supply-side distortion but evolved into a multi-year price downturn. In these types of drawn-out declines, firms using longer dated futures and static hedge ratios often found themselves poorly positioned. Static strategies lagged behind the prolonged and deliberate price suppression, while longer-term contracts failed to respond effectively to the evolving market conditions (Behar & Ritz, 2016). These cases highlight the need to tailor hedge duration and methodology to both the type and direction of the price shock.

In contrast, demand-side shocks, like the 2008 Financial Crisis and the COVID-19 Pandemic produced intense, short term depreciative scenarios, driven by rapid contractions in global consumption. These shocks tend to push prices sharply lower over brief time frames. Dynamic strategies can be effective in capturing initial downside gains however can also overexpose a firm when prices began to recover. The price reversal in mid 2020 after the COVID-19 induced collapse is a prime example, hedgers who remained aggressively short saw futures losses outweigh physical gains. During the 2008 Crash, the surge in volatility combined with speculative hedging strategies, lead to imperfect hedges, liquidity stress and increased capital costs for firms exposed to crude oil (Singleton, 2014). Across both supply and demand driven events and in both rising and falling markets, one consistent emerges: hedging strategies perform best when their design aligns with both the direction and duration of the shock, taking into account flexibility, responsiveness, and cost efficiency.

3. Background: Major Oil Price Shocks

Each of these events are characterized by unique drivers of crude oil price volatility. These shocks provide a comprehensive framework for evaluating various short futures hedging strategies across various economic environments. The following scenarios will be analyzed in this study.

3.1. The 1990 Gulf War

The 1990 Gulf War was a sharp, supply driven geopolitical shock that triggered severe volatility in global oil markets. In August 1990, Iraq's invasion of Kuwait disrupted production and exports from two major oil-producing nations. The conflict effectively removed 4.3 million barrels per day from the global oil supply. This represented 6% of the world's daily production at the time. This sudden shock led to a rapid doubling of crude oil prices within a few months as market participants reacted about the possibility of longer-term instability in the region. The sudden nature of the disruption resulted in heightened futures prices, volatility, and a period of steep backwardation. Thus, the Gulf War serves as a critical case for evaluating how different crude oil futures perform under acute supply side pressures.

3.2. The 2008 Financial Crisis

The 2008 Financial Crisis was a severe, demand driven disruption that led unprecedented collapse in global oil prices. In the months leading up to the crisis, crude oil prices surged to record highs, peaking at $140 per barrel in July 2008 which was driven by global economic expansion and a strong demand in emerging markets. However, the subprime mortgage crisis that followed triggered a global banking collapse. This triggered one of the sharpest contractions in industrial activity and transportation demand in modern history. As financial panic spread and global trade slowed, oil demand plummeted, and prices subsequently entered a free fall. By early 2009, WTI Crude had dropped below $40 per barrel. Unlike supply-side shocks, the GFC highlighted the extent to which crude oil had become financialized. Its price had become tied to macroeconomic conditions and liquidity flows rather than traditional physical supply restraints.

3.3. The 2014 OPEC Price War

The 2014 OPEC Price War was a prolonged, supply driven disruption rooted not only in geopolitical tensions but also technological change. The U.S. shale boom in the early 2010s transformed the U.S. into a major oil producer which challenged OPEC's market dominance. In response OPEC, led by Saudi Arabia, refused to cut output despite an oversupply in the market. They sought to pressure shale producers, which required higher production costs, out of the market and to defend their long-term market share. This resulted in a collapse in oil prices. Unlike geo-political conflicts which resulted in short term shocks, this slow-moving price war created a persistent oversupply and required hedgers to rethink strategy. The extended duration and structural nature of analyzing the 2014 OPEC Price War raises unique operational challenges for crude producers.

3.4. The 2020 COVID-19 Pandemic

The COVID-19 Pandemic triggered an extreme demand-side shock in global oil markets. As lockdowns spread worldwide in March 2020, transportation demand collapsed which slashed oil consumption by nearly 30%. To exacerbate this price collapse, a brief price war between Saudi Arabia and Russia fractured OPEC+ coordination, which compounded the excess supply in the market. By April, U.S. storage facilities approached capacity, and WTI futures for May 2020 infamously plunged below zero. This historic dislocation revealed how physical constraints and panic selling can drive extreme price behavior. For crude producers and hedgers, the crisis exposed the importance of contract structure and responsiveness as different strategies yielded vastly different outcomes during the turmoil.

3.5. The 2022 Russian Invasion of Ukraine

The Russian Invasion of Ukraine triggered a geopolitical supply shock layered on top of an oil market still recovering from COVID-19. As the world's third-largest crude oil exporter, Russia's invasion provoked sweeping western sanctions and voluntary boycotts by major importers, which abruptly tightened the global oil supply. These constraints drove WTI crude prices sharply upward in early 2022, as markets priced in the risk of prolonged disruptions. While the displaced Russian supply was eventually rerouted to India and China, this realignment of global trade flows introduced uncertainty and volatility across energy markets. The shocks supply-driven nature was compounded by existing inflationary pressures, pandemic-era supply chain instability, and heightened financial market volatility. For futures-based hedging strategies, this environment presented unique challenges such as contract responsiveness, hedge timing, and volatility capture all played a critical role in determining hedge performance.

Through analyzing these scenarios, this study aims to uncover real insights into which strategies are optimal across different shock scenarios. Each shocks highlights distinct market challenges and provides valuable context in understanding different scenarios that can impact crude oil prices in various ways.

4. Methodology

4.1. Data Collection

This study utilizes historical data on West Texas Intermediate (WTI) crude oil to evaluate the effectiveness of short futures based hedging strategies during periods of price shocks. Monthly spot prices for WTI were collected across multiple historical time frames. In addition to spot prices, monthly last prices for crude oil futures contracts with maturities of 3-month, 6-month, and 12-month durations were collected via a Bloomberg Terminal. These futures prices represent standardized contracts traded on the NYMEX and provide a consistent basis for comparing hedging strategies across different time horizons. All data was gathered on a monthly frequency to align with the analysis of margin requirements, profit/loss outcomes, and hedge effectiveness in the long term.

4.2. Back Test Constants

Fixed Inventory Assumption

This back test models the hedging of a fixed physical inventory of 10,000 barrels of crude oil, reflecting the real-world approach taken by producers who typically hedge based on volume rather than monetary value. Each month the market value of the inventory is updated using the current WTI spot price, ensuring the exposure reflects real time valuation. As mentioned, each futures contract represents 1000 barrels of crude oil. This structure creates a direct relationship between the hedge ratio and the number of contracts used. For example, a hedge ratio of 0.6 corresponds to six futures contracts used to hedge 6000 barrels.

Through holding the inventory volume constant, this methodology isolates the performance of different hedging strategies (varying by contract length and hedge ratio type), allowing for a clearer comparison of their effectiveness and cost efficiency.

Rolling Futures Contracts and Entry/Exit Pricing

To maintain a continuous hedge over each 2-year back test window, futures contracts are rolled at expiration and replaced with new contracts of the same maturity. This results in 8 rolls for 3-month contracts, 4 for 6-month contracts, and 2 for 12-month contracts. Entry and exit prices are defined using the last available futures prices from monthly data: the entry price is taken as the final price from the month prior to the start of the contract and the exit price is the final price from the contract's expiration month. For example, a 3-month contract entered in July 2008 would use the last monthly 3-month futures price from June 2008 as the entry price and the September 2008 last price as the exit price. This methodology is utilized given the use of monthly data and approximates realistic trade execution points, ensuring consistently in evaluating hedge performance. It also aligns with the study's broader goal of assessing long-term hedging effectiveness by capturing full period price changes while minimizing noise from day-to-day price fluctuations.

4.3. Back Test Dynamic Parameters

Contract Length

This study evaluates 3 contract maturities: 3-month, 6-month, and 12-month in order to assess how hedge duration impacts performance during crude oil price shocks. 3-month contracts offer maximum flexibility and allow for frequent hedge adjustments which can be particularly valuable during sudden market movements. However, they come with higher transaction costs, greater basis risk, and more frequent margin calls which can strain liquidity. 6-month contracts strike a balance as they reduce the frequency of rollovers while maintaining some responsiveness to market shifts. This medium-term structure can be advantageous during prolonged demand side disruptions such as recessions as they offer moderate operational agility and lower cost volatility. 12-month contracts provide the greatest price stability over a full fiscal year and are most suitable for producers with long-term financial obligations or predictable production volumes. Although less responsive to rapidly changing market conditions, this longer-term approach reduces rollover frequency and simplifies planning. Through the evaluation of all three durations, this study captures a wide spectrum of hedging behaviors from tactical short-term protection to strategic long term risk management.

Hedge Ratios

This study compares 2 hedging methodologies: a static hedge ratio and a dynamic hedge ratio, each designed to assess the effectiveness across different contract lengths and market conditions. The static hedge ratio is fixed at 0.5, meaning 50% of the 10,000-barrel inventory (i.e., 5 futures contracts) is hedged consistently throughout the back test period. In contrast the dynamic hedge ratios is calculated monthly using the minimum variance hedge formula which divides the covariance between spot and futures returns by the variance of futures returns:

h = Covariance (Rs, Rf)/Variance (Rf)*

where Rs and Rf represent the monthly returns of spot and futures prices respectively. These returns are calculated as:

Rs(t) = {(S(t) – S(t-1)) / S(t-1)}
Rf(t) = {(F(t) – F(t-1)) / F(t-1)}

Where St and Ft represent the spot and futures time at time t and t-1 represents values from the prior monthly period.

To initialize the dynamic hedge ratio in the initial values for the Covariance (Rs, Rf) and the Variance (Rf), the initial values will be calculated using sample statistics (using the following functions in excel) over the previous 12 months:

Var(initial) = VAR.S (Rf(t-12): Rf (t))
Cov(initial) = COVARIANCE.S(Rs(t-12): Rs(t), Rf(t-12), Rf(t))

Subsequent months use an Exponentially Weighted Moving Average (EWMA) approach to update these values, which gives more weight to recent observations and improves the hedge's responsiveness to everchanging market dynamics. The recursive EWMA formulas are:

*Variance(t) = λ * Variance (t-1) +(1- λ) * Rf(t)^2*
*Covariance (t) = λ * Covariance (t-1) + (1- λ) * (Rs(t) * Rf (t))*

where λ is the decay factor, set to 0.94 in line with standard commodity risk management. This approach smooths the data by prioritizing more recent observations, which allows the model to better adapt to shifts in market volatility and correlation without overreacting to short term noise, which is especially useful in turbulent commodity markets like crude oil. Each monthly updated variance and covariance estimates are plugged back into the hedge ratio formula to recalculate it based on the month end conditions in order to find the monthly value for h*. Additionally, it should be noted that when rolling into a new contract, the hedge ratio utilized to determine the number of futures contracts to short will be from the prior month just as the entry price for the futures contract is the last price from the prior month. For example, when entering into a new position in July 2008, the dynamic hedge ratio calculated at the end of June 2008 would be utilized to determine the number of crude oil futures contracts to short.

Once the dynamic hedge ratios (h*) have been calculated, when entering into a futures position, the number of futures contracts to short is determined using this formula:

$$Contracts(t) = h^*(t-1) * 10{,}000 / 1000$$

Where 10,000 represents the physical inventory volume and 1,000 is the volume covered by a single crude oil futures contract. The result is rounded up to the nearest whole number to ensure a conservative over-hedge. To reflect realistic operational constraints, the number of contracts is bounded between a minimum of 2 and a maximum of 8 contracts every time a new futures position is entered.

4.4. Profit/Loss Calculations

This study tracks profit and loss (P/L) monthly to evaluate the relative performance of hedged vs unhedged positions. The unhedged P/L reflects the change in the market value of the 10,000- barrel physical crude oil inventory due to spot price fluctuations and is calculated as:

$$Unhedged\ P/L\ (t) = Exposure\ Value\ (t-1) * Spot\ Return(t)$$

Where:

$$Spot\ Return = Rs(t) = \{(S(t) - S(t-1)) / S(t-1)\}$$

And exposure Value (t-1) is the value of the inventory at the beginning of the month. The exposure value is updated monthly to reflect ongoing changes in spot prices using the formula:

$$Exposure\ Value\ (t) = Exposure\ Value\ (t-1) + Unhedged\ P/L\ (t)$$

The Hedged Position can only be evaluated upon the expiration of each futures contract, meaning every 3, 6, or 12 months depending on the contract duration. This reflects real world futures hedging practices where profit or loss can only be realized upon the settlement of the futures position. During the active contract period, the futures position remains open, and no P/L is recorded. When the contract expires the futures P/L is calculated as:

$$Futures\ P/L\ (t) = (Entry\ Price - Exit\ Price) * 1000 * Number\ of\ Contracts$$

Since the hedge is a short position, a decline in futures prices results in a gain. At expiration, the hedged P/L is then calculated as the sum of the unhedged P/L throughout the total contract's duration and the futures P/L. for example for a three-month futures contract the hedged profit/loss would be calculated as follows:

Hedged P/L (t) = {Unhedged P/L (t-2) + Unhedged P/L (t-1) + Unhedged P/L (t)} + Futures P/L (t)

This formula captures the total gain or loss from both the physical inventory and the hedge by aggregating all unhedged spot driven movements during the contracts life and then combining them with the futures position's payoff upon expiration.

4.5. Portfolio Value Calculations

To assess the overall performance of each strategy, this study tracks both unhedged and hedged portfolio values on a monthly basis. The unhedged portfolio value is equal to the current market value of the physical inventory, which is updated monthly based on spot price changes. For the hedged portfolio, the methodology follows the principle that futures P/L is only recognized at contract expiration. Therefore, the hedged portfolio value is updated monthly based on the updated inventory value while the futures component is only added in months when a futures contract expires. The formula is:

Hedged Portfolio Value (t) = Exposure Value (t) + Futures P/L (t)

Where futures P/L = 0 for all months except those in which a contract expires. This approach ensures a realistic modeling of hedge performance by aligning the timing of futures settlements with portfolio valuation. It also allows for a more accurate comparison between the hedged and unhedged strategies by highlighting the timing effects of contract rollover, especially during volatile periods.

4.6. Margin Balance Calculations

Initial and Maintenance Margin Calculations

To simulate real-world trading conditions, this study implements a dynamic initial margin framework based on an Exponentially Weighted Moving Average (EWMA) volatility model, which allows margin requirements to adjust with market risk. Rather than using a fixed margin percentage, the EWMA volatility of monthly futures returns is calculated using the recursive formula:

$\sigma^2(t) = \lambda * \sigma^2(t-1) + (1-\lambda) * r^2(t)$

where $\lambda = 0.94$ is the decay factor and r(t) represents the monthly return on crude oil futures. This method gives greater weight to recent price movements, making margin calculations more responsive to market volatility while smoothing out short term noise. The resulting volatility is then annualized by multiplying it by $\sqrt{12}$ to align with standard financial risk measures.

Based on the computed annualized volatility, a tiered structure is applied to determine the initial margin percentage when entering into a futures position the following month. This tiered system is structured as followed:

- *If annualized volatility < 20%: Initial Margin = 6%*

- *If annualized volatility is between 20% - 30%: initial Margin = 8%*
- *If annualized volatility > 30%: Initial Margin = 10%*

This logic mirrors the approach used by futures exchanges, which raise margin requirements during volatile period to reduce counterparty risk. For each new contract, the initial margin value is then calculated using the prior month's futures price and margin rate:

*Initial Margin (t) = Futures Price (t) * Initial Margin % (t) * 1000*

The maintenance margin is set at 75% of the initial margin, reflecting common industry standards:

*Maintenance Margin (t) = Initial Margin (t) * 0.75*

This methodology ensures that margin requirements in the back test adapt to prevailing market conditions at the time of contract initiation, promoting realism and reflecting how exchanges manage risk exposure over time. It also captures periods of elevated stress, for example the 2008 financial crisis, by requiring larger collateral buffers when volatility is more severe.

Margin Account Tracking

To simulate the financial impact of holding crude oil futures contracts, this study tracks a monthly margin account balance for each active contract. Each month, the gain or loss on the futures position is calculated as:

*Monthly Futures G/L(t) = (F(t-1) – F(t) * 1000*

This monthly gain or loss is added to the ending margin balance from the previous month to compute the running margin balance for the current month:

Running Margin Balance (t) = Running Margin Balance (t-1) + Monthly G/L (t)

If the running balance falls below the maintenance margin, a margin call is triggered. The required deposit depends on the size of the shortfall:

- If the running margin balance > 0 but below the maintenance margin, then the margin call amount is equal to:
  Margin Call = Maintenance Margin – Running Margin Balance
- If the running margin balance < 0 then the margin call amount is equal to:
  Margin Call = | Running Margin Balance | + Maintenance Margin

These formulas ensure that the right amount is deposited to restore the margin account to the required maintenance level and keep the position open. Monthly tracking of this margin mechanism provides a simulated representation of the capital demands placed on futures traders particularly during volatile periods where there are more frequent margin calls.

4.7. Net Margin Profit/Loss Methodology

This study calculates profitability and cost of the margin account using a margin-account based framework, reflecting how futures contracts are managed and collateralized in actual trading practice. This net margin profit/loss analysis is distinct from the actual profit/loss of the futures position itself. It reflects the realized cash gain or loss from maintaining the futures position throughout the contract's lifetime. This includes initial margin collateral required, ongoing margin calls throughout the contracts life, and final settlement payout or liability at expiration. Each contract is tracked from initiation to expiration using monthly price data and margin adjustments. While margin calls are issued during the contract if the margin balance drops below maintenance, no margin call is made at expiration, even if the balance is negative because the position is settled. At this point, there is no longer any market exposure to collateralize, so only the final net result matters.

To determine final net cost or profit, the model aggregates the initial margin deposit, any margin calls issued throughout the contract's duration, and the final margin balance at expiration.

1) If the position results in a net loss (Final Margin Balance < 0), it is calculated as:

   Net Margin Loss = Total Cash Deposited – Final Margin Balance

   Where: *Total Cash Deposited = Initial Margin + Σ Margin Calls*
   If the final balance is negative, the trader must cover that shortfall at expiration, increasing the total out of pocket cash costs.
2) If the position ends in a net profit (Final Margin Balance > 0), it is calculated as:

   Net Margin Profit/loss = Final Margin Balance – Total Cash Deposited

It is important to note that while a negative margin balance at expiration always results in a net loss, if the final margin balance is positive at contract expiration, this can still result in a net loss if the initial margin + Σ margin calls exceed the final margin balance. By incorporating these rules, the model captures the true cash impact of holding a futures position over its life, offering a more accurate depiction of capital pressures rather than the futures P/L alone. This is particularly important for the volatile periods that will be examined in this study when margin demands can materially affect the profitability and liquidity of hedging strategies.

4.8. Practical Caveats and Real-World Considerations

Although this back test is designed to evaluate the effectiveness and cost efficiency of different futures contract lengths (3-month, 6-month, and 12-month) and hedge ratio methodologies (static vs. dynamic), several practical limitations exist that may impact how these strategies perform in live market settings. These real-world considerations are not explicitly modeled in the back tests but are essential for interpreting the results and understanding their application in actual operational hedging scenarios.

Slippage and Execution Costs

This study assumes that futures contracts are entered and exited at the last available monthly price, representing idealized, frictionless execution. However, in reality, market participants rarely achieve fills at the exact end of month settlement prices. During volatile periods particularly in the short term (3-month contracts), bid-ask spreads can widen, and execution timing may significantly affect price. This is known as slippage, and it can erode hedging performance by increasing trading costs. While simplification allows for cleaner comparisons across strategies in an academic context, it does understate the cost burden producers can face when implementing these hedges in practice.

Basis Risk

This back test assumes that futures prices move in lockstep with the spot price of the physical crude oil inventory being hedged. However, basis risk: the risk that the futures and spot prices diverge, can reduce hedge accuracy. This divergence can be attributed due to delivery location, grade mismatch, or changing market structure such as contango or backwardation. While highly correlated in the long term, these differences can affect the performance for both static and dynamic hedge ratios. For longer dated futures (12-month contracts), basis risk is especially relevant as mispricing can persist longer than with short term contracts.

Execution Timing and Roll Logistics

The back test assumes contracts are rolled precisely at month-end, using the last price of the month to close the current contract and to open the new one. However, traders often roll futures a few days before expiration to avoid potential illiquidity, volume drops, or price distortions near expiry. This introduces a timing risk, especially for dynamically adjusted hedge ratios that rely on recent volatility and correlation inputs. Additionally, the logistics of rolling longer dated contracts may differ compared to the more frequently adjusted strategies, which can create delays or slippage that are not captured in this model using monthly data. While the use of monthly data simplifies this modeling process and ensures consistency across strategies, it limits the back test's real-world application.

4.9. Evaluation Metrics

Futures Profit/Loss Evaluation

To assess the raw performance of each futures contract, depending on different contract length and hedge ratio methodology, the performance of each futures contract will be evaluated across the various shock scenarios. This analysis is prior to the integration into the broader spot portfolio. The study conducts this standalone evaluation of the futures P/L upon expiration of each contract (this expiration date varies across the different contracts). The futures P/L is described using the entry and exit pricing methodology described above. This analysis is conducted independently of the unhedged position to identify the responsiveness of the individual futures contracts to market volatility. This includes how well the hedge captured the directional movement of crude oil prices during shocks. This section additionally allows for the identification of performance across short, medium, and long term hedging approaches in a vacuum free from the effects of spot price changes. This data will serve as a key input in the subsequent portfolio evaluation section.

Portfolio Evaluation: Hedged vs. Unhedged Performance
In order to measure the real-world impact of hedging on inventory value, this study evaluates portfolio performance through a comparison of the unhedged position to the hedged positions at each futures contract expiration. As mentioned above the unhedged portfolio value is calculated monthly based on spot price fluctuations and the assumed 10,000-barrel crude oil volume. In contrast, the hedged portfolio values only incorporates futures P/L at the expiration of each contract which is consistent with the industry practice where hedge outcomes are only realized upon future contract settlement. This avoids introducing distortions that could result from trying to incorporate unrealized futures performance.

Although Hedge Effectiveness (HE) ratios are commonly used to evaluate risk-reduction, they are extremely sensitive to variance-based distortions which is evident during crisis periods where volatility spikes. HE proved an unreliable metric for this study as the values that were calculated suggested poor or even negative hedge performance due to increased volatility in futures pricing, despite the hedged portfolio value preserving higher monetary value compared to the unhedged portfolio value. For this reason, HE is not used as a primary performance metric in this study and instead we will focus on a direct comparison of hedged vs. unhedged portfolio values to provide a more intuitive and practical measure of how well capital was preserved.

Therefore, this evaluation is anchored to the expiration dates of each respective contract length (3-month, 6-month, and 12-month). At each of these intervals, the hedged portfolio (inventory value + realized futures P/L) is directly compared to the unhedged value. To allow for consistent comparison across hedging strategies with differing lengths, this study adopts a time horizon normalization methodology. This approach aggregates the realized futures profit/loss from multiple shorter contracts and adds that total to the unhedged portfolio value at a given expiration point. For example, two consecutive 3-month futures cycles are summed and added to the unhedged portfolio value at t=6 to evaluate performance over the same period as a single 6-month hedge. This method aligns with strategies to a common valuation point while holding the inventory constant which prevents distortion from intermediate revaluations. Thus, when comparing contracts of different lengths, it is implicitly assumes that the inventory is continuously held and not liquidated throughout this evaluation window. At each evaluatory window the different strategies will be compared. (Assuming a given back test start date in July 2008) In September 2008 we would only be able to compare 3-month contracts (static vs dynamic) whereas in December 2008, we could compare 3-month and 6-month contracts (static vs. dynamic as well), using this framework. During each comparison window, each hedge will be compared to the unhedged portfolio value to see which provided the most protection during this period. While shorter contracts may generate interim performance swings or margin activity, those dynamics are captured elsewhere in the analysis. The goal of this analysis is to evaluate how different contract lengths help preserve the physical inventory over time and determine the monetary value at which the portfolio is protected across different intervals.

Net Margin Profit/Loss Evaluation

Net Margin Profit/Loss is a key evaluative metric in this study by focusing on the actual cash flows involved in maintaining a futures hedge. This approach reflects the realized capital impacts of hedging by capturing the full cost or gain experienced throughout a contract's life. This includes the initial margin required to initiate the position, any margin calls issued throughout the contract's duration, and the final settlement value at expiration. As previously mentioned, the actual futures profit/loss is calculated using the difference between the entry and exit prices which is utilized to offset unhedged losses in the portfolio value. However, it does not reflect the liquidity required to sustain the hedge throughout the contract's life. This is where Net Margin P/L is an invaluable metric which focuses on the realized cash exposure of the hedging strategy by capturing the full funding burden placed on the hedger.

By emphasizing realized cash flows, this metric enables a more practical comparison of strategy performance across different shock scenarios. It highlights the capital intensity and liquidity burden associated with each strategy. For example, a hedge that effectively offsets price risk may be undesirable if it generates more frequent and costly margin calls. To allow for fair comparisons across different contract lengths, the net margin P/L values can be aggregated over equivalent time horizons. For instance, we sum the realized cash flows for two consecutive 3-month hedges to evaluate their combined net margin profit/cost against a single 6-month contract. This approach ensures that hedging costs are evaluated in constant temporal windows and reveals whether the greater responsiveness of short duration hedges comes with the expense of greater capital demands. Net margin P/L offers a more complete picture of a strategy's costs by showing the realized cash burden of holding a futures position.

Summary Statistics

The following table presents summary statistics for the WTI spot and crude oil futures returns across 3-, 6-, and 12-month contracts. Metrics include the number of observations, mean, median, standard deviation, minimum, and maximum values. These statistics are calculated both for each individual economic shock period and as an aggregate summary across all return data within the full back test date ranges.

Total Data Summary

Return Type	Observations	Mean	Median	Std. Dev.	Min	Max
R(St)	209	0.00828	0.01333	0.11716	-0.43341	0.72568
3-Month R(Ft)	209	0.00818	0.00743	0.10219	-0.38603	0.48543
6-Month R(Ft)	209	0.00490	0.00358	0.08666	-0.29803	0.31161
12-Month R(Ft)	209	0.00424	0.00664	0.07949	-0.27891	0.41304

1990 Gulf War

Return Type	Observations	Mean	Median	Std. Dev.	Min	Max
R(St)	49	0.01121	-0.00444	0.10344	-0.18827	0.48022
3-Month R(Ft)	49	0.00946	0.00093	0.09268	-0.25496	0.38314
6-Month R(Ft)	49	0.00832	0.00053	0.07587	-0.22541	0.31161
12-Month R(Ft)	49	0.00722	0.00664	0.05771	-0.18573	0.21169

2008 Financial Crisis

Return Type	Observations	Mean	Median	Std. Dev.	Min	Max
R(St)	46	0.01478	0.02742	0.10566	-0.28250	0.22640
3-Month R(Ft)	46	0.01331	0.01121	0.10040	-0.31131	0.26816
6-Month R(Ft)	46	0.01236	0.01595	0.09438	-0.29803	0.22673
12-Month R(Ft)	46	0.01117	0.01491	0.08685	-0.27891	0.16789

2014 OPEC Price War

Return Type	Observations	Mean	Median	Std. Dev.	Min	Max
R(St)	45	-0.00805	0.00157	0.09532	-0.21771	0.23846
3-Month R(Ft)	45	-0.00797	-0.01040	0.08451	-0.19784	0.20737
6-Month R(Ft)	45	-0.00824	-0.01412	0.07549	-0.17682	0.17194
12-Month R(Ft)	45	-0.00871	-0.00614	0.06161	-0.14938	0.12439

2020 COVID-19 Pandemic

Return Type	Observations	Mean	Median	Std. Dev.	Min	Max
R(St)	46	0.02537	0.03956	0.16961	-0.43341	0.72568
3-Month R(Ft)	46	0.02699	0.04875	0.14115	-0.38603	0.48543
6-Month R(Ft)	46	0.01306	0.04115	0.11008	-0.29432	0.28552
12-Month R(Ft)	46	0.01196	0.02411	0.11258	-0.23067	0.41304

2022 Russian Invasion of Ukraine

Return Type	Observations	Mean	Median	Std. Dev.	Min	Max
R(St)	48	0.02555	0.03907	0.09135	-0.11512	0.34139
3-Month R(Ft)	48	0.01869	0.01705	0.07969	-0.11958	0.24829
6-Month R(Ft)	48	0.01756	0.02142	0.07389	-0.15471	0.21213
12-Month R(Ft)	48	0.01737	0.01086	0.09230	-0.21061	0.41304

5. Results

In the following sections, we analyze the performance of each hedging strategy during individual historical crude oil price shocks. This includes a breakdown of strategy effectiveness across the 1990 Gulf War, the 2008 Financial Crisis, the 2014 OPEC Price War, the 2020 COVID-19 Pandemic, and the 2022 Russian Invasion of Ukraine. The full datasets for the evaluative metrics referenced throughout this analysis including futures profit/loss, hedged vs. unhedged portfolio values, and net margin profit/loss can be found in the appendix section.

5.1. The 1990 Gulf War

Spot and Futures Price Trends

Between March 1990 and March 1992 crude oil markets experienced extreme volatility driven by the geopolitical upheaval surrounding the Gulf War. Spot prices for WTI crude fell in the months leading up to the conflict, declining by around 18% from march to June 1990. However, Iraq's invasion of Kuwait in August 1990 triggered a supply shock which drove spot prices up. Between the end of June and October 1990, spot prices rose from $16.70 to $36.04, doubling prices within the four-month span. This spike is attributed to the market panic over disrupted exports and the uncertainty about military escalation in the region. However following Operation Desert Storm in January 1991 which saw the swift expulsion of Iraqi forces from Kuwait, spot prices reversed course quickly falling from $36.04 in October 1990 to under $19.90 by the end of March 1991.

Futures contracts across all maturities generally tracked the spot price direction but showed differing sensitivities and lags. 3-month futures were the most responsive to spot movements. Particularly during the run-up and immediate aftermath of the invasion which is evident by the high return covariance which peaked at 0.0138 in September 1990. The 6-month contracts were moderately responsive and captured the broader trend. Their return covariance reached 0.0102 during the same period. In contrast the 12-month futures lagged significantly behind the spot price showing the lowest responsiveness and return variance, with covariance peaking at .0065 in September 1990. This lag reflects the longer date contracts' slower adjustments to these fast-paced market events and can be attributed to lower liquidity and longer-term pricing expectations.

During this period futures markets exhibited a profound shift in term structure. Futures moved from mild contango to strong backwardation because of fears of supply shortages drove short-term contract prices above longer-term expectations. This backwardation is evident between August to October 1990 where 3-month futures traded above 12-month contracts by nearly $10 reflecting the urgency in the market for immediate oil supply. Overall, the data shows that short term contracts were more aligned with spot price volatility during the Gulf War especially during the rapid ascent and descent of crude oil prices as longer-term contracts were less reactive during the most volatile windows of the conflict which were largely only short-term occurrences.

Futures Profit/Loss Evaluation

Given the 3-month contracts had the highest sensitivity to price movements this came with a sharp volatility in the futures p/l performance. The dynamic hedge ratios calculated called for the use of 8 contracts throughout the back test. The 3-month dynamic strategy saw extreme results during the August – October 1990 price spike. It posted a massive loss of -$147,920 for the contract expiring in September 1990 which reflects the risk of being short futures during rapid price surges. However, this strategy recovered the following window with a $80,320 gain by December 1990 and a $58,720 gain in March 1991 as oil prices subsided from the initial spike. The static strategy, using 5 contracts, experienced smaller price swings with losses and gains in the same direction, posting -$92,450 and $50,200 in September and December 1990 respectively. These results show the 3-month contracts' ability to quickly respond to price reversals but also their exposure given mistimed entries. The dynamic hedge ratio amplified both gains and losses portraying the tradeoff between responsiveness and exposure scaling.

The 6-month contracts offered a more balanced risk profile. The contracts expiring in September 1990 also experienced large losses (dynamic: -$97,920, static: -$61,200), but the strategy rebounded with strong gains by March 1991 as price movements reversed (dynamic: $109,680, static: $68,550). These contracts benefited by capturing broader directional shifts in oil prices with fewer transactions. Thus the 6-month strategy dampened some of the extreme drawdowns during the price spike, lessening losses during this period, while still benefiting from the price reversal that followed. The same trend was seen where dynamic hedging amplified both gains and losses.

The 12-month contracts matured only twice during the back test window, which offered muted but stable results. The dynamic hedge strategy, which held 7 contracts for the first cycle and 8 for the second, realized a modest $9,590 profit in March 1991 and a slight -$400 loss in March 1992. The static strategy, with 5 contracts, followed a similar path with a $6,850 profit and a -$250 loss. This data shows the longer-term maturities of the contracts which smoothed over short-term price fluctuations and captured the broader price cycle from escalation to resolution. However, the slower reaction meant they were less effective at exploiting short-term price swings.

Portfolio Evaluation: Hedged vs. Unhedged

3-Month Window

The 3-Month hedging strategies demonstrated rapid responsiveness to the volatility of the Gulf War with dynamic and static hedges altering portfolio outcomes during critical months. The contrast became apparent by September 1990 as the unhedged portfolio value surged to $335,100 as prices went up. Here the static strategy preserved $55,470 more than the dynamic strategy showing how a lower hedge ratio limited directional losses during the price spike of the invasion. However, as prices reversed, the dynamic strategy outperformed culminating in a hedged portfolio value of $257,720 by March 1991 compared to $235,700 for the static hedge. However, both hedged positions outperformed the unhedged position of $199,000 showing that these short-term hedges were responsive to the price drops following Operation Desert Storm.

6-Month Window

When evaluating over a 6-month horizon, both 3-month and 6-month contracts showed the ability to offset massive losses in crude oil value. By September 1990, 3-month and 6-month static hedges both outperformed their dynamic counterparts ($254,800 and $273,900 vs. $206,620 and $237,180) due to the dynamic hedges being overexposed during the initial price rally. However, over the full 6-month window ending in March 1991, the dynamic hedging approaches recaptured value efficiently. The 3-month dynamic hedge resulted in the highest portfolio value ($338,040), followed by the 6-month dynamic strategy at $308,680. Meanwhile the static hedges landed lower ($285,900 and $267,550, respectively). These results emphasize that while dynamic exposure increases downside risk during abrupt spikes, it offers greater recovery potential when trends reverse particularly in fast paced geopolitical shocks like this. The 6-month contracts offered a smoother ride with fewer entries however it still trailed the 3-month dynamic strategy by the time things had settled in March 1991.

12-month Window

By the one-year market, the benefits or hedging were apparent across all strategies. The unhedged crude oil portfolio fell to $199,000, while all hedged version exceeded this value, portraying the role of risk management in protecting inventory value especially in the long term. The dynamic 3-month strategy again performed best, ending at $209,560, just slightly above the 6-month dynamic ($210,760) and 12-month dynamic ($208,590). The static hedges clustered closely ranging from $205,600 to $206,350. The convergence of values in the long term reflects the resolution of the initial panic and the stabilization of oil prices by March 1991. While no hedge strategy produced significantly larger gains, the consistent value preserved across all strategies shows that longer time horizons due reward stability. However, the shorter contracts, while more volatile, captured larger swings over the shock cycle.

Net Margin Profit/Loss

3-Month Window

During the first year of the Gulf War, the 3-month dynamic hedge exhibited the highest volatility in realized margin-based performance. The strategy started with a modest gain in June 1990 (+$19,440), but as oil prices surged, the dynamic hedge suffered a massive loss of -$147,920 by September 1990 due to the higher margin calls and overexposure. Excluding initial margin, margin costs totaled -$138,155 for the dynamic strategy and -$86,972 for the static during this period. Although subsequent contracts – rebounded generating $80,320 in December 1990 and $58,720 in March 1991, the strategy required high capital to remain solvent. The static 3-month strategy followed these general trends also posting a substantial drawdown in September 1990 (-$92,450) however this exposure was more manageable. By March 1991, the cumulative net P/L favored the dynamic strategy in absolute terms but in the short term (June – September 1990) there were significant capital demands to maintain the position.

6-Month Window

When examined across the 6-month window, the capital intensity of both the 6-month strategies appear reduced compared to their 3-month counterparts. For 6-month contracts expiring in September of 1990, the dynamic hedge resulted in a net margin-based loss of -$97,920 while the static version incurred a -$61,200 loss. This shows that even for longer position, less rolling could not fully mitigate the pressures of extreme volatility from the oil price spike. The margin costs for 6-month contracts totaled $87,955 for the dynamic and $54,972 for the static. However, by March 1991 the 6-month contracts recovered well with both dynamic ($109,680) and static ($68,550) strategies posting gains. This shows how longer contracts reduce the frequency of cash demands but still face much of the volatility that impacted the 3-month contracts in the short term. Dynamic hedging outperformed static in terms of total dollar gain however the cash demands during the price spike were still significant but in general were less for the 6-month contracts in comparison to the 3-month.

12-Month Window

Looking across the full year window ending in March 1991, dynamic strategies outperformed all static strategies with the same contract length, with the dynamic 3-month ($10,560) and 6-month ($11,760) having the greatest realized cash flows from the futures' positions during this period compared to the 12-month ($9,959) gain which was slightly lower. However, when we look at the margin calls during this period, it paints a clearer picture about the cost of reactivity. Margin costs during the year totaled $139,155 for the dynamic 3-month and $87955 for 6-month in contrast to only $53,255 for the 12-month dynamic. This shows that while shorter contracts are more reactive to market trends, that this reactivity comes at a cost.

Included are Figures 5.1.1 and 5.1.2, which display portfolio outcomes for hedged versus unhedged positions and the net margin profit/loss for each strategy under a 6-month evaluation window during the 1990 Gulf War.

Figure 5.1.1: Portfolio Evaluation (Hedged vs. Unhedged) under the 6-Month Window – 1990 Gulf War

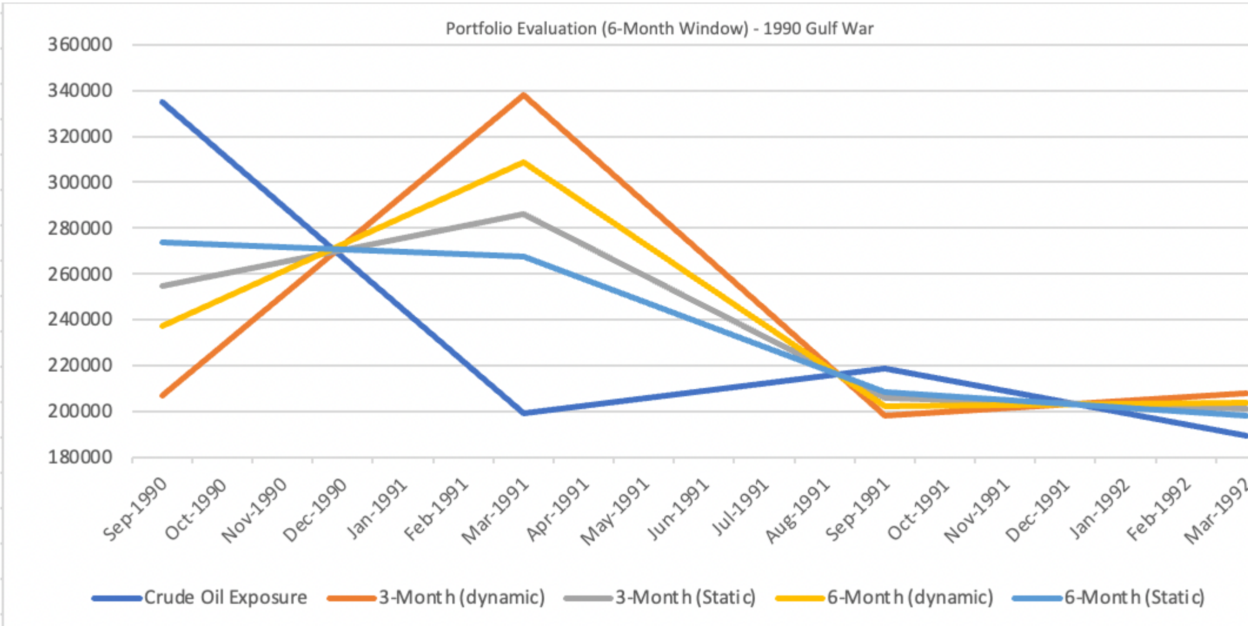
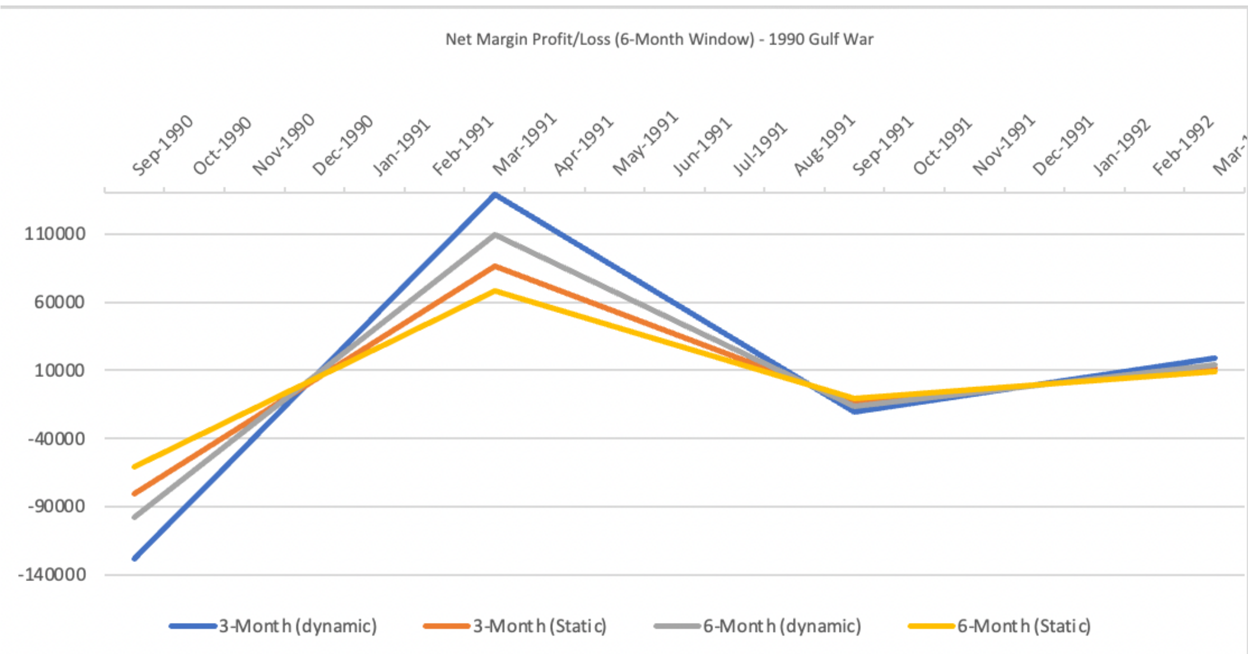


Figure 5.1.2: Net Margin Profit/Loss under the 6-Month Window – 1990 Gulf War



5.2. The 2008 Financial Crisis

Spot and Futures Price Trends

Between June 2008 and June 2010, crude oil markets underwent a historic demand fueled collapse which was followed by a gradual recovery. This reflected the severe duration of the 2008 Financial Crisis. Spot prices for WTI crude peaked at $133.88 in June 2008, then plunged by over 70% in just six months, bottoming out at $41.12 in December 2008. The steep decline in prices between June and December 2008 coincides with the failure of Lehman Brothers and the global banking crisis that ensued. While mid 2009 saw prices begin to recover, the rebound was slow and inconsistent. By mid-2010, spot prices had stabilized near $75, reflecting a rebalance in global supply and demand, but these were still well below pre-crisis highs.

Futures contracts across all maturities tracked the broad direction of spot prices but showed distinct differences in timing and volatility. 3-month contracts were the most reactive, closely following the crash and subsequent rebound. Their return covariance with spot and futures peaked at 0.0117 in December 2008 while volatility was at its highest. The 6-month futures also followed the general trajectory of spot prices but in a more delayed and dampened manner. 6-month futures' return covariance peaked in May 2009 at 0.0119. In contrast the 12-month contracts lagged behind significantly, with a lower peak covariance of 0.0106 and slower adjustments during periods of rapid price movements.

During the crisis, the futures curve, underwent a dramatic shift from mild backwardation into deep contango as collapsing spot prices fell well below longer term futures. The shift was most evident from October 2008 to early 2009 when the market took into account the rapid demand shock. For example, in December 2008, the 12-month futures traded nearly $18 above spot meanwhile 3-month contracts were $9.5 higher. This signaled the elevated basis risk across maturities. Overall short-term contracts proved more responsive during steep downturns and early recover while longer-term futures offered greater price stability but at the cost of delayed reactivity. This divergence highlights the complexity of hedging during prolonged demand-side shocks.

Futures Profit/Loss Evaluation

The 3-month contracts were very responsive to the rapid price movements during the early stages of the 2008 Financial Crisis, particularly as oil collapsed in late 2008. The dynamic hedge delivered strong returns in the first two expiries, posting a $161,760 gain in September 2008 (4 contracts) and an even larger $249,700 gain in December 2008 (5 contracts), reflecting short futures strong performance following the price collapse in the early months of the crisis. The static strategy also performed fairly similar, even outperforming in September ($202,200) and matching the dynamic result in December. However, this success was only temporary during the immense price collapse. From March 2009 to March 2010, the dynamic strategy experienced more volatile outcomes due to its greater exposure most notably a -$150,000 drawdown in June 2009 compared to -$93,750 for the static strategy. These losses occurred during a period of price recovery which greatly hurt the short positions. While the dynamic strategy captured early downside risk more aggressively it allowed for greater losses during the market rebound period.

Like their 3-month counterparts, the 6-month contracts also generated strong returns for the initial downturn. Particularly during the first expiry in December 2008. Both dynamic and static strategies posted gains of $436,250 benefiting from their exposure across the largest stage of the price collapse. Similar to the 3-month contracts, performance sharply reversed in June 2009 expiry with both dynamic (-$150,560) and static (-$94,100) strategies experiencing losses during the spot rebound. The dynamic strategy, which had been scaled up to 8 contracts, saw more substantial losses. Subsequent expiries in December 2009 and June 2010 showed improved results with the June dynamic hedge rebounding to a $34,00 gain. While the 6-month contracts captured broader directional swings, it still wasn't immune to the pain of mistimed entries during recoveries.

Finally, the 12-month contracts offered a more stable risk profile across the back test period. The first expiry in June 2009 produced the strongest results among all strategies, with both the dynamic and static positions earning $328,650. This was due to the contracts capturing the full downside of price collapse. However, as prices reversed the dynamic strategy lost -$35,920 and the static strategy posted a smaller -$22,450 loss. These results reflect the gradual price rebound that undercut short hedge positions over the second year. The 12-month contracts did smooth out much of the volatility that was experienced by short term contracts. They ultimately worked very well during long-trend environments like the 2008 collapse however still underperformed in later periods when price direction flattened. Like the other contracts, they offered more upside in the first year, but the higher cost of exposure became evident in the second cycle.

Portfolio Evaluation: Hedged vs. Unhedged
3-Month Window

During the early stages of the 2008 Financial Crisis, 3-month hedging strategies significantly outperformed the unhedged portfolio by providing vital downside protection. For example, in September 2008, both the dynamic and static strategies preserved portfolio value ($1,202,860 and $1,243,300 respectively) compared to the unhedged crude oil exposure of $1,041,100 effectively offsetting the price shocks. However, as prices continually dropped into December 2008, while still preserving significant portfolio value, the shock to the market was still evident in each of the hedged portfolios. As volatility continued, the dynamic strategy began to underperform during less direction windows like March 2009 where the dynamic value ($461,160) dropped below both the unhedged ($479,400) and static ($468,000). By mid-2009, the static strategy again proved superior preserving greater monetary value than the dynamic ($602,650 vs. $546,400). Over time as prices normalized both strategies converged with strong recoveries by June 2010 (dynamic: $817,160, static: $793,250), each outperforming the unhedged portfolio value of $753,400 while also reflecting the stabilization of oil prices with less difference between hedged vs unhedged positions. Overall, the 3-month static hedge delivered more consistent protection through the trough of the crisis while the dynamic yielded larger gains during the recovery.

6-Month Window

When performance is analyzed across a 6-month time horizon, hedged portfolios continued to outperform the unhedged baseline across all strategies, confirming the effectiveness of hedging during prolonged downturns. In December 2008, the strategies dramatically outpaced the unhedged portfolio value ($411,200), with static 3-month ($863,100) and 6-month ($847,450) strategies leading slightly over their dynamic counterparts. For contracts ending in June 2009, the static 6-month hedge ($602,300) again preserved more value than the dynamic 6-month ($548,840) and either 3-month approaches. This suggests that fewer rollovers provided more stability during the deep downturns. By June 2010, dynamic and static 6-month contracts produced nearly identical outcomes ($787,400 vs. $774,650), indicating convergence as the markets stabilized. These results highlight that during demand driven price collapses, 6-month contracts smoothed returns and were especially effective in reducing interim volatility.

12-Month Window

Looking at the broader 1-year horizon, hedging effectiveness was most pronounced at the peak of the crisis in June 2009, where all hedge strategies provided a dramatic buffer compared to the unhedged portfolio value ($696,400). The 3-month static hedge and 6-month static hedge were the top performers ($1,043,150 and $1,038,550 respectively), followed closely by the 12-month static ($1,025,050). Meanwhile their dynamic counterparts followed closely behind, their initially lower hedge ratios relative to the static put them at a disadvantage. In the second window, gains from recovering crude oil prices were slightly offset by hedge positions that were either closed too early (in shorter contracts) or failed to fully capture late-stage price rebounds (in longer ones). While the static 12-month hedge ($730,950) preserved the greatest value, all hedged positions fell below the unhedged portfolio value ($753,400).

Net Margin Profit/Loss

3-Month Window

During the 2008 Financial Crisis, the margin-based performance of 3-month futures hedges, highlighted the tradeoff between responsiveness and capital intensity. Initially, both the dynamic and static 3-month strategies generated sizable positive cash flows, with the dynamic hedge posting $161,760 in September 2008 and $249,700 in December 2008. But as the crisis deepened and volatility surged, the dynamic strategy experienced large margin based drawdowns. By June 2009, it recorded a loss of -$150,000 and margin costs totaled -$108,380 for that expiry. The 3-month static strategy experience similar swings but in a milder fashion. Over the 2-year period, the dynamic strategy cycled between cash-intensive losses and smaller recoveries, ending with a final gain of $63,760. Thus while 3-month hedges were very reactive to the changing market conditions, they also demanded substantial liquidity to withstand sustain price declines.

6-Month Window

When we aggregate margin-based results over 6-month windows, a similar pattern emerges. In the second half of 2008, both 3-month and 6-month strategies delivered strong gains, with 6-month strategies both delivering $436,250 in gains. However, during the trough of the crisis in June 2009, cash burdens intensified across different contract maturities. The dynamic 3-month hedge recorded a combined loss of -$168,240 while the 6-month dynamic strategy posted a nearly equivalent loss of -$150,560. This implies that longer contracts did not significantly reduce capital stress during the worst of the crisis. Static Hedges again moderated the downside but still faced significant cash flow losses, with the 6-month static strategy seeing the least severe results with a net margin loss of -$94,100 and margin costs totaling roughly -$67661 during the price reversal for the period ended June 2009. The prolonged decline in crude prices made all strategies cash negative during this interval. By June 2010, all strategies returned to positive territory, although the net gains were relatively modest.

12-Month Window

Over the 12-month windows, longer time horizons revealed how capital burdens evolved throughout the duration of the financial shock. In the first year ending June 2009, all hedging strategies posted fairly consistent positive margin-based P/L. The static 3-month strategy generated the greatest $346,750 while the 6-month static followed close behind at $342,150. Meanwhile both the dynamic and static 12-month generated $328,650. This suggests that hedgers who could absorb the initial liquidity demands benefited from the eventual payoffs as prices crashed and short positions matured. But the following year, as oil prices rebounded more erratically, all strategies turned cash negative. The dynamic 3-month saw the greatest losses of -$40,000. While all other strategies saw losses in the range of $20,000 - $40,000. These results illustrate that while longer maturities can smooth intermediate volatility, they are still exposed to sustained recovery phases where short futures lost value.

Included are Figures 5.2.1 and 5.2.2, which display portfolio outcomes for hedged versus unhedged positions and the net margin profit/loss for each strategy under a 6-month evaluation window during the 2008 Financial Crisis.

Figure 5.2.1 – Portfolio Evaluation (Hedged vs. Unhedged) under the 6-Month Window – 2008 Financial Crisis

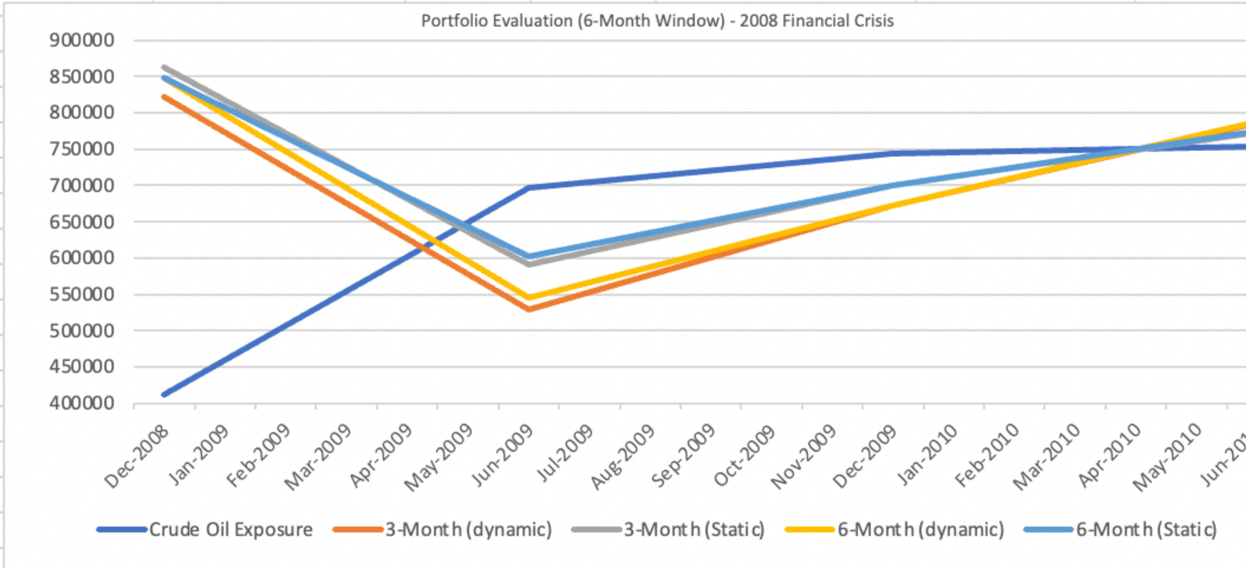
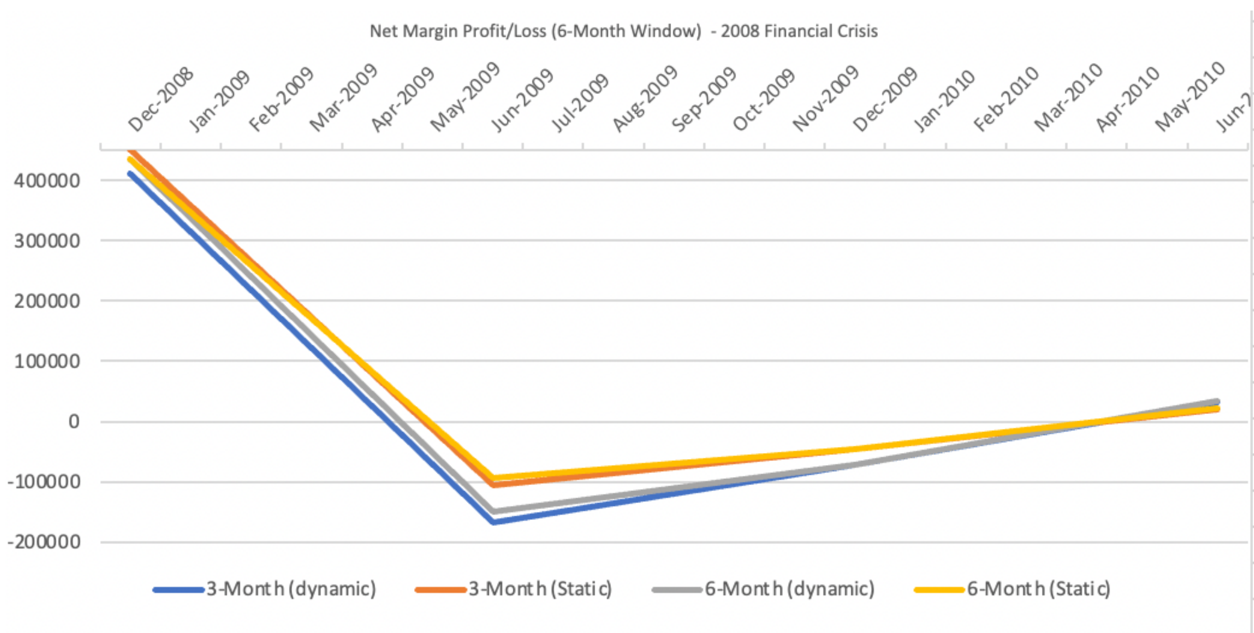


Figure 5.2.2 – Net Margin Profit/Loss under the 6-Month Window – 2008 Financial Crisis



5.3. The 2014 OPEC Price War

Spot and Futures Price Trends

Between September 2014 and September 2016, WTI Crude oil experienced an extremely prolonged period of price declines. Spot prices fell sharply from $93.21 in September 2014 to $47.22 by January 2015. Prices ultimately bottomed out at $30.02 in February 2016 before stabilizing in the mid-40s range. Unlike previously examined shocks, the price swing was not sudden but instead characterized by rolling lows, brief recoveries, and continual structural pressure. For example, there was a modest rally in the spring of 2015 which pushed prices around $60 but these gains were quickly erased by renewed selling in mid-2015 and further declines through 2016, as the market remained bearish given concerns about oversupply.

Futures contracts across all maturities mirrored both spot price decline however there was clear variation in responsiveness. The 3-month futures exhibited the highest sensitivity to spot movements, especially during major price inflection points in late 2014 and early 2016. This is supported by covariance of spot and futures return values during key months. Covariance peaked at 0.0071 in April 2015 and 0.0075 in both April and May 2016. In contrast, 6-month futures responded with a slight lag, achieving a peak covariance of 0.0066 in July 2015 while the 12-month futures showed the smoothest trajectory, with a lower and more stable covariance range topping out at 0.0051 during multiple months. This lag in longer dated contracts implies that traders on the 12-month horizon were anchoring to longer term expectations which muted short term volatility.

Throughout the period, the futures curve remained in contango, especially in early 2015 and in early 2016. As spot markets continued falling, futures prices remained consistently higher, particularly for 12-month contracts which held a premium of up to $10 per barrel over 30month futures during some months. This persistent contango reflected market expectations of long-term recovery even amidst short term weakness. The term structure meant that shorter contracts captured sharp drops and rebounds while the longer dated contracts could better absorb broader trends while missing short term pivots. This highlights the importance of selecting the appropriate contract length for effective hedge alignment during prolonged structural downturns like the 2014 OPEC Price War.

Futures Profit/Loss Evaluation

The 3-Month contracts displayed the highest price sensitivity but also the widest performance swings across the 2 year back test. Given the increased volatility during this period, the dynamic hedge ratio assumed 8 contracts throughout the back test period. The dynamic 3-month hedge delivered a solid gain of $284,000 in December 2014, capitalizing on the early collapse in crude prices. These gains were followed by sharp drawdowns like in June 2015 (-$74,560) which reflected the brief spot comebacks in the market. But these drawbacks were rebounded by significant gains like in September 2015 ($111,520). The static strategy followed the same pattern but with dampened exposure giving the constant 5 contracts. The static strategy posted $177,500 in December 2014 and $69,700 in September 2015. The static strategy's lower hedge ratio limited gains during depreciative periods but limited losses during brief price comebacks. These results highlight the high responsiveness and risk of short-dated contracts during uneven periods of prolonged price declines.

The 6-month contracts offered a more balanced trajectory. All dynamic 6-month contracts also had hedge ratios calling for 8 contracts for all positions. The dynamic 6-month contract recorded its strongest return early on in the back test, with $281,840 in March 2015 followed by more modest gains of $44,320 and $44,460 in September and December 2015. However, the final contract cycle ended in September 2016 saw a substantial loss of -$67,840, showing that even longer dated contracts were not immune to downside risk during price rebounds. The static 6-month strategy followed in suit with a substantial initial gain of $176,150 in March 2015 and also closing out with a reduced loss of -$42,000. These contracts captured broader directional movements making them attractive for hedgers seeking reduced transaction frequency albeit at the cost of responsiveness at turning points.

The 12-month contracts, which matured only twice during the back test, delivered the most stable and smoothed results. Like the shorter-term strategies, all dynamic hedge ratios in the 12-month contracts also called for 8 contracts. The dynamic strategy yielded a massive gain of $297,360 in September 2015 reflecting its alignment with the broader trend of sustained falling prices before reversing for a loss of -$17,520 in September 2016 as prices rebounded. The static 12-month strategy followed the same arc, with $185,850 gains in 2015 followed by a -$10,950 loss. These results illustrate the stability and long-term trend capture of the 12-month contracts. They offer stable future returns during a long-term depreciative scenario like this where price swings are more stretched out compared to previous shocks where fluctuations occurred more rapidly.

Portfolio Evaluation: Hedged vs. Unhedged
3-Month Window

The 3-month hedging strategies reflected strong initial responses during the initial price collapse of the OPEC Price War. By December 2014, the unhedged portfolio dropped to $592,900, but the 3-month dynamic hedge preserved value impressively, lifting the hedged portfolio value to $876,900. The static hedge followed close behind at $770,400. As the price war endured, both strategies saw diminished advantages. By March 2015, both hedged portfolios still exceeded the unhedged value but by slimmer margins (dynamic: $506,040, static: $495,600 vs. unhedged: $478,200). The unhedged portfolio value ($598,200) briefly outperformed both hedged strategies in June 2015, following the brief price comeback but this was short lived. In September 2015 the dynamic hedging strategy significantly outperformed the static and unhedged portfolios with an ending value of $566,320. However, towards the end of the backtest, especially towards mid 2016, the benefit of hedging narrowed. By September 2016 the dynamic and static strategies converged closely with the unhedged value, portraying that prices had roughly stabilized and that short-term hedging was no longer as necessary given volatility had subsided.

6-Month Window

When viewed at the 6-month horizon, both 3-month and 6-month strategies effectively protected inventory value during critical inflection points. In March 2015. The aggregated 3-month dynamic hedge led to a portfolio value of $790,040, outperforming both 6-month strategies (dynamic:$760,040, static:$654,350). The static 3-month approach also held an advantage over the static 6-month strategy during this initial period. However, all portfolio values converged in the period ending September 2015, with all hedged portfolios still exceeding the unhedged portfolio value. As the shocks effects evolved into a prolonged slump rather than a sharp rebound, the downside protection provided by all hedging strategies proved valuable during this period. As prices began to slowly rebound and flatten by September 2016, the unhedged portfolio ($451,800) exceeded all hedged portfolio values reflecting the shift in market dynamics. Overall, the 6-month contracts offered a solid middle ground which reduced volatility exposure while still being able to capture broader directional trends without the intense sensitivity seen in the 3-month strategies.

12-Month Window

By the 12-month evaluation points, the impact of hedging became more muted and convergent across all strategies. In September 2015, the most significant hedge performance occurred with the 3-month dynamic portfolio value peaking at $803,600, while the dynamic 6-month and 12-month hedged produced $780,960 and $752,160 respectively. The static strategies generally followed these trends but with less protection given their small positions. All hedged positions were greater than the unhedged portfolio value of $454,800. By September 2016, all hedged portfolios converged between a range of $410,000 - $450,000 with the 12-month static performing the best with a value of $440,050. But all of these values were outweighed by the unhedged portfolio value of $451,800. This can once again be attributed to the price stabilization seen by September 2016. This suggests that as the market stabilized, the marginal benefits of hedging diminished and longer contracts, while less reactive still provided comparable capital protection in the long run.

Net Margin Profit/Loss

3-Month Window

Between 2014 – 2016, the 3-month dynamic hedge experience sharp swings in realized performance which mirrored the volatility and prolonged downward trend in spot prices. This strategy initially posted an outsized gain of $284,000 in December 2014 as prices crashed. However subsequent windows showed how quickly short-term hedges could swing negative if mistimed. Losses of -$74,560 in June 2015 and -$71,200 in June 2016 illustrate the capital strain during intermediate rebounds. Margin Costs in June 2015 totaled -$76,115 for the dynamic and -$47,572 for the static. Despite this the dynamic strategy generated strong gains when prices once again dropped, generating $111,520 in September 2015. The static strategy followed a similar trajectory but with smaller amplitude: $177,500 in December 2014 and $69,700 in September 2015 while incurring losses during rebound periods like June 2015 (-$46,600) and June 2016 (-$44,500). Overall, while the dynamic hedge delivered larger total returns, it also demanded more liquidity and exposed the portfolio to greater interim drawdowns.

6-Month Window

Under the 6-month window, margin-based performance became less volatile. For the March 2015 expiration both dynamic and static 3-month hedges outperformed their 6-month counterparts. For example, the 3-month dynamic strategy gained $311,840 compared to the 6-month dynamic which trailed at $281,840. This initial advantage shows the benefit of shorter-term rolling contracts and the faster reactiveness of the 3-month futures prices to spot changes. In general, over the longer time horizon, the realized margin returns were not as volatile given that the short-term rebounds, which had a larger impact under the 3-month window, was smoothed out during the 6-month time horizon. For example, the margin costs for the 6-month dynamic strategy (-$64,968) were noticeably lower than the 3-month dynamic strategy (-$76,115). However, this larger time horizon still resulted in losses when prices settled in the period ending June 2016 where the dynamic strategies' larger exposure resulted in greater losses (3-month strategy: -$69,680, 6-month strategy: -$67,840). Although values somewhat converge during the longer time-horizon for realized returns, the 3-month positions were were slightly more expensive to maintain in terms of margin call cost and frequency as a result of the 3-month contacts greater sensitivity to price comebacks.

12-Month Window

When viewed across the full year, the results were more muted and stable but nevertheless aligned with broader market cycles. At September 2015, all hedge strategies delivered strong net gains, with the 3-month dynamic hedge outperforming at $348,800, followed by the 6-month dynamic at $326,160 and the 12-month dynamic at $297,360. This portrays the dynamic strategies' ability to capture greater downside reward during these prolonged depreciative periods. The static strategies delivered consistent but lower results across all maturities. However, for the September 2016 horizon, all strategies showed losses, reflecting the change in market direction. The 3-month dynamic posted the greatest loss of -$32,950, followed by the 6-month dynamic at -$23,200. Static strategies exhibited reduced losses. These losses are substantially smaller in comparison to the gains that the hedges made upon the onset of the shock which shows the advantage of dynamic hedge ratios during prolonged depreciative scenarios.

Included are Figures 5.3.1 and 5.3.2, which display portfolio outcomes for hedged versus unhedged positions and the net margin profit/loss for each strategy under a 6-month evaluation window during the 2014 OPEC Price War.

Figure 5.3.1 – Portfolio Evaluation (Hedged vs. Unhedged) under the 6-Month Window – 2014 OPEC Price War

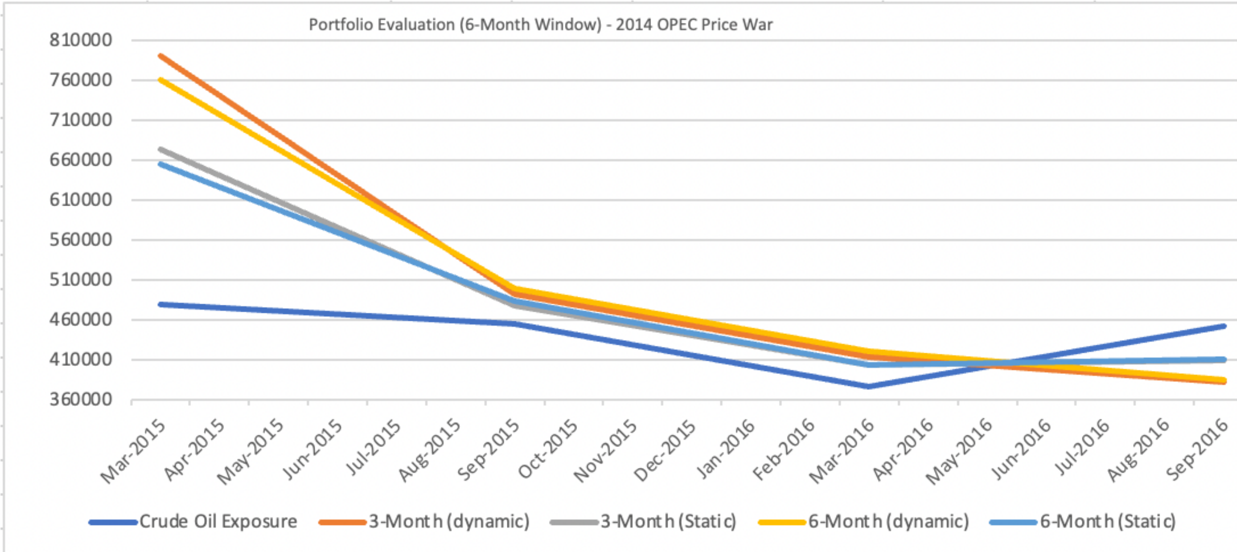
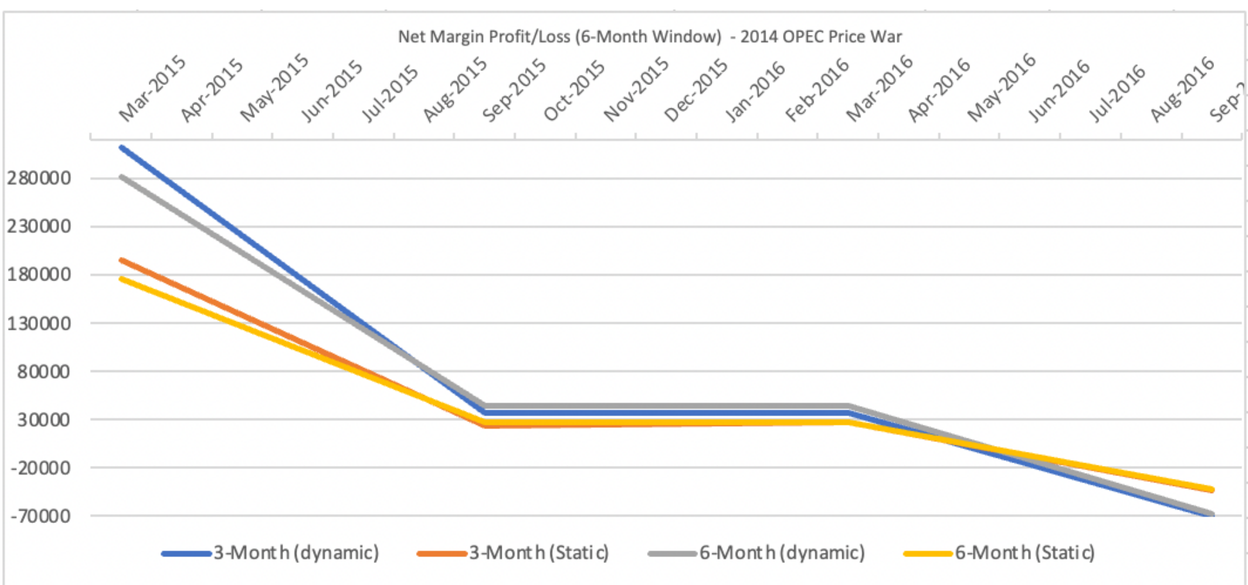


Figure 5.3.2 – Net Margin Profit/Loss under the 6-Month Window – 2014 OPEC Price War



5.4. The COVID-19 Pandemic

Spot and Futures Price Trends

Between December 2019 and December 2020, the crude oil market underwent a violent demand collapse followed by a volatile and uneven recovery. Spot prices for WTI crude dropped from $59.88 in December 2019 to just $16.55 by April 2020, a nearly 72% decline in just four months. This crash followed the global lockdowns worsened by the brief OPEC+ breakdown in March 2020. In April 2020, the market entered a tailspin due to the collapsing demand and the overflow of supply. A rebound began in May 2020 as OPEC+ cut production and economies slowly reopened. Spot prices climbed back to $47.02 in December 2020. However, this recovery was staggered, marked by sharp monthly swings due to lingering uncertainty about recurring waves of the pandemic.

Throughout this period, all futures maturities tracked the directional swings of spot prices but differed in their reactivity and alignment. The 3-month contracts were most closely tied to spot prices especially during the crisis period from March-May 2020. Covariance between spot and 3-month futures returns spiked from a pre-crisis low of 0.0064 in January 2020 to 0.0163 in March before peaking at 0.0385 in May 2020 as markets rebounded. This high responsiveness was driven by traders rapidly pricing in short-term demand shocks. The 6-month contracts followed a similar path from 0.0054 in January 2020 to 0.0065 by May-June 2020. Meanwhile 12-month futures were the slowest to adjust to these rapid market dynamics, with covariances of .0048 in January 2020 and subsequently peaking at 0.0192 in May 2020. This implies longer dated contracts were anchored to long-term recovery assumptions.

During the worst of the crisis, the term structure underwent a dramatic shift into deep contango. This was especially pronounced in April when 3-month futures traded at nearly an $8 premium to spot as prices collapse into the teens. The 6-month and 12-month traded even higher, reflecting expectations of recovery. However, this steep contango diminished over the year as spot prices recovery and near-term supply-demand conditions stabilized. By December 2020, the curve had flattened, with 3-,6-, and 12-month futures pricing at $48.69, $48.52, and $47.49 respectively vs. a spot price of $47.02. Overall, the short-dated futures captured sharp inflections with high volatility, while longer-dated contracts buffered these swings but lagged to rapid price reversals.

Futures Profit/Loss Evaluation

The 3-month contracts were highly sensitive to early market movements, with both dynamic and static strategies having strong performances during the initial collapse. The static hedge outperformed the dynamic in March 2020 expiry, earning $163,000 (5 contracts) vs. $130,880 for the dynamic strategy (4 contracts). However, as volatility persisted, the dynamic strategy ramped up to 7 then 8 contracts, increasing both exposure and ultimately risk. In June 2020, the dynamic strategy recorded a sizable -$82,530 loss while the static strategy fell -

$58,950. Losses continued throughout the remainder of the back test as spot prices recovered. These results show that while the 3-month contracts offered early downside capture, their reactivity led to amplified drawdowns during recovery periods especially under the dynamic strategy where exposure was higher.

The 6-month contracts offered a more balanced yet still volatile trajectory. The dynamic strategy entered its first expiration in June 2020 with 6 contracts and captured $114,540 gain while the static strategy posted $95,450. This solid performance reflects the tail-end of the collapse as the early stages of recovery offset the immense gains seen in the 3-month contracts. However, with the hedge ratio increasing to 8 for subsequent cycles, the dynamic began to incur steep losses during this price stabilization period. Losses mounted to -$69,920 in December 2020, with the static strategy showing a similar but less severe outcome -$43,700. The 6-month contracts struggled with timing. While they benefited from the trend continuity early on, the struggled to adapt when market conditions we're improving especially the dynamic contract which amplified losses given the higher hedge ratio.

Between the year ended December 2020, the 12-contract cycles delivered more stable cycles. The December 2020 expiry posted modest gains pf $49,780 for the dynamic strategy (7 contracts) and $42,700 for the static. The results reflect the longer contract's ability to capture the full arc of the collapse and partial recovery. If this strategy were rolled into the following year ended December 2021, both strategies were deep in the red with the dynamic strategy recording a -$152,530 loss while the static position ended -$108,950. These losses suggest that the 12-month strategies lagged the reversal in price trajectory and held on to short positions too long during the 2021 oil rally. While they did allow for smoothing of short-term volatility, given their failure to capitalize on the rebound of the market, these strategies are ultimately inefficient during fast paced price movements.

Portfolio Evaluation: Hedged vs. Unhedged
3-Month Window
During the extreme volatility of early 2020, the 3-month hedging strategies offered critical downside protection. At the height of the COVID induced collapse in March 2020, the unhedged portfolio plunged to $292,100 while the 3-month static hedge preserved value at $455,700 and the dynamic hedge trailed at $422,980. This divergence was driven by the static positions larger positions size (5 vs. 4 contracts respectively), allowing it to capture a greater amount of the early fall. However this excellent performance was short-lived as prices began to recover by June 2020. This saw the unhedged portfolio outperform both 3-month hedged portfolios for the expiries from June 2020 – December 2020. For example as prices recovered in June 2020, the unheeded portfolio ($383,100) outperformed both static ($324,150) and dynamic ($300,570). hedged portfolios. But given the dynamic hedge ratios reactiveness to market conditions, the dynamic strategy called for 8 contracts throughout the remainder of the backtest which amplified

losses during the slow recovery period in comparison to the static strategy. This shows a weakness of the dynamic strategy in adjusting to rapidly changing market conditions where the hedge is initially unprepared for an unexpected downturn while failing to adjust when the market begins to recover.

6-Month Window

When viewed on a 6-month horizon, broader patterns emerge. For contracts expiring in June 2020, the 6-month dynamic hedge preserved the most value ($497,640), slightly outperforming the static 6-month ($478,550) and both aggregated 3-month counterparts. This was due to the dynamic hedge's ability to reactively scale positions heading into the worst of the crash. However as price movements reversed, all hedged portfolio values once again fell below the unhedged portfolio value ($470,200) by the expiries in December 2020. We see the same pattern emerge during the 6-month time horizon as the dynamic strategies' greater number of contracts was its weakness as they increased exposure which amplified losses. Both of the static strategies came out on top, with the 6-month preserving a portfolio value of $426,500 while the aggregated 3-month preserved a total value of $424,150. Meanwhile the dynamic strategies both incurred greater losses due to their greater exposure with the 6-month maintaining $400,280 and the 3-month having $396,520. Thus, the static strategies proved more advantageous during this period of rapid collapse as they still provided solid protection while not overexposing themselves during the prolonged recovery period.

12-month Window

The benefit of long dated hedging was most evident during the first expiry in December 2020. During this period, the 12-month dynamic hedge yielded the strongest capital preservation at $529,980, followed by the 3-month static hedge at $528,800. During the 2021 oil price rally, all strategies underperformed the unhedged position ($717,100). All of the static strategies managed to preserve more value compared to their dynamic counterparts which remained over exposed during the 2021 recovery period. Overall, during a highly volatile and nonlinear shock like COVID-19, the 12-month dynamic hedge was most effective in preserving capital during the initial downturn, while the static strategy managed to gain the edge by the end of the recovery.

Net Margin Profit/Loss

3-Month Window

In the beginning of the pandemic, both 3-month strategies offered critical-short term liquidity, with the dynamic strategy yielding $130,880 and the static $163,600 in March 2020. However, this responsiveness came at a cost as by May 2020, margin calls spiked to $54,724 for the dynamic and $39,088 for the static which posed significant capital demands during this period. For the period ended June 2020, the dynamic strategy experienced a loss of -$82,530 followed by the static strategy with -$58,950. Margin call burdens persisted during this period for both strategies as spot prices began to slowly appreciate. Their frequent rollover and higher capital demands made them more challenging to sustain especially following the initial collapse of the pandemic.

6-Month Window

Over the 6-Month horizon, longer-dated contracts smoothed volatility but still incurred meaningful liquidity demands. During the first half of 2020, both the dynamic and static 6-month strategies posted strong gains of $114,540 and $95,450 respectively without any margin call pressure. However, during the latter half of the year, both flipped negative with the dynamic losing -$69,920 and static -$43,700. Margin calls occurred consistently as prices recovered during Q3 and Q4 2020. Overall, both dynamic strategies incurred significantly higher capital restraints to maintain the position compared to the static strategies. While the 6-month strategies were not immune to margin calls, the 3-month strategies' higher rollover frequency and greater reaction to short term trends made them more costly in the long-term.

12-Month Window

Over the full year window, for the year ended 2020, the dynamic 12-month strategy had the greatest gain of $59,780 which was followed by the aggregated static 3-month net margin profit/loss at $58,600. But all values generally fell in this range for this expiry except for the 3-month dynamic which showed a net negative cash flow of -$25,330. For the following year, as expected, all strategies had negative net margin-based cash flows following the 2021 price rally. The 12-month dynamic hedge ended with margin-based losses of -$152,530 while the static hedge limited losses to -$108,950, highlighting the static strategy's superior capital preservation during this shock. These results underscore how dynamic hedges, although potentially more responsive, imposed much heavier liquidity burdens during prolonged recoveries where short positions were exacerbated these losses. During this shock static hedges proved more capital efficient by offering more consistent cash flow profiles and reducing burden during appreciative periods.

Included are Figures 5.4.1 and 5.4.2, which display portfolio outcomes for hedged versus unhedged positions and the net margin profit/loss for each strategy under a 6-month evaluation window during the 2020 COVID-19 Pandemic.

Figure 5.4.1 – Portfolio Evaluation (Hedged vs. Unhedged) under the 6-Month Window – 2020 COVID-19 Pandemic

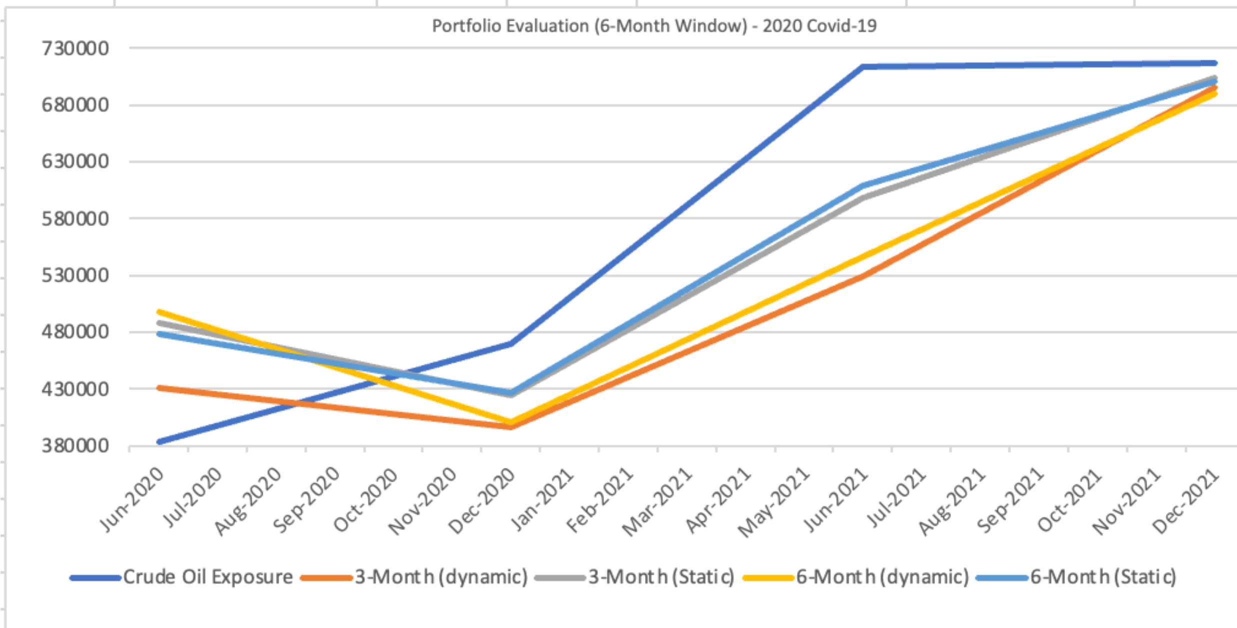
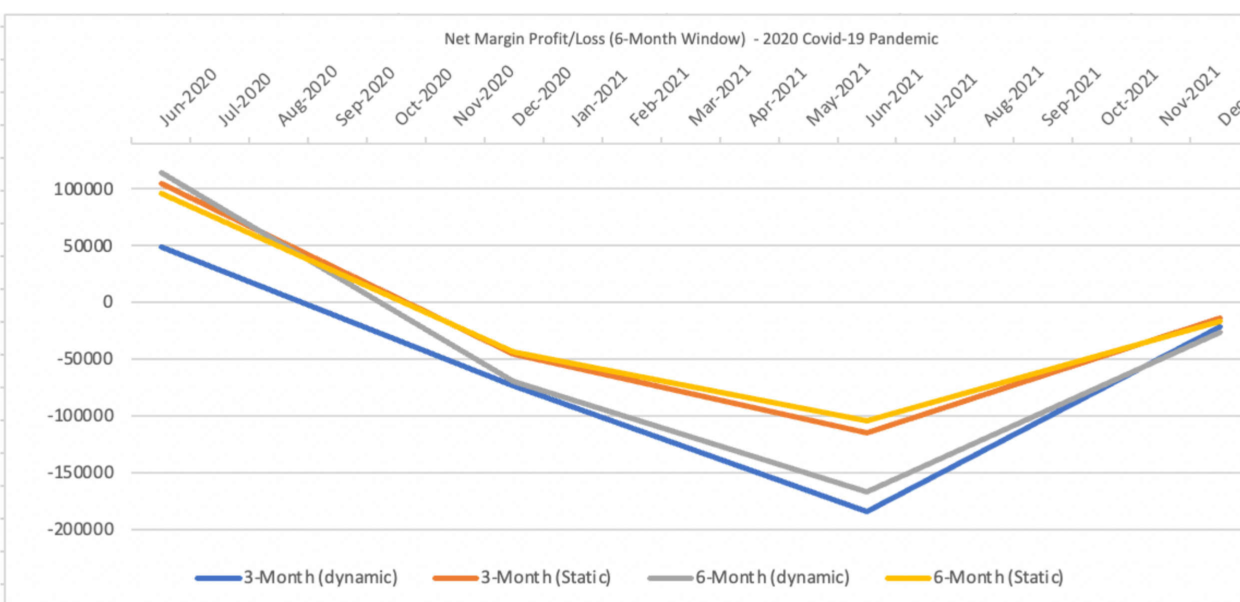


Figure 5.4.2 – Net Margin Profit/Loss under the 6-Month Window – 2020 COVID-19 Pandemic



5.5. The 2022 Russian Invasion of Ukraine

Spot and Futures Price Trends

Between September 2021 and September 2023, the crude oil market experienced one of the most acute geopolitical supply shocks in recent memory. Following Russia's invasion of Ukraine in February 2022, WTI spot surged from $91.64 in February to a peak of $114.84 in June 2022, driven by fears of major supply disruptions and widespread sections on the world's top three oil exporters. Spot prices climbed from $71.65 in September 2021 to $83.22 in January 2022, reflecting the building geo-political tensions and already tightening global supply. However, as markets absorbed the shock and global trade flows realigned, prices began to normalize. By the end of 2022, WTI spot had fallen to $76.44 and despite periodic rebounds, it remained volatile, yet range bound throughout 2023, closing at $89.43 in September. This price arc reflects an initial panic-driven rally followed by market adjustments and macro headwinds like recession fears.

The 3-Month contracts were sensitive to real-time developments, particularly from February 2022 to May 2022, mirroring the sharp rise in spot. During this window, 3M futures jumped from $90.98 to $108.90 closely following the spot peak. 3M futures prices. The 6M futures, while following the general trend but to a lesser extent, peaking in May 2022 at $101.42. Finally, the 12M contracts while increasing relative to pre shock prices were much lower with a May 2022 12M contract being priced $92.23. Covariance between spot and futures returns peaked for 3M and 6M maturities during the initial shock phase with the 3-month contract reaching 0.0039 in March 2022, while the 6-month hit 0.0044 in the same month. Meanwhile the 12-Month had a delayed covariance peak of 0.0005 in August 2022. This indicates that short-term contracts were more agile in capturing the sudden movements seen following the invasion.

The term structure underwent multiple shifts throughout the shock window. In the early months, the curve was relatively flat or mildly backwardated, but quickly steepened into backwardation as near-term prices surged faster than long-term expectations. In March 2022, the 3-month future traded nearly $12 below the spot price, indicating an aggressive short-term premium. The backwardation persisted into mid-2022 before narrowing as prices fell. By late 2022, the curve began flattening and even moved into mild contango at times, reflecting market uncertainty. This evolving term structure underscores the challenges in hedge positioning during such rapid appreciative scenarios.

Futures Profit/Loss Evaluation

The December 2021 expiry saw negligible movements for both static and dynamic hedges (-$1,300), marking a stable pre-invasion baseline. However, the shocks impact became evident by March 2022, where the dynamic strategy (3 contracts) recorded a -$67,920 loss and the static strategy (5 contracts) was hit harder at -$112,150. These steep drawdowns came from initiating shorts ahead of the invasion and liquidating the positions into a price spike. Losses continued into the June 2022 expiry, although dampened, with both strategies posting losses of -$16,950, reflecting poor timing as prices peaked. The tide turned in September 2022 when both static and dynamic strategies rebounded strongly, each earning $112,600 as short positions initiated near WTI highs captured the mid-year correction. This was followed by minor losses in December 2022 (dynamic: -$16,680, static: -$13,900). Overall while the 3-month contracts were extensively volatile during this period, their high responsiveness eventually allowed them to capitalize on the post-shock corrections, especially under the dynamic exposure.

In March 2022, both dynamic and static 6-month strategies were heavily underwater as prices surged. The dynamic hedge, maintaining 6 contracts, posted a -$116,640 loss, while the static hedge lost -$97,200. The dynamic 6-month strategy was the worst outcome for this period, given its notably high exposure in comparison to other strategies and reflect how the positions were initiated in late 2021, well before the full scope of the invasion-driven rally was priced in. The September 2022 expiry showed sharp reversal performance with the dynamic strategy gaining $103,260 and the static earning $86,050 as both hedges benefited from short positions initiated near peak prices in March and rolled into the summer decline. The dynamic strategy’s larger exposure allowed it to outperform during the correction. Both strategies show the importance of hedge entry timing in longer-dated contracts, where slower response to macro shifts can either dull losses or miss upside depending on market direction.

The 12-month contracts had the lowest frequency of realizations but offered an insightful lens on trend following potential. With only one active expiry near the main shock window (September 2022), the dynamic strategy recorded a relatively small loss of -$3,720 compared to -$9,300 for the static. This shows how longer-dated contracts were less sensitive to short-term volatility and smooth through this fast-paced supply shock. During the second cycle (expiring in September 2023), both strategies faced meaningful drawdowns. The dynamic hedge lost -$16,320 while the static hedge posted a deeper -$40,800 loss. These results suggested that the 12-month strategies failed to reposition following the mid-2022 correction, remaining short into a year-end rebound. The muted P/L range confirms the contracts reduced sensitivity which put these contracts at a disadvantage given the rapid market fluctuations seen during this short period.

Portfolio Evaluation: Hedged vs. Unhedged
3-Month Window

Following the Russian invasion in 2022, 3-month strategies were mostly ineffective in preserving portfolio value given the appreciative nature of this shock. At the initial expiration in December 2021, all portfolio values were nearly identical as geopolitical tensions had yet to fully erupt. By March 2022, following the crude oil prices spikes, both strategies significantly underperformed the unhedged inventory ($1,085,000), with the dynamic hedge at $1,017,710 and the static hedge at just $972,850, highlighting the cost of short exposure during unexpected rallies. The strategies rebounded in June and September 2022 as prices began to correct, with both hedged portfolios preserving $955,200 compared to the unhedged $842,600 in September. From that point forward, 3-month hedges stabilized, though slightly underperformed during later rebounds. By December 2022, the dynamic preserved $747,720 and the static was $750,500 vs. the unhedged $764,400 showing modest losses.

6-Month Window

The 6-month contracts offered a more consistent performance during the shock's volatile trajectory. At the March 2022 expiration which captured the invasions initial onset, the static strategy preserved $987,800 and the dynamic strategy $968,360. While the 6-month static outperformed its aggregated 3-month static, the aggregated 3-month dynamic outperformed the 6-month dynamic which reflected its lower hedge ratio which reduced their exposure during the spike. For the September 2022 expiry, this trend reversed as the aggregated 3-month static ($938,250) outperformed the 6-month static ($928,650) meanwhile the 6-month dynamic ($945,860) outperformed the aggregated 3-month dynamic ($938,250). However, all hedged portfolios outperformed the unhedged portfolio during this period reflecting the shifting market dynamics.

12-Month Window

Over the longer horizon, 12-month contracts initially lagged but gained relevance as the market stabilized. At the September 2022 expiration, 12-month static and dynamic hedges preserved $833,300 and $838,880 respectively, with both underperforming the unhedged portfolio ($842,600). The aggregated 3-month dynamic strategy ($869,960) was the only portfolio to outperform all other hedged portfolios and the unhedged portfolio for the expiry ended September 2022. This shows the advantage of dynamic shorter-term strategies in these types of scenarios where losses are initially minimized during the brief spike given the lower hedge ratio but the reactiveness to market conditions allows it to gain more as the market recovers. However, in the longer term, taking into account the next roll for the period ended September 2023, all longer-term portfolios outperformed the shorter-term aggregated strategies but all hedged portfolios still underperformed the unhedged portfolio value.

Net Margin Profit/Loss

3-Month Window

Following the Russian invasion of Ukraine in February, 3-month contracts experienced deep drawdowns during the initial price surge for contracts expiring in March 2022. The dynamic strategy experiences net margin losses of -$58,774 while the static strategy performed even worse that quarter (-$97,956). The margin call burden followed suit shortly after the invasion with February 2022 alone producing $23,453 in calls for the dynamic strategy and nearly $39,089 for the static. These pressures underscore the liquidity challenge of short-term contracts in periods of steep price appreciation. However both strategies rebounded by September 2022 as the market stabilized. Both dynamic and static strategies had net margin gains of $112,600 for the expiry in September 2022, showing a strong upside when trends reversed. In terms of capital requirements, the static 3-month hedges incurred consistently higher margin calls which can be attributed to the dynamic strategy's initially lower hedge ratio going into the shock.

6-Month Window

When evaluated over the 6-month interval, for the first expiry ended March 2022, the 6-month dynamic contract experience a net margin loss of -$116,440, which was significantly higher than the aggregated 3-month dynamic strategy which had total losses of -$60,073.75. This can be attributed to the smaller exposure of the short-term strategy during this period. Meanwhile both the 6-month (-$97,200) and aggregated 3-month (-$99,256) static strategies had relatively similar margin losses during this period. For the dynamic strategies, the margin calls between January and February 2022 were significantly higher than its 3-month counterpart with margin calls for the 6-month dynamic strategy totaling $53,880 notably higher than $35,490 for the 3-month contracts. The 6-month strategies did manage to recover during the price stabilization for expiry in September 2022 with the dynamic gaining $103,260 and the static gaining $86,050. However, both strategies still lagged behind the aggregated 3-month strategies showing how they were able to better adapt to the changing market dynamics.

12-Month Window

Over the full year window, 12-month contracts demonstrated the lowest margin call burden but at the expense of hedge responsiveness and downside capture. The 12-month dynamic strategy recorded a modest net margin loss of -$3,720 while the static had a slightly greater loss of -$9,300. However, both strategies lagged significantly behind the aggregated 3-month dynamic hedge which generated over $66,801.25 during the same period. This discrepancy highlights the key limitation of longer-dated contracts as they were unable to adapt quickly enough to capture the sharp price reversals in Q2 and Q3. As a result, they missed substantial profit opportunities that the shorter hedges captured during those volatile market corrections. For the dynamic strategies, margin calls during tis period totaled roughly $43,000 for the 12-month contract, $124,000 for the 6-month contracts, and $100,000 for the 3-month contracts. While the longer-term strategies were more cash efficient, they fail to capture the rapid downside movements which shorter tern contracts exploited during the recovery period.

Included are Figures 5.5.1 and 5.5.2, which display portfolio outcomes for hedged versus unhedged positions and the net margin profit/loss for each strategy under a 6-month evaluation window during the 2022 Russian Invasion of Ukraine.

Figure 5.5.1 – Portfolio Evaluation (Hedged vs. Unhedged) under the 6-Month Window – 2022 Russian Invasion of Ukraine

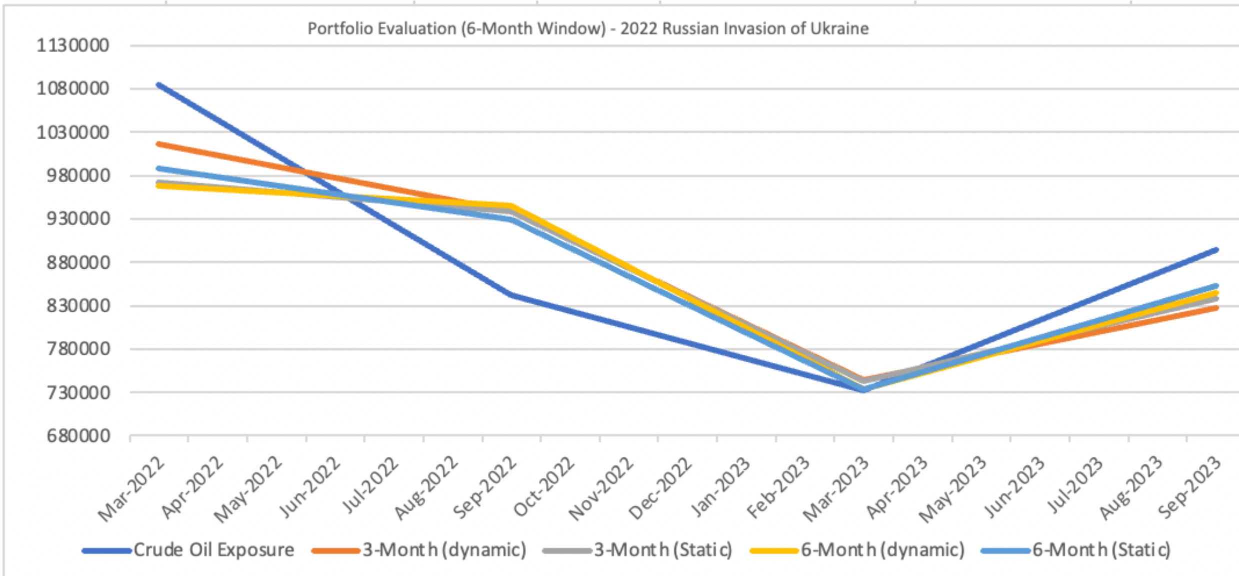
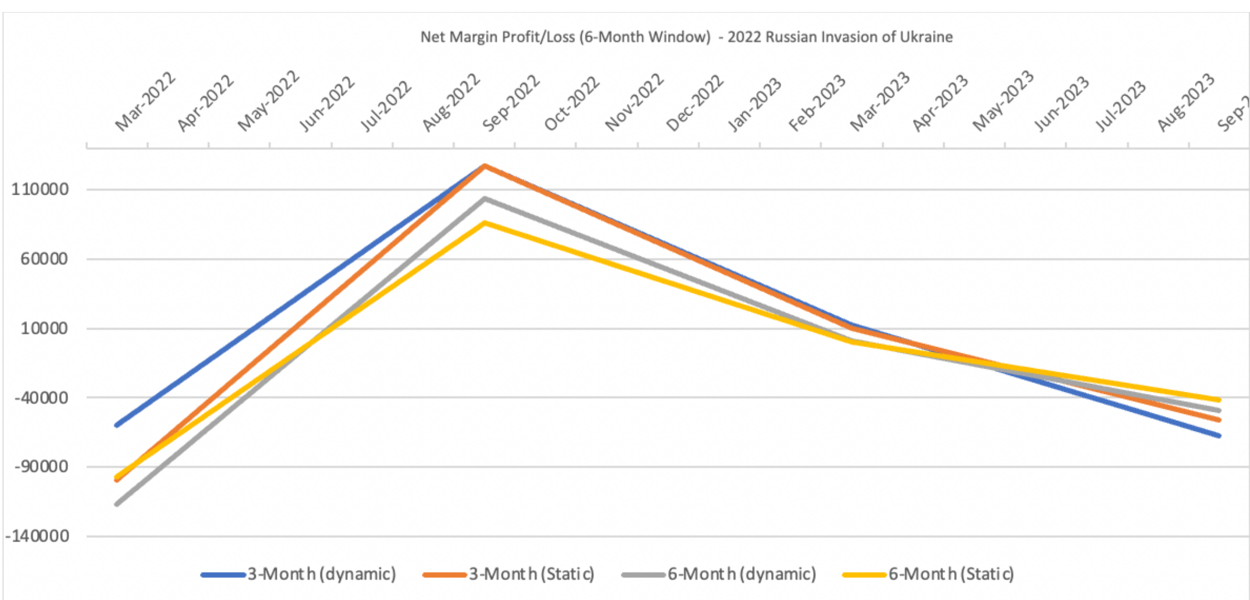


Figure 5.5.2 – Net Margin Profit/Loss under the 6-Month Window – 2022 Russian Invasion of Ukraine



6. Conclusion

6.1. Introduction

In the following section we will identify the optimal strategy across individual shock types then identifying broader patterns in order to determine which strategy is most adaptable across varying market conditions. When evaluating the performance of various short futures hedging strategies across different oil price shock scenarios, this study utilizes a comparative framework that emphasizes shock characteristics, namely the direction of price movement (appreciative vs. depreciative), the duration (short-term vs. long term), and the underlying cause (supply-driven vs. demand driven). While the optimal contract maturity depends on a hedger's specific operations, such as their sales frequency or the purpose of the hedge (e.g., protecting inventory value vs. timing sales), this study controls for such factors by holding strategies constant during each shock window. The objective is to isolate which contract maturity and hedge ratio combination most effectively preserves portfolio value while minimizing maintenance costs across a variety of economic contexts. The analysis considers the practical limitations of real world implementation such as the volatile environments, mistiming risk remains a major concern, especially as exiting positions mid shock may not be feasible.

As such, we not only identify which strategies offer the greatest protection or upside efficiency across individual shock types, but also which one offers the most balanced performance when moving into unforeseen shocks. A keen analyst can pick up on certain trends such as an upcoming geo-political conflict and adjust as needed however, black-swan events like COVID-19 show that hedgers need to be prepared for all possible scenarios. This comparative framework aims to equip hedgers with actionable insights on how to adapt short futures strategies based on the anticipated nature of an oil price shock, while recognizing the limitations of prediction and the structure constraints of their operation. Based on the hedging strategy identified as most optimal in each of the shock-specific analyses, we will qualitatively assess why these strategies were effective within the context of their respective shocks. This will allow us to link performance outcomes to the structure features of each shock such as speed, volatility, and directional bias, highlighting why certain hedge designs outperformed others given the nature of the price movement and the duration of exposure.

6.2. Optimal Strategy by Shock

Based on individual shock analyses evaluating futures profit and loss, hedged vs. unhedged portfolio values, and net margin profit/loss, this study identifies the optimal short futures hedging strategy for each scenario balancing portfolio value preservation and cost efficiency. The following section outlines each shock's context, summarizes the key findings, and higlights the hedging strategy that proved most effective given the price movement, shock duration, and cost considerations.

During the 1990 Gulf War, the 6-month strategies proved to be the most balanced and effective hedging options. While the 3-month dynamic strategy achieved the highest portfolio value by March 1991 following the price reversal, it incurred the most substantial losses and costs during the initial price spike due to its elevated pre-shock hedge ratio. Similarly, the 3-month static offered better initial protection, incurring smaller drawdowns, and requiring less liquidity than its dynamic counterpart, but its short-term reactivity left it more vulnerable to rapid price swings, resulting in higher overall volatility and less stability during the shock. In contrast, the 6-month static strategy preserved the highest portfolio value through the initial spike and maintained a tight range of incomes, offering hedgers a particularly safe and cost-efficient buffer during this volatile period. Meanwhile the 6-month dynamic strategy absorbed greater losses early on but adapted well during the price reversal. Ultimately, the 6-month contract length proved optimal for during fast paced, appreciative shocks like this, effectively dampening the spike's effects while enabling recovery participation. The choice between static and dynamic variants should be based on the hedger's risk tolerance and available liquidity but both 6-month strategies provided superior balance in this context.

The 2008 Financial Crisis highlights the delicate balance that exists between hedge responsiveness, liquidity burdens, and contract durations when managing extreme demand driven shocks. Dynamic 3-month contracts offered the strongest downside protection during the collapse however their high reactivity led to steep losses when prices began recovering while also demanding substantial liquidity to maintain. Static hedges preserved more consistent portfolio value with lower margin stress especially over longer horizons. However, a key limitation of dynamic hedge ratios during an unbeknownst depreciative shock is that they are often initially unhedged and unprepared for extreme losses because their exposure scales based on prior conditions thus, they lag behind sudden price collapses. Conversely as volatility remains elevated or prices began to recover, dynamic strategies tend to overprotect, increasing hedge ratios even as the worst of the downturn has passed, resulting in missed upside and amplified losses. The static 6-month hedge proved most optimal during this shock. It successfully captured the majority of downside price movement while minimizing capital strain. Additionally, it offered consistent performance across both crash and recovery cycles making it the most balanced and resilient strategy for producers seeking protection and stability during a prolonged crisis.

Given the extended duration and structural cause of the 2014 OPEC Price War, the 6-month dynamic hedge is the most optimal strategy for crude oil producers seeking to balance responsiveness with capital efficiency. While the 3-month dynamic strategy achieved higher early portfolio values and sharper downside return, it was more sensitive to short-term rebounds resulting in steeper drawdowns and margin costs. In contrast, the 6-month dynamic hedge effectively captured major downside movements while smoothing over temporary price comebacks that the shorter contracts suffered from. Its reduced transaction frequency and more stable margin profile made it more capital efficient over time. Crucially, its longer contract length better matched the nature of this slow-moving supply shock, where short-term reactivity offered diminishing returns. The dynamic hedge ratio enhanced its ability to scale exposure during key inflection points. As a result, the 6-month dynamic hedge struck the ideal balance between protection, performance, and liquidity management given the nature of this shock.

Based on the results of this back test, the 6-month static hedging strategy proved to be the most optimal approach for navigating a demand-driven price shock, as seen during COVID-19. Although it was initially outperformed in capital preservation by both the 3-month static and the 12-month dynamic during the initial collapse, the 6-month static hedge delivered superior performance throughout the remainder of 2020 and into the 2021 recovery by preserving more capital and minimizing cash burdens. Thus, this strategy balances reactivity and cost efficiency, offering more frequent re-entry points than the 12-month hedge which failed to capture late-stage rebounds while avoiding the capital intensity and frequent rollover demands of 3-month strategies. Notably during the 2021 price rally, the 6-month static hedge incurred $96,406.25 in total margin calls which was significantly lower than those of the 3-month static and 12-month static strategies. This makes the 6-month strategy the most advantageous for shocks like this where prices collapse sharply but recovery gradually over time.

The 2022 Russian Invasion of Ukraine created a fast-paced and volatile market environment, and in this context, the 3-month dynamic futures strategy emerged as the most effective hedge. Its initially lower hedge ratio limited losses during the price spike, outperforming its static counterpart in preserving value. As prices later corrected, the dynamic strategy scaled exposure in response to market shifts, capturing greater downside gains than either the static strategy or long-dated contracts. While the 3-month dynamic strategy incurred higher margin call activity, especially in Q1 and Q2 2022, it remained less costly than the 6-month strategies. Overall, the 3-month dynamic approach proved the most adaptable and cost-efficient, making it the optimal strategy for managing short-lived but intense geo-political supply shocks.

6.3. Supply-Side Shocks

Supply-side oil price shocks, particularly those driven by geo-political conflicts or natural disasters, tend to trigger short-term price appreciations that are often sharp and temporary. This is because markets typically expect short term disruptions to resolve in the near term. Strategic petroleum reserves and spare production help alleviate these shocks over time, leading to relatively swift price normalization. During fast-paced, appreciative supply shocks like the 1990 Gulf War and the 2022 Russian invasion of Ukraine, all short hedging strategies initially incur losses due to the upward price spike. Thus, strategy effectiveness in this context is measured not by profitability during the spike, but by a contract's ability to minimize realized losses and margin costs during the initial appreciation while effectively capturing gains during the eventual price reversal. In terms of costs, the longer term and more exposed (greater the hedge ratio), a given strategy is, than the less costly it will be. However given their reactiveness, 3-month contracts were able to capture the most downside gain during rapidly evolving market conditions. During the 2022 invasion, the dynamic 3-month strategy outperformed the static strategy as its lower pre-shock hedge ratio limited upside losses and allowed for post-spike adjustments to profit from the correction. In contrast during the Gulf War, dynamic hedging carried greater risk as the elevated pre-shock hedge ratio resulted in amplified losses when prices initially surged. When anticipating a supply-driven price spike of this nature, the 3-month dynamic strategy is only optimal when it enters the shock period with a relatively low hedge ratio, allowing it to limit initial upside losses and then quickly adjust to maximize downside capture during the subsequent price correction. Otherwise, depending on the hedger's liquidity and risk tolerance, a 6-month dynamic or static strategy offers a viable alternative, as it reduces margin and rollover costs while smoothing over short-term volatility even if it sacrifices some responsiveness in capturing rapid price reversals.

While less common, depreciative supply-side shocks, generally result from structural shifts such as technological advancements, long-term increases in production, or breakdowns in cartel coordination. These shocks create sustained downward pressure on oil prices as the market adjust to a new supply equilibrium. Unlike rapid appreciation, these are characterized by gradual declines occasionally interrupted by brief price recoveries. In such contexts, longer duration contracts perform more consistently. The dynamic 6-month hedge emerged as the most effective strategy due to its ability to adjust to longer-term trends while minimizing sensitivity to short-lived price rebounds. In contrast, 3-month hedges were more exposed during these interim recoveries, making them less effective at preserving portfolio value. Dynamic hedging was also superior to static hedging given the slow-moving nature of this depreciative shock which gave the hedge ratio more time to adjust and capture more downside gains.

Considering both appreciative and depreciative supply shock scenarios, the dynamic 6-month strategy presents the most balanced performance in terms of value preservation and risk mitigation. While its not the most reactive option during short-term price spikes, it is significantly less risky than 3-month contracts during appreciative supply shocks due to its longer duration and lower exposure to sudden volatility. Its dynamic nature enables it to adjust hedge ratios effectively, cushioning against prolonged downward trends in depreciative scenarios while also capitalizing on price reversals in appreciative environments. Although it may initially carry greater exposure during sudden price surges, its ability to recalibrate positions over time helps mitigate those losses and enhances downside capture as prices normalize. In environments that allow for tactical adjustments, this strategy can even perform well during rapid appreciative shocks where early upside losses are dampened, and ensuing downside movements is effectively hedged. For hedgers facing uncertainty around the direction or duration of a supply shock, the dynamic 6-month hedge offers a resilient, adaptable option that strikes a balance between responsiveness and stability.

6.4. Demand-Side Shocks

Demand-driven oil price shocks are typically triggered by sharp macroeconomic contractions or sudden drops in industrial and consumer activity, which cause oil demand to plummet. These shocks are predominantly depreciative in nature and often characterized by steep initial prices collapses followed by gradual recoveries. Unlike supply side-disruptions, appreciative demand shocks are rare, as rising demand usually unfolds gradually, giving supply chains time to adjust. Shocks we analyzed such as the 2008 Financial Crisis and the 2020 COVID-19 Pandemic exemplify this pattern with prices falling dramatically over a short period and then beginning a slow recovery as demand rebounded with stimulus efforts or policy adjustments. Given this trajectory hedging strategies must be evaluated not only on their ability to capture downside gains during the collapse but also on how effectively they preserve portfolio value during the recovery phase, when margin costs and missed upside exposure become major concerns. Frequent rollovers, as required by short-term contracts like 3-month futures, can become especially costly during recoveries, while the cumulative effect of margin calls and unrealized upside losses can erode the initial benefits of the hedging during the downturn.

In this context, the 6-month static hedging strategy proves most effective during demand-driven depreciative shocks. While the 3-month strategies may offer more reactive downside protection at the onset of a collapse, they often become a liability during the rebound phase, as rollovers intensify capital strain and repeated contract settlement limits upside participation. The 6-month time horizon, on the other hand, smooths over short-term price troughs while still offering reasonable protection during the downturn. Importantly, static positioning offers an advantage over dynamic strategies in these conditions. Dynamic strategies often enter the shock period with lower hedge ratios due to prior stable market conditions, reducing their effectiveness just when protection is most needed. Additionally, as prices began to rebound, these same dynamic strategies can become over-hedged, resulting in greater unrealized losses and higher margin costs. In contrast, the static 6-month strategy avoids these pitfalls by maintaining consistent protection through both phases of the shock, mitigating early losses while avoiding excessive exposure during the recovery. Its moderate duration and fixed hedge ratio offer a cost efficient and resilient solution for hedgers navigating sharp demand collapses and uncertain rebounds.

6.5. Summary of Cross-Shock Findings

In summarizing the results across a wide spectrum of oil price shock scenarios, distinguished by price direction, duration and underlying cause, this study finds that the 6-month static hedging strategy offers the most consistently effective performance. It provides reliable downside protection during depreciative environments while managing costs more effectively than shorter-term contracts during appreciative scenarios. Its moderate contract length allows it to smooth over sudden price spikes or reversals while remaining adaptable enough to respond to broader market trends. In appreciative supply-driven shocks like the 1990 Gulf War and the 2022 Russian Invasion, the 3-month contracts were more reactive, capturing downside gains more efficiently once prices stabilized. However, this reactivity came at a cost, particularly during the initial surge, resulting in significant margin burdens and futures losses. While dynamic 3-month strategies showed strong performance in the 2022 invasion due to favorable hedge ratio timing, this advantage was not replicated during the Gulf War, where high pre shock hedge ratios amplified early losses. In contrast, 6-month strategies, both static and dynamic, proved more resilient by buffering short term volatility while still capturing a substantial portion of downside movement. The dynamic 6-month strategy offered higher downside gains in certain cases such as the 2014 OPEC Price War, due to its ability to gradually adjust during slow-moving depreciative conditions. However, its higher cost profile and exposure to mistimed adjustments made it less reliable during demand-driven scenarios.

In the demand-driven shocks examined like the 2008 Financial Crisis and 2020 Pandemic, sharp price collapses were followed by prolonged recoveries. Although 3-month contracts captured early downside gains, the cost of frequent rollovers and margin calls during recovery severely impaired long-term effectiveness. Meanwhile, the dynamic 6-month strategy often entered such shocks under-hedged and became over-hedged as prices rebounded which amplified losses. In contrast, the static 6-month strategy avoided these pitfalls, maintaining sufficient protection through the downturn without excessive capital strains during the recovery period. Its fixed hedge ratio and semi-annual rollover schedule helped balance reactivity with cost containment. Across all scenarios analyzed, whether driven by supply or demand, whether short or long term depreciative or appreciative, the 6-month static strategy emerged as the most balanced and reliable approach. It protects value across multiple market conditions, avoids the volatility of dynamic misalignment, and reduces the capital burden associate with short-term rollovers. For hedgers navigating uncertainty and unable to accurately predict the nature or duration of upcoming shocks, this strategy offers a structurally sound and operationally practical solution.

7. Appendix

This section contains the full the data collected for the back test and the evaluatory metrics used to assess the performance of each hedging strategy during major crude oil price shocks. The data collected includes monthly West Texas Intermediate (WTI) spot prices and 3-, 6-, and 12-month crude oil futures prices. Spot returns were calculated as R(St) and futures returns were calculated as R(Ft). Additionally, there are detailed figures for futures profit/loss, portfolio evaluations comparing hedged vs. unhedged positions, and net margin profit/loss values. These metrics are calculated on a monthly basis, aligned with the expiration of the respective futures contracts which varies by contract maturity (3, 6, or 12 month).

All values are presented across the two-year back test period for each individual shock event.

7.1. Data Collected

This section presents the spot and futures price data (3-month, 6-month, and 12-month contracts) for the shocks examined in this study. This data was collected and utilized in the hedging analysis to determine profit outcomes for each contract maturity. Calculated monthly returns for both spot and futures contracts are included.

Table 7.1.1
1990 Gulf War
3-Month Futures

Month	Spot Price	3M Futures Price	R(St)	R(Ft)
Nov-1988	14.14	15.07		
Dec-1988	16.38	16.25	0.1584	0.0783
Jan-1989	18.02	16.4	0.1001	0.0092
Feb-1989	17.94	17.36	-0.0044	0.0585
Mar-1989	19.48	19.03	0.0858	0.0962
Apr-1989	21.07	18.76	0.0816	-0.0142
May-1989	20.12	18.39	-0.0451	-0.0197
Jun-1989	20.05	18.95	-0.0035	0.0305
Jul-1989	19.78	18.14	-0.0135	-0.0427
Aug-1989	18.58	18.62	-0.0607	0.0265
Sep-1989	19.59	19.68	0.0544	0.0569
Oct-1989	20.1	19.44	0.0260	-0.0122
Nov-1989	19.86	19.47	-0.0119	0.0015
Dec-1989	21.1	21.16	0.0624	0.0868
Jan-1990	22.86	21.51	0.0834	0.0165
Feb-1990	22.11	21.53	-0.0328	0.0009
Mar-1990	20.39	20.69	-0.0778	-0.0390
Apr-1990	18.43	19.67	-0.0961	-0.0493
May-1990	18.2	18.63	-0.0125	-0.0529
Jun-1990	16.7	18.26	-0.0824	-0.0199
Jul-1990	18.45	21.62	0.1048	0.1840
Aug-1990	27.31	26.57	0.4802	0.2290
Sep-1990	33.51	36.75	0.2270	0.3831
Oct-1990	36.04	32.44	0.0755	-0.1173
Nov-1990	32.33	29.22	-0.1029	-0.0993
Dec-1990	27.28	26.71	-0.1562	-0.0859
Jan-1991	25.23	19.9	-0.0751	-0.2550
Feb-1991	20.48	18.42	-0.1883	-0.0744
Mar-1991	19.9	19.37	-0.0283	0.0516
Apr-1991	20.83	20.57	0.0467	0.0620

May-1991	21.23	21.31	0.0192	0.0360
Jun-1991	20.19	20.52	-0.0490	-0.0371
Jul-1991	21.4	21.54	0.0599	0.0497
Aug-1991	21.69	22	0.0136	0.0214
Sep-1991	21.89	21.98	0.0092	-0.0009
Oct-1991	23.23	22.89	0.0612	0.0414
Nov-1991	22.46	21.1	-0.0331	-0.0782
Dec-1991	19.5	19.19	-0.1318	-0.0905
Jan-1992	18.79	19.14	-0.0364	-0.0026
Feb-1992	19.01	18.98	0.0117	-0.0084
Mar-1992	18.92	19.63	-0.0047	0.0342
Apr-1992	20.23	20.87	0.0692	0.0632
May-1992	20.98	22.04	0.0371	0.0561
Jun-1992	22.39	21.53	0.0672	-0.0231
Jul-1992	21.78	21.69	-0.0272	0.0074
Aug-1992	21.34	21.3	-0.0202	-0.0180
Sep-1992	21.88	21.57	0.0253	0.0127
Oct-1992	21.69	20.62	-0.0087	-0.0440
Nov-1992	20.34	19.9	-0.0622	-0.0349
Dec-1992	19.41	19.69	-0.0457	-0.0106

Table 7.1.2
6-Month Contracts

Month	Spot Price	6M Futures Price	R(St)	R(Ft)
Nov-1988	14.14	15.05		
Dec-1988	16.38	15.72	0.1584	0.0445
Jan-1989	18.02	15.96	0.1001	0.0153
Feb-1989	17.94	16.71	-0.0044	0.0470
Mar-1989	19.48	17.93	0.0858	0.0730
Apr-1989	21.07	17.91	0.0816	-0.0011
May-1989	20.12	17.63	-0.0451	-0.0156
Jun-1989	20.05	18.12	-0.0035	0.0278
Jul-1989	19.78	18.01	-0.0135	-0.0061
Aug-1989	18.58	18.41	-0.0607	0.0222
Sep-1989	19.59	19.25	0.0544	0.0456
Oct-1989	20.1	19.02	0.0260	-0.0119
Nov-1989	19.86	19.03	-0.0119	0.0005
Dec-1989	21.1	20.29	0.0624	0.0662
Jan-1990	22.86	20.54	0.0834	0.0123
Feb-1990	22.11	21.07	-0.0328	0.0258
Mar-1990	20.39	20.76	-0.0778	-0.0147
Apr-1990	18.43	20.2	-0.0961	-0.0270
May-1990	18.2	19.93	-0.0125	-0.0134

Jun-1990	16.7	18.97	-0.0824	-0.0482
Jul-1990	18.45	21.83	0.1048	0.1508
Aug-1990	27.31	25.16	0.4802	0.1525
Sep-1990	33.51	33	0.2270	0.3116
Oct-1990	36.04	29.06	0.0755	-0.1194
Nov-1990	32.33	25.92	-0.1029	-0.1081
Dec-1990	27.28	24.4	-0.1562	-0.0586
Jan-1991	25.23	18.9	-0.0751	-0.2254
Feb-1991	20.48	18.23	-0.1883	-0.0354
Mar-1991	19.9	19.29	-0.0283	0.0581
Apr-1991	20.83	20.23	0.0467	0.0487
May-1991	21.23	21.47	0.0192	0.0613
Jun-1991	20.19	20.38	-0.0490	-0.0508
Jul-1991	21.4	21.17	0.0599	0.0388
Aug-1991	21.69	21.53	0.0136	0.0170
Sep-1991	21.89	21.38	0.0092	-0.0070
Oct-1991	23.23	22.1	0.0612	0.0337
Nov-1991	22.46	20.77	-0.0331	-0.0602
Dec-1991	19.5	19.33	-0.1318	-0.0693
Jan-1992	18.79	19.16	-0.0364	-0.0088
Feb-1992	19.01	19.13	0.0117	-0.0016
Mar-1992	18.92	19.57	-0.0047	0.0230
Apr-1992	20.23	20.7	0.0692	0.0577
May-1992	20.98	21.75	0.0371	0.0507
Jun-1992	22.39	21.31	0.0672	-0.0202
Jul-1992	21.78	21.34	-0.0272	0.0014
Aug-1992	21.34	21.01	-0.0202	-0.0155
Sep-1992	21.88	21.22	0.0253	0.0100
Oct-1992	21.69	20.52	-0.0087	-0.0330
Nov-1992	20.34	19.84	-0.0622	-0.0331
Dec-1992	19.41	19.77	-0.0457	-0.0035

Table 7.1.3
12-Month Contracts

Month	Spot Price	12M Futures Price	R(St)	R(Ft)
Nov-1988	14.14	15.05		
Dec-1988	16.38	15.15	0.1584	0.0066
Jan-1989	18.02	15.72	0.1001	0.0376
Feb-1989	17.94	16.26	-0.0044	0.0344
Mar-1989	19.48	16.67	0.0858	0.0252
Apr-1989	21.07	17.04	0.0816	0.0222
May-1989	20.12	16.97	-0.0451	-0.0041
Jun-1989	20.05	17.51	-0.0035	0.0318

Jul-1989	19.78	17.89	-0.0135	0.0217
Aug-1989	18.58	18.22	-0.0607	0.0184
Sep-1989	19.59	18.69	0.0544	0.0258
Oct-1989	20.1	18.49	0.0260	-0.0107
Nov-1989	19.86	18.49	-0.0119	0.0000
Dec-1989	21.1	19.54	0.0624	0.0568
Jan-1990	22.86	19.84	0.0834	0.0154
Feb-1990	22.11	20.92	-0.0328	0.0544
Mar-1990	20.39	20.7	-0.0778	-0.0105
Apr-1990	18.43	20.16	-0.0961	-0.0261
May-1990	18.2	20.17	-0.0125	0.0005
Jun-1990	16.7	19.28	-0.0824	-0.0441
Jul-1990	18.45	21.73	0.1048	0.1271
Aug-1990	27.31	23.62	0.4802	0.0870
Sep-1990	33.51	28.62	0.2270	0.2117
Oct-1990	36.04	25.8	0.0755	-0.0985
Nov-1990	32.33	23.19	-0.1029	-0.1012
Dec-1990	27.28	22.99	-0.1562	-0.0086
Jan-1991	25.23	18.72	-0.0751	-0.1857
Feb-1991	20.48	18.4	-0.1883	-0.0171
Mar-1991	19.9	19.33	-0.0283	0.0505
Apr-1991	20.83	19.87	0.0467	0.0279
May-1991	21.23	21.16	0.0192	0.0649
Jun-1991	20.19	19.9	-0.0490	-0.0595
Jul-1991	21.4	20.76	0.0599	0.0432
Aug-1991	21.69	20.95	0.0136	0.0092
Sep-1991	21.89	20.82	0.0092	-0.0062
Oct-1991	23.23	21.31	0.0612	0.0235
Nov-1991	22.46	20.52	-0.0331	-0.0371
Dec-1991	19.5	19.59	-0.1318	-0.0453
Jan-1992	18.79	19.19	-0.0364	-0.0204
Feb-1992	19.01	19.15	0.0117	-0.0021
Mar-1992	18.92	19.38	-0.0047	0.0120
Apr-1992	20.23	20.32	0.0692	0.0485
May-1992	20.98	21.15	0.0371	0.0408
Jun-1992	22.39	20.68	0.0672	-0.0222
Jul-1992	21.78	20.63	-0.0272	-0.0024
Aug-1992	21.34	20.46	-0.0202	-0.0082
Sep-1992	21.88	20.72	0.0253	0.0127
Oct-1992	21.69	20.33	-0.0087	-0.0188
Nov-1992	20.34	19.76	-0.0622	-0.0280
Dec-1992	19.41	19.78	-0.0457	0.0010

2008 Financial Crisis
Table 7.1.4
3-Month Contracts

Month	Spot Price	3M Futures Price	R(St)	R(Ft)
Feb-2007	59.28	63.97		
Mar-2007	60.44	68.25	0.0196	0.0669
Apr-2007	63.98	68.1	0.0586	-0.0022
May-2007	63.46	65.83	-0.0081	-0.0333
Jun-2007	67.49	71.06	0.0635	0.0794
Jul-2007	74.12	76.82	0.0982	0.0811
Aug-2007	72.36	72.46	-0.0237	-0.0568
Sep-2007	79.92	79.58	0.1045	0.0983
Oct-2007	85.8	92.14	0.0736	0.1578
Nov-2007	94.77	87.84	0.1045	-0.0467
Dec-2007	91.69	95.24	-0.0325	0.0842
Jan-2008	92.97	91.52	0.0140	-0.0391
Feb-2008	95.39	100.97	0.0260	0.1033
Mar-2008	105.45	100.56	0.1055	-0.0041
Apr-2008	112.58	111.97	0.0676	0.1135
May-2008	125.4	127.42	0.1139	0.1380
Jun-2008	133.88	140.95	0.0676	0.1062
Jul-2008	133.37	124.95	-0.0038	-0.1135
Aug-2008	116.67	116.31	-0.1252	-0.0691
Sep-2008	104.11	100.51	-0.1077	-0.1358
Oct-2008	76.61	69.22	-0.2641	-0.3113
Nov-2008	57.31	57.09	-0.2519	-0.1752
Dec-2008	41.12	50.57	-0.2825	-0.1142
Jan-2009	41.71	48.52	0.0143	-0.0405
Feb-2009	39.09	48.05	-0.0628	-0.0097
Mar-2009	47.94	52.85	0.2264	0.0999
Apr-2009	49.65	53.4	0.0357	0.0104
May-2009	59.03	67.72	0.1889	0.2682
Jun-2009	69.64	71.6	0.1797	0.0573
Jul-2009	64.15	72.4	-0.0788	0.0112
Aug-2009	71.05	71.38	0.1076	-0.0141
Sep-2009	69.41	71.31	-0.0231	-0.0010
Oct-2009	75.72	78.27	0.0909	0.0976
Nov-2009	77.99	79.84	0.0300	0.0201
Dec-2009	74.47	80.63	-0.0451	0.0099
Jan-2010	78.33	73.95	0.0518	-0.0828
Feb-2010	76.39	80.37	-0.0248	0.0868
Mar-2010	81.2	84.57	0.0630	0.0523

Apr-2010	84.29	89.68	0.0381	0.0604
May-2010	73.74	76.12	-0.1252	-0.1512
Jun-2010	75.34	76.6	0.0217	0.0063
Jul-2010	76.32	79.95	0.0130	0.0437
Aug-2010	76.6	75.1	0.0037	-0.0607
Sep-2010	75.24	81.81	-0.0178	0.0893
Oct-2010	81.89	82.73	0.0884	0.0112
Nov-2010	84.25	85.08	0.0288	0.0284
Dec-2010	89.15	92.91	0.0582	0.0920

Table 7.1.5
6-Month Contracts

Month	Spot Price	6M Futures Price	R(St)	R(Ft)
Feb-2007	59.28	65.8		
Mar-2007	60.44	69.35	0.0196	0.0540
Apr-2007	63.98	69.74	0.0586	0.0056
May-2007	63.46	67.57	-0.0081	-0.0311
Jun-2007	67.49	71.63	0.0635	0.0601
Jul-2007	74.12	74.88	0.0982	0.0454
Aug-2007	72.36	71	-0.0237	-0.0518
Sep-2007	79.92	77.82	0.1045	0.0961
Oct-2007	85.8	89.56	0.0736	0.1509
Nov-2007	94.77	86.71	0.1045	-0.0318
Dec-2007	91.69	93.45	-0.0325	0.0777
Jan-2008	92.97	90.89	0.0140	-0.0274
Feb-2008	95.39	100.14	0.0260	0.1018
Mar-2008	105.45	99.21	0.1055	-0.0093
Apr-2008	112.58	110.24	0.0676	0.1112
May-2008	125.4	126.91	0.1139	0.1512
Jun-2008	133.88	141.56	0.0676	0.1154
Jul-2008	133.37	125.51	-0.0038	-0.1134
Aug-2008	116.67	117.13	-0.1252	-0.0668
Sep-2008	104.11	101.4	-0.1077	-0.1343
Oct-2008	76.61	71.18	-0.2641	-0.2980
Nov-2008	57.31	60.28	-0.2519	-0.1531
Dec-2008	41.12	54.31	-0.2825	-0.0990
Jan-2009	41.71	52.07	0.0143	-0.0412
Feb-2009	39.09	50.57	-0.0628	-0.0288
Mar-2009	47.94	55.85	0.2264	0.1044
Apr-2009	49.65	56.41	0.0357	0.0100
May-2009	59.03	69.2	0.1889	0.2267

Jun-2009	69.64	73.13	0.1797	0.0568
Jul-2009	64.15	74.73	-0.0788	0.0219
Aug-2009	71.05	73.18	0.1076	-0.0207
Sep-2009	69.41	72.79	-0.0231	-0.0053
Oct-2009	75.72	79.72	0.0909	0.0952
Nov-2009	77.99	82.24	0.0300	0.0316
Dec-2009	74.47	82.1	-0.0451	-0.0017
Jan-2010	78.33	75.58	0.0518	-0.0794
Feb-2010	76.39	81.29	-0.0248	0.0755
Mar-2010	81.2	85.19	0.0630	0.0480
Apr-2010	84.29	91.33	0.0381	0.0721
May-2010	73.74	78.24	-0.1252	-0.1433
Jun-2010	75.34	77.85	0.0217	-0.0050
Jul-2010	76.32	81.55	0.0130	0.0475
Aug-2010	76.6	77.68	0.0037	-0.0475
Sep-2010	75.24	83.69	-0.0178	0.0774
Oct-2010	81.89	83.99	0.0884	0.0036
Nov-2010	84.25	85.85	0.0288	0.0221
Dec-2010	89.15	94.06	0.0582	0.0956

Table 7.1.6
12-Month Contracts

Month	Spot Price	12M Futures Price	R(St)	R(Ft)
Feb-2007	59.28	67.53		
Mar-2007	60.44	69.99	0.0196	0.0364
Apr-2007	63.98	71.24	0.0586	0.0179
May-2007	63.46	69.37	-0.0081	-0.0262
Jun-2007	67.49	72.4	0.0635	0.0437
Jul-2007	74.12	73.4	0.0982	0.0138
Aug-2007	72.36	70.05	-0.0237	-0.0456
Sep-2007	79.92	75.54	0.1045	0.0784
Oct-2007	85.8	85.84	0.0736	0.1364
Nov-2007	94.77	84.94	0.1045	-0.0105
Dec-2007	91.69	90.54	-0.0325	0.0659
Jan-2008	92.97	89.79	0.0140	-0.0083
Feb-2008	95.39	98.89	0.0260	0.1013
Mar-2008	105.45	96.86	0.1055	-0.0205
Apr-2008	112.58	107.63	0.0676	0.1112
May-2008	125.4	125.7	0.1139	0.1679
Jun-2008	133.88	140.87	0.0676	0.1207
Jul-2008	133.37	124.87	-0.0038	-0.1136

Aug-2008	116.67	117.52	-0.1252	-0.0589
Sep-2008	104.11	103.08	-0.1077	-0.1229
Oct-2008	76.61	74.33	-0.2641	-0.2789
Nov-2008	57.31	65.42	-0.2519	-0.1199
Dec-2008	41.12	59.51	-0.2825	-0.0903
Jan-2009	41.71	55.89	0.0143	-0.0608
Feb-2009	39.09	54.19	-0.0628	-0.0304
Mar-2009	47.94	60.59	0.2264	0.1181
Apr-2009	49.65	61.07	0.0357	0.0079
May-2009	59.03	71.19	0.1889	0.1657
Jun-2009	69.64	75.14	0.1797	0.0555
Jul-2009	64.15	77.62	-0.0788	0.0330
Aug-2009	71.05	75.72	0.1076	-0.0245
Sep-2009	69.41	75.29	-0.0231	-0.0057
Oct-2009	75.72	81.86	0.0909	0.0873
Nov-2009	77.99	85.46	0.0300	0.0440
Dec-2009	74.47	84.44	-0.0451	-0.0119
Jan-2010	78.33	78.25	0.0518	-0.0733
Feb-2010	76.39	82.76	-0.0248	0.0576
Mar-2010	81.2	85.9	0.0630	0.0379
Apr-2010	84.29	92.73	0.0381	0.0795
May-2010	73.74	80.44	-0.1252	-0.1325
Jun-2010	75.34	79.63	0.0217	-0.0101
Jul-2010	76.32	83.81	0.0130	0.0525
Aug-2010	76.6	80.05	0.0037	-0.0449
Sep-2010	75.24	85.54	-0.0178	0.0686
Oct-2010	81.89	85.6	0.0884	0.0007
Nov-2010	84.25	86.97	0.0288	0.0160
Dec-2010	89.15	94.43	0.0582	0.0858

Table 7.1.7
2014 OPEC Price War
3-Month Contracts

Month	Spot Price	3M Futures Price	R(St)	R(Ft)
May-2013	94.51	92.3		
Jun-2013	95.77	95.81	0.0133	0.0380
Jul-2013	104.67	102.94	0.0929	0.0744
Aug-2013	106.57	105.71	0.0182	0.0269
Sep-2013	106.29	101.15	-0.0026	-0.0431
Oct-2013	100.54	96.66	-0.0541	-0.0444
Nov-2013	93.86	93.24	-0.0664	-0.0354

Dec-2013	97.63	98.44	0.0402	0.0558
Jan-2014	94.62	95.8	-0.0308	-0.0268
Feb-2014	100.82	100.95	0.0655	0.0538
Mar-2014	100.8	99.9	-0.0002	-0.0104
Apr-2014	102.07	98.28	0.0126	-0.0162
May-2014	102.18	101.03	0.0011	0.0280
Jun-2014	105.79	103.85	0.0353	0.0279
Jul-2014	103.59	96.73	-0.0208	-0.0686
Aug-2014	96.54	94.37	-0.0681	-0.0244
Sep-2014	93.21	89.76	-0.0345	-0.0489
Oct-2014	84.4	80.36	-0.0945	-0.1047
Nov-2014	75.79	66.41	-0.1020	-0.1736
Dec-2014	59.29	54.26	-0.2177	-0.1830
Jan-2015	47.22	50.07	-0.2036	-0.0772
Feb-2015	50.58	53.84	0.0712	0.0753
Mar-2015	47.82	50.78	-0.0546	-0.0568
Apr-2015	54.45	61.31	0.1386	0.2074
May-2015	59.27	60.79	0.0885	-0.0085
Jun-2015	59.82	60.1	0.0093	-0.0114
Jul-2015	50.9	48.21	-0.1491	-0.1978
Aug-2015	42.87	50.77	-0.1578	0.0531
Sep-2015	45.48	46.16	0.0609	-0.0908
Oct-2015	46.22	48.26	0.0163	0.0455
Nov-2015	42.44	43.93	-0.0818	-0.0897
Dec-2015	37.19	39.13	-0.1237	-0.1093
Jan-2016	31.68	36.78	-0.1482	-0.0601
Feb-2016	30.32	36.87	-0.0429	0.0024
Mar-2016	37.55	40.69	0.2385	0.1036
Apr-2016	40.75	47.14	0.0852	0.1585
May-2016	46.71	49.93	0.1463	0.0592
Jun-2016	48.76	49.59	0.0439	-0.0068
Jul-2016	44.65	43.09	-0.0843	-0.1311
Aug-2016	44.72	45.91	0.0016	0.0654
Sep-2016	45.18	49.4	0.0103	0.0760
Oct-2016	49.78	48.05	0.1018	-0.0273
Nov-2016	45.66	51.21	-0.0828	0.0658
Dec-2016	51.97	55.43	0.1382	0.0824
Jan-2017	52.5	53.94	0.0102	-0.0269
Feb-2017	53.47	54.75	0.0185	0.0150

Table 7.1.8
6-Month Contracts

Month	Spot Price	6M Futures Price	R(St)	R(Ft)
May-2013	94.51	91.28		
Jun-2013	95.77	93.64	0.0133	0.0259
Jul-2013	104.67	99.14	0.0929	0.0587
Aug-2013	106.57	101.34	0.0182	0.0222
Sep-2013	106.29	98.14	-0.0026	-0.0316
Oct-2013	100.54	95.61	-0.0541	-0.0258
Nov-2013	93.86	93.12	-0.0664	-0.0260
Dec-2013	97.63	96.45	0.0402	0.0358
Jan-2014	94.62	92.9	-0.0308	-0.0368
Feb-2014	100.82	97.91	0.0655	0.0539
Mar-2014	100.8	97.04	-0.0002	-0.0089
Apr-2014	102.07	95.67	0.0126	-0.0141
May-2014	102.18	98.05	0.0011	0.0249
Jun-2014	105.79	101.4	0.0353	0.0342
Jul-2014	103.59	95.35	-0.0208	-0.0597
Aug-2014	96.54	93.66	-0.0681	-0.0177
Sep-2014	93.21	88.68	-0.0345	-0.0532
Oct-2014	84.4	80.23	-0.0945	-0.0953
Nov-2014	75.79	67.1	-0.1020	-0.1637
Dec-2014	59.29	56.26	-0.2177	-0.1615
Jan-2015	47.22	53.44	-0.2036	-0.0501
Feb-2015	50.58	57.91	0.0712	0.0836
Mar-2015	47.82	53.45	-0.0546	-0.0770
Apr-2015	54.45	62.64	0.1386	0.1719
May-2015	59.27	61.51	0.0885	-0.0180
Jun-2015	59.82	61.08	0.0093	-0.0070
Jul-2015	50.9	50.28	-0.1491	-0.1768
Aug-2015	42.87	52.98	-0.1578	0.0537
Sep-2015	45.48	47.91	0.0609	-0.0957
Oct-2015	46.22	50	0.0163	0.0436
Nov-2015	42.44	46.05	-0.0818	-0.0790
Dec-2015	37.19	41.33	-0.1237	-0.1025
Jan-2016	31.68	39.75	-0.1482	-0.0382
Feb-2016	30.32	39.1	-0.0429	-0.0164
Mar-2016	37.55	42.33	0.2385	0.0826
Apr-2016	40.75	48.02	0.0852	0.1344
May-2016	46.71	50.86	0.1463	0.0591
Jun-2016	48.76	51.02	0.0439	0.0031

Jul-2016	44.65	45.06	-0.0843	-0.1168
Aug-2016	44.72	47.54	0.0016	0.0550
Sep-2016	45.18	50.81	0.0103	0.0688
Oct-2016	49.78	49.55	0.1018	-0.0248
Nov-2016	45.66	52.73	-0.0828	0.0642
Dec-2016	51.97	56.76	0.1382	0.0764
Jan-2017	52.5	54.9	0.0102	-0.0328
Feb-2017	53.47	55.25	0.0185	0.0064

Table 7.1.9
12-Month Contracts

Month	Spot Price	12M Futures Price	R(St)	R(Ft)
May-2013	94.51	89.17		
Jun-2013	95.77	90.26	0.0133	0.0122
Jul-2013	104.67	94.41	0.0929	0.0460
Aug-2013	106.57	95.39	0.0182	0.0104
Sep-2013	106.29	93.63	-0.0026	-0.0185
Oct-2013	100.54	92.23	-0.0541	-0.0150
Nov-2013	93.86	90.83	-0.0664	-0.0152
Dec-2013	97.63	91.94	0.0402	0.0122
Jan-2014	94.62	88.4	-0.0308	-0.0385
Feb-2014	100.82	92.34	0.0655	0.0446
Mar-2014	100.8	92.08	-0.0002	-0.0028
Apr-2014	102.07	91.52	0.0126	-0.0061
May-2014	102.18	93.53	0.0011	0.0220
Jun-2014	105.79	97.02	0.0353	0.0373
Jul-2014	103.59	92.88	-0.0208	-0.0427
Aug-2014	96.54	92.31	-0.0681	-0.0061
Sep-2014	93.21	87.16	-0.0345	-0.0558
Oct-2014	84.4	80.2	-0.0945	-0.0799
Nov-2014	75.79	68.22	-0.1020	-0.1494
Dec-2014	59.29	59.97	-0.2177	-0.1209
Jan-2015	47.22	58	-0.2036	-0.0328
Feb-2015	50.58	61.49	0.0712	0.0602
Mar-2015	47.82	56.92	-0.0546	-0.0743
Apr-2015	54.45	64	0.1386	0.1244
May-2015	59.27	62.6	0.0885	-0.0219
Jun-2015	59.82	61.99	0.0093	-0.0097
Jul-2015	50.9	53.16	-0.1491	-0.1424
Aug-2015	42.87	54.87	-0.1578	0.0322
Sep-2015	45.48	49.99	0.0609	-0.0889

Oct-2015	46.22	51.81	0.0163	0.0364
Nov-2015	42.44	48.54	-0.0818	-0.0631
Dec-2015	37.19	44.21	-0.1237	-0.0892
Jan-2016	31.68	42.51	-0.1482	-0.0385
Feb-2016	30.32	41.63	-0.0429	-0.0207
Mar-2016	37.55	44.09	0.2385	0.0591
Apr-2016	40.75	48.84	0.0852	0.1077
May-2016	46.71	51.54	0.1463	0.0553
Jun-2016	48.76	52.31	0.0439	0.0149
Jul-2016	44.65	47.01	-0.0843	-0.1013
Aug-2016	44.72	49.14	0.0016	0.0453
Sep-2016	45.18	52.18	0.0103	0.0619
Oct-2016	49.78	50.96	0.1018	-0.0234
Nov-2016	45.66	53.31	-0.0828	0.0461
Dec-2016	51.97	56.99	0.1382	0.0690
Jan-2017	52.5	55.42	0.0102	-0.0275
Feb-2017	53.47	55.17	0.0185	-0.0045

2020 COVID-19 Pandemic

Table 7.1.10
3-Month Contracts

Month	Spot Price	3M Futures Price	R(St)	R(Ft)
Aug-2018	68.06	46.08		
Sep-2018	70.23	51.23	0.0319	0.1118
Oct-2018	70.75	65.58	0.0074	0.2801
Nov-2018	56.96	51.23	-0.1949	-0.2188
Dec-2018	49.52	46.08	-0.1306	-0.1005
Jan-2019	51.38	54.31	0.0376	0.1786
Feb-2019	54.95	58.06	0.0695	0.0690
Mar-2019	58.15	60.4	0.0582	0.0403
Apr-2019	63.86	63.97	0.0982	0.0591
May-2019	60.83	53.73	-0.0474	-0.1601
Jun-2019	54.66	58.4	-0.1014	0.0869
Jul-2019	57.35	58.61	0.0492	0.0036
Aug-2019	54.81	54.56	-0.0443	-0.0691
Sep-2019	56.95	53.7	0.0390	-0.0158
Oct-2019	53.96	54.16	-0.0525	0.0086
Nov-2019	57.03	54.98	0.0569	0.0151
Dec-2019	59.88	60.41	0.0500	0.0988
Jan-2020	57.52	51.77	-0.0394	-0.1430

Feb-2020	50.54	45.1	-0.1213	-0.1288
Mar-2020	29.21	27.69	-0.4220	-0.3860
Apr-2020	16.55	24.37	-0.4334	-0.1199
May-2020	28.56	36.2	0.7257	0.4854
Jun-2020	38.31	39.48	0.3414	0.0906
Jul-2020	40.71	40.91	0.0626	0.0362
Aug-2020	42.34	43.21	0.0400	0.0562
Sep-2020	39.63	40.79	-0.0640	-0.0560
Oct-2020	39.4	36.57	-0.0058	-0.1035
Nov-2020	40.94	45.65	0.0391	0.2483
Dec-2020	47.02	48.69	0.1485	0.0666
Jan-2021	52	51.88	0.1059	0.0655
Feb-2021	59.04	60.74	0.1354	0.1708
Mar-2021	62.33	59.03	0.0557	-0.0282
Apr-2021	61.72	63.14	-0.0098	0.0696
May-2021	65.17	65.6	0.0559	0.0390
Jun-2021	71.38	71.76	0.0953	0.0939
Jul-2021	72.49	72.43	0.0156	0.0093
Aug-2021	67.73	67.94	-0.0657	-0.0620
Sep-2021	71.65	74.19	0.0579	0.0920
Oct-2021	81.48	79.98	0.1372	0.0780
Nov-2021	79.15	65.49	-0.0286	-0.1812
Dec-2021	71.71	74.45	-0.0940	0.1368
Jan-2022	83.22	85.11	0.1605	0.1432
Feb-2022	91.64	90.98	0.1012	0.0690
Mar-2022	108.5	96.88	0.1840	0.0648
Apr-2022	101.78	100.88	-0.0619	0.0413
May-2022	109.55	108.9	0.0763	0.0795
Jun-2022	114.84	100.88	0.0483	-0.0736

Table 7.1.11
6-Month Contracts

Month	Spot Price	6M Futures Price	R(St)	R(Ft)
Aug-2018	68.06	68.16		
Sep-2018	70.23	72.31	0.0319	0.0609
Oct-2018	70.75	65.99	0.0074	-0.0874
Nov-2018	56.96	51.6	-0.1949	-0.2181
Dec-2018	49.52	47.3	-0.1306	-0.0833
Jan-2019	51.38	55.04	0.0376	0.1636
Feb-2019	54.95	59.06	0.0695	0.0730
Mar-2019	58.15	60.47	0.0582	0.0239

Apr-2019	63.86	63.38	0.0982	0.0481
May-2019	60.83	53.55	-0.0474	-0.1551
Jun-2019	54.66	57.71	-0.1014	0.0777
Jul-2019	57.35	58.08	0.0492	0.0064
Aug-2019	54.81	53.43	-0.0443	-0.0801
Sep-2019	56.95	52.49	0.0390	-0.0176
Oct-2019	53.96	53.31	-0.0525	0.0156
Nov-2019	57.03	54.1	0.0569	0.0148
Dec-2019	59.88	58.87	0.0500	0.0882
Jan-2020	57.52	51.59	-0.0394	-0.1237
Feb-2020	50.54	45.46	-0.1213	-0.1188
Mar-2020	29.21	32.08	-0.4220	-0.2943
Apr-2020	16.55	28.72	-0.4334	-0.1047
May-2020	28.56	36.92	0.7257	0.2855
Jun-2020	38.31	39.78	0.3414	0.0775
Jul-2020	40.71	41.75	0.0626	0.0495
Aug-2020	42.34	44.06	0.0400	0.0553
Sep-2020	39.63	41.78	-0.0640	-0.0517
Oct-2020	39.4	37.76	-0.0058	-0.0962
Nov-2020	40.94	45.77	0.0391	0.2121
Dec-2020	47.02	48.52	0.1485	0.0601
Jan-2021	52	51	0.1059	0.0511
Feb-2021	59.04	58.81	0.1354	0.1531
Mar-2021	62.33	57.76	0.0557	-0.0179
Apr-2021	61.72	61.55	-0.0098	0.0656
May-2021	65.17	63.91	0.0559	0.0383
Jun-2021	71.38	69.43	0.0953	0.0864
Jul-2021	72.49	70.1	0.0156	0.0097
Aug-2021	67.73	66.82	-0.0657	-0.0468
Sep-2021	71.65	72.38	0.0579	0.0832
Oct-2021	81.48	76.27	0.1372	0.0537
Nov-2021	79.15	64.47	-0.0286	-0.1547
Dec-2021	71.71	72.78	-0.0940	0.1289
Jan-2022	83.22	81.66	0.1605	0.1220
Feb-2022	91.64	85.25	0.1012	0.0440
Mar-2022	108.5	91.82	0.1840	0.0771
Apr-2022	101.78	94.94	-0.0619	0.0340
May-2022	109.55	101.42	0.0763	0.0683
Jun-2022	114.84	93.67	0.0483	-0.0764

Table 7.1.12
12-Month Contracts

Month	Spot Price	12M Futures Price	R(St)	R(Ft)
Aug-2018	68.06	66.25		
Sep-2018	70.23	70.45	0.0319	0.0634
Oct-2018	70.75	65.64	0.0074	-0.0683
Nov-2018	56.96	51.89	-0.1949	-0.2095
Dec-2018	49.52	48.5	-0.1306	-0.0653
Jan-2019	51.38	54.71	0.0376	0.1280
Feb-2019	54.95	58.72	0.0695	0.0733
Mar-2019	58.15	59.32	0.0582	0.0102
Apr-2019	63.86	61.21	0.0982	0.0319
May-2019	60.83	52.58	-0.0474	-0.1410
Jun-2019	54.66	55.99	-0.1014	0.0649
Jul-2019	57.35	56.19	0.0492	0.0036
Aug-2019	54.81	51.78	-0.0443	-0.0785
Sep-2019	56.95	50.76	0.0390	-0.0197
Oct-2019	53.96	51.59	-0.0525	0.0164
Nov-2019	57.03	52.31	0.0569	0.0140
Dec-2019	59.88	56.03	0.0500	0.0711
Jan-2020	57.52	50.48	-0.0394	-0.0991
Feb-2020	50.54	46.17	-0.1213	-0.0854
Mar-2020	29.21	35.52	-0.4220	-0.2307
Apr-2020	16.55	32.61	-0.4334	-0.0819
May-2020	28.56	38.46	0.7257	0.1794
Jun-2020	38.31	30.36	0.3414	-0.2106
Jul-2020	40.71	42.9	0.0626	0.4130
Aug-2020	42.34	44.99	0.0400	0.0487
Sep-2020	39.63	42.92	-0.0640	-0.0460
Oct-2020	39.4	39.12	-0.0058	-0.0885
Nov-2020	40.94	45.32	0.0391	0.1585
Dec-2020	47.02	47.49	0.1485	0.0479
Jan-2021	52	49.19	0.1059	0.0358
Feb-2021	59.04	55.92	0.1354	0.1368
Mar-2021	62.33	55.31	0.0557	-0.0109
Apr-2021	61.72	58.85	-0.0098	0.0640
May-2021	65.17	61.22	0.0559	0.0403
Jun-2021	71.38	66.01	0.0953	0.0782
Jul-2021	72.49	66.65	0.0156	0.0097
Aug-2021	67.73	64.01	-0.0657	-0.0396
Sep-2021	71.65	68.71	0.0579	0.0734

Oct-2021	81.48	71.92	0.1372	0.0467
Nov-2021	79.15	62.5	-0.0286	-0.1310
Dec-2021	71.71	69.28	-0.0940	0.1085
Jan-2022	83.22	76.84	0.1605	0.1091
Feb-2022	91.64	79.74	0.1012	0.0377
Mar-2022	108.5	86.05	0.1840	0.0791
Apr-2022	101.78	86.83	-0.0619	0.0091
May-2022	109.55	92.23	0.0763	0.0622
Jun-2022	114.84	86.79	0.0483	-0.0590

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Table 7.1.13
3-Month Contracts

Month	Spot Price	3M Futures Price	R(St)	R(Ft)
May-2020	28.56	36.2		
Jun-2020	38.31	39.48	0.3414	0.0906
Jul-2020	40.71	40.91	0.0626	0.0362
Aug-2020	42.34	43.21	0.0400	0.0562
Sep-2020	39.63	40.79	-0.0640	-0.0560
Oct-2020	39.4	36.57	-0.0058	-0.1035
Nov-2020	40.94	45.65	0.0391	0.2483
Dec-2020	47.02	48.69	0.1485	0.0666
Jan-2021	52	51.88	0.1059	0.0655
Feb-2021	59.04	60.74	0.1354	0.1708
Mar-2021	62.33	59.03	0.0557	-0.0282
Apr-2021	61.72	63.14	-0.0098	0.0696
May-2021	65.17	65.6	0.0559	0.0390
Jun-2021	71.38	71.76	0.0953	0.0939
Jul-2021	72.49	72.43	0.0156	0.0093
Aug-2021	67.73	67.94	-0.0657	-0.0620
Sep-2021	71.65	74.19	0.0579	0.0920
Oct-2021	81.48	67.94	0.1372	-0.0842
Nov-2021	79.15	65.49	-0.0286	-0.0361
Dec-2021	71.71	74.45	-0.0940	0.1368
Jan-2022	83.22	85.11	0.1605	0.1432
Feb-2022	91.64	90.98	0.1012	0.0690
Mar-2022	108.5	96.88	0.1840	0.0648
Apr-2022	101.78	100.88	-0.0619	0.0413
May-2022	109.55	108.9	0.0763	0.0795
Jun-2022	114.84	100.27	0.0483	-0.0792

Jul-2022	101.62	95.3	-0.1151	-0.0496
Aug-2022	93.67	88.31	-0.0782	-0.0733
Sep-2022	84.26	77.75	-0.1005	-0.1196
Oct-2022	87.55	84.1	0.0390	0.0817
Nov-2022	84.37	80.75	-0.0363	-0.0398
Dec-2022	76.44	80.53	-0.0940	-0.0027
Jan-2023	78.12	79.38	0.0220	-0.0143
Feb-2023	76.83	77.14	-0.0165	-0.0282
Mar-2023	73.28	75.73	-0.0462	-0.0183
Apr-2023	79.45	76.24	0.0842	0.0067
May-2023	71.58	68.14	-0.0991	-0.1062
Jun-2023	70.25	70.72	-0.0186	0.0379
Jul-2023	76.07	80.84	0.0828	0.1431
Aug-2023	81.39	82.26	0.0699	0.0176
Sep-2023	89.43	86.98	0.0988	0.0574
Oct-2023	85.64	79.96	-0.0424	-0.0807
Nov-2023	77.69	75.99	-0.0928	-0.0496
Dec-2023	71.9	72.01	-0.0745	-0.0524
Jan-2024	74.15	75.56	0.0313	0.0493
Feb-2024	77.25	76.81	0.0418	0.0165
Mar-2024	81.28	81.67	0.0522	0.0633
Apr-2024	85.35	80.61	0.0501	-0.0130
May-2024	80.02	76.4	-0.0624	-0.0522

Table 7.1.14
6-Month Contracts

Month	Spot Price	6M Futures Price	R(St)	R(Ft)
May-2020	28.56	36.92		
Jun-2020	38.31	39.78	0.3414	0.0775
Jul-2020	40.71	41.75	0.0626	0.0495
Aug-2020	42.34	44.06	0.0400	0.0553
Sep-2020	39.63	41.78	-0.0640	-0.0517
Oct-2020	39.4	37.76	-0.0058	-0.0962
Nov-2020	40.94	45.77	0.0391	0.2121
Dec-2020	47.02	48.52	0.1485	0.0601
Jan-2021	52	51	0.1059	0.0511
Feb-2021	59.04	58.81	0.1354	0.1531
Mar-2021	62.33	57.76	0.0557	-0.0179
Apr-2021	61.72	61.55	-0.0098	0.0656
May-2021	65.17	63.91	0.0559	0.0383
Jun-2021	71.38	69.43	0.0953	0.0864

Jul-2021	72.49	70.1	0.0156	0.0097
Aug-2021	67.73	66.82	-0.0657	-0.0468
Sep-2021	71.65	72.38	0.0579	0.0832
Oct-2021	81.48	76.27	0.1372	0.0537
Nov-2021	79.15	64.47	-0.0286	-0.1547
Dec-2021	71.71	72.78	-0.0940	0.1289
Jan-2022	83.22	81.66	0.1605	0.1220
Feb-2022	91.64	85.25	0.1012	0.0440
Mar-2022	108.5	91.82	0.1840	0.0771
Apr-2022	101.78	94.94	-0.0619	0.0340
May-2022	109.55	101.42	0.0763	0.0683
Jun-2022	114.84	93.67	0.0483	-0.0764
Jul-2022	101.62	91.29	-0.1151	-0.0254
Aug-2022	93.67	85.84	-0.0782	-0.0597
Sep-2022	84.26	74.61	-0.1005	-0.1308
Oct-2022	87.55	80.83	0.0390	0.0834
Nov-2022	84.37	80.37	-0.0363	-0.0057
Dec-2022	76.44	79.83	-0.0940	-0.0067
Jan-2023	78.12	78.75	0.0220	-0.0135
Feb-2023	76.83	76.05	-0.0165	-0.0343
Mar-2023	73.28	74.51	-0.0462	-0.0202
Apr-2023	79.45	74.61	0.0842	0.0013
May-2023	71.58	67.34	-0.0991	-0.0974
Jun-2023	70.25	70.2	-0.0186	0.0425
Jul-2023	76.07	79.35	0.0828	0.1303
Aug-2023	81.39	80.35	0.0699	0.0126
Sep-2023	89.43	82.78	0.0988	0.0302
Oct-2023	85.64	78.47	-0.0424	-0.0521
Nov-2023	77.69	75.47	-0.0928	-0.0382
Dec-2023	71.9	71.97	-0.0745	-0.0464
Jan-2024	74.15	74.64	0.0313	0.0371
Feb-2024	77.25	74.86	0.0418	0.0029
Mar-2024	81.28	79.29	0.0522	0.0592
Apr-2024	85.35	78.57	0.0501	-0.0091
May-2024	80.02	75.17	-0.0624	-0.0433

Table 7.1.15
12-Month Contracts

Month	Spot Price	12M Futures Price	R(St)	R(Ft)
May-2020	28.56	38.46		
Jun-2020	38.31	30.36	0.3414	-0.2106

Jul-2020	40.71	42.9	0.0626	0.4130
Aug-2020	42.34	44.99	0.0400	0.0487
Sep-2020	39.63	42.92	-0.0640	-0.0460
Oct-2020	39.4	39.12	-0.0058	-0.0885
Nov-2020	40.94	45.32	0.0391	0.1585
Dec-2020	47.02	47.49	0.1485	0.0479
Jan-2021	52	49.19	0.1059	0.0358
Feb-2021	59.04	55.92	0.1354	0.1368
Mar-2021	62.33	55.31	0.0557	-0.0109
Apr-2021	61.72	58.85	-0.0098	0.0640
May-2021	65.17	61.22	0.0559	0.0403
Jun-2021	71.38	66.01	0.0953	0.0782
Jul-2021	72.49	66.65	0.0156	0.0097
Aug-2021	67.73	64.01	-0.0657	-0.0396
Sep-2021	71.65	68.71	0.0579	0.0734
Oct-2021	81.48	71.92	0.1372	0.0467
Nov-2021	79.15	62.5	-0.0286	-0.1310
Dec-2021	71.71	69.28	-0.0940	0.1085
Jan-2022	83.22	76.84	0.1605	0.1091
Feb-2022	91.64	79.74	0.1012	0.0377
Mar-2022	108.5	86.05	0.1840	0.0791
Apr-2022	101.78	86.83	-0.0619	0.0091
May-2022	109.55	92.23	0.0763	0.0622
Jun-2022	114.84	86.79	0.0483	-0.0590
Jul-2022	101.62	86.13	-0.1151	-0.0076
Aug-2022	93.67	81.47	-0.0782	-0.0541
Sep-2022	84.26	70.57	-0.1005	-0.1338
Oct-2022	87.55	76.9	0.0390	0.0897
Nov-2022	84.37	77.92	-0.0363	0.0133
Dec-2022	76.44	76.79	-0.0940	-0.0145
Jan-2023	78.12	75.66	0.0220	-0.0147
Feb-2023	76.83	73.22	-0.0165	-0.0322
Mar-2023	73.28	71.89	-0.0462	-0.0182
Apr-2023	79.45	72.15	0.0842	0.0036
May-2023	71.58	65.76	-0.0991	-0.0886
Jun-2023	70.25	68.73	-0.0186	0.0452
Jul-2023	76.07	76.48	0.0828	0.1128
Aug-2023	81.39	77.4	0.0699	0.0120
Sep-2023	89.43	78.73	0.0988	0.0172
Oct-2023	85.64	76.05	-0.0424	-0.0340
Nov-2023	77.69	73.32	-0.0928	-0.0359

Dec-2023	71.9	69.94	-0.0745	-0.0461
Jan-2024	74.15	72.03	0.0313	0.0299
Feb-2024	77.25	71.74	0.0418	-0.0040
Mar-2024	81.28	75.53	0.0522	0.0528
Apr-2024	85.35	75.29	0.0501	-0.0032
May-2024	80.02	73.12	-0.0624	-0.0288

7.2. Futures Profit/Loss

This section presents the profitability of holding short futures positions across 3-month, 6-month, and 12-month contracts during each of the examined oil price shocks. The tables show the cumulative profit or loss over the life of each contract, based on futures price movements.

Table 7.2.1
1990 Gulf War

	3-Month		6-Month		12-Month	
Month	**Dynamic**	**Static**	**Dynamic**	**Static**	**Dynamic**	**Static**
Jun-1990	19440	12150				
Sep-1990	-147920	-92450	-97920	-61200		
Dec-1990	80320	50200				
Mar-1991	58720	36700	109680	68550	9590	6850
Jun-1991	-9200	-5750				
Sep-1991	-11680	-7300	-16720	-10450		
Dec-1991	22320	13950				
Mar-1992	-3520	-2200	14480	9050	-400	-250

Table 7.2.2
2008 Financial Crisis

	3-Month		6-Month		12-Month	
Month	**Dynamic**	**Static**	**Dynamic**	**Static**	**Dynamic**	**Static**
Sep-2008	161760	202200				
Dec-2008	249700	249700	436250	436250		
Mar-2009	-18240	-11400				
Jun-2009	-150000	-93750	-150560	-94100	328650	328650
Sep-2009	2320	1450				
Dec-2009	-74560	-46600	-71760	-44850		
Mar-2010	-31520	-19700				
Jun-2010	63760	39850	34000	21250	-35920	-22450

Table 7.2.3
2014 OPEC Price War

	3-Month		6-Month		12-Month	
Month	**Dynamic**	**Static**	**Dynamic**	**Static**	**Dynamic**	**Static**
Dec-2014	284000	177500				
Mar-2015	27840	17400	281840	176150		
Jun-2015	-74560	-46600				
Sep-2015	111520	69700	44320	27700	297360	185850
Dec-2015	49210	35150				
Mar-2016	-12480	-7800	44640	27900		
Jun-2016	-71200	-44500				
Sep-2016	1520	950	-67840	-42400	-17520	-10950

Table 7.2.4
2020 COVID-19 Pandemic

	3-Month		6-Month		12-Month	
Month	**Dynamic**	**Static**	**Dynamic**	**Static**	**Dynamic**	**Static**
Mar-2020	130880	163600				
Jun-2020	-82530	-58950	114540	95450		
Sep-2020	-10480	-6550				
Dec-2020	-63200	-39500	-69920	-43700	59780	42700
Mar-2021	-82720	-51700				
Jun-2021	-101840	-63650	-167280	-104550		
Sep-2021	-19440	-12150				
Dec-2021	-2080	-1300	-26800	-16750	-152530	-108950

Table 7.2.5
2022 Russian Invasion of Ukraine

	3-Month		6-Month		12-Month	
Month	**Dynamic**	**Static**	**Dynamic**	**Static**	**Dynamic**	**Static**
Dec-2021	-1300	-1300				
Mar-2022	-67290	-112150	-116640	-97200		
Jun-2022	-16950	-16950				
Sep-2022	112600	112600	103260	86050	-3720	-9300
Dec-2022	-16680	-13900				
Mar-2023	28800	24000	600	500		
Jun-2023	30060	25050				
Sep-2023	-97560	-81300	-49620	-41350	-16320	-40800

7.3. Portfolio Evaluation: Hedged vs. Unhedged

This section evaluates the effectiveness of futures-based hedging by comparing the cumulative returns of unhedged portfolios against those partially hedged using short futures contracts of varying maturities. Using a fixed 10,000-barrel spot inventory assumption, the unhedged portfolio value is calculated from monthly spot prices. These values are combined with the futures profit/loss results from section 7.2 to assess the degree to which each contract length offsets losses during price shocks. Strategies are analyzed across common time windows, 3-month, 6-month, and 12-month periods, allowing for a direct comparison of different contract lengths within consistent hedging horizons.

1990 Gulf War
Table 7.3.1
3-Month Window

		3-Month Contracts	
Month	**Crude Oil Exposure**	**Dynamic**	**Static**
Jun-1990	167000	186440	179150
Sep-1990	335100	187180	242650
Dec-1990	272800	353120	323000
Mar-1991	199000	257720	235700
Jun-1991	201900	192700	196150
Sep-1991	218900	207220	211600
Dec-1991	195000	217320	208950
Mar-1992	189200	185680	187000

Table 7.3.2
6-Month Window

		3-Month Contracts		6-Month Contracts	
Month	**Crude Oil Exposure**	**Dynamic**	**Static**	**Dynamic**	**Static**
Sep-1990	335100	206620	254800	237180	273900
Mar-1991	199000	338040	285900	308680	267550
Sep-1991	218900	198020	205850	202180	208450
Mar-1992	189200	208000	200950	203680	198250

Table 7.3.3
12-Month Window

		3-Month Contracts		6-Month Contracts		12-Month Contracts	
Month	**Crude Oil Exposure**	**Dynamic**	**Static**	**Dynamic**	**Static**	**Dynamic**	**Static**
Mar-1991	199000	209560	205600	210760	206350	208590	205850
Mar-1992	189200	187120	187900	186960	187800	188800	188950

2008 Financial Crisis
Table 7.3.4
3-Month Window

		3-Month Contracts	
Month	Crude Oil Exposure	Dynamic	Static
Sep-2008	1041100	1202860	1243300
Dec-2008	411200	660900	660900
Mar-2009	479400	461160	468000
Jun-2009	696400	546400	602650
Sep-2009	694100	696420	695550
Dec-2009	744700	670140	698100
Mar-2010	812000	780480	792300
Jun-2010	753400	817160	793250

Table 7.3.5
6-Month Window

		3-Month Contracts		6-Month Contracts	
Month	Crude Oil Exposure	Dynamic	Static	Dynamic	Static
Dec-2008	411200	822660	863100	847450	847450
Jun-2009	696400	528160	591250	545840	602300
Dec-2009	744700	672460	699550	672940	699850
Jun-2010	753400	785640	773550	787400	774650

Table 7.3.6
12-Month Window

		3-Month Contracts		6-Month Contracts		12-Month Contracts	
Month	Crude Oil Exposure	Dynamic	Static	Dynamic	Static	Dynamic	Static
Jun-2009	696400	939620	1043150	982090	1038550	1025050	1025050
Jun-2010	753400	713400	728400	715640	729800	717480	730950

2014 OPEC Price War
Table 7.3.7
3-Month Window

		3-Month Contracts	
Month	Crude Oil Exposure	Dynamic	Static
Dec-2014	592900	876900	770400
Mar-2015	478200	506040	495600
Jun-2015	598200	523640	551600
Sep-2015	454800	566320	524500
Dec-2015	371900	421110	407050
Mar-2016	375500	363020	367700

Jun-2016	487600	416400	443100
Sep-2016	451800	453320	452750

Table 7.3.8
6-Month Window

		3-Month Contracts		6-Month Contracts	
Month	**Crude Oil Exposure**	**Dynamic**	**Static**	**Dynamic**	**Static**
Mar-2015	478200	790040	673100	760040	654350
Sep-2015	454800	491760	477900	499120	482500
Mar-2016	375500	412230	402850	420140	403400
Sep-2016	451800	382120	408250	383960	409400

Table 7.3.9
12-Month Window

		3-Month Contracts		6-Month Contracts		12-Month Contracts	
Month	**Crude Oil Exposure**	**Dynamic**	**Static**	**Dynamic**	**Static**	**Dynamic**	**Static**
Sep-2015	454800	803600	672800	780960	658650	752160	640650
Sep-2016	451800	418850	435600	428600	437300	434280	440850

2020 COVID-19 Pandemic
Table 7.3.10
3-Month Window

		3-Month Contracts	
Month	**Crude Oil Exposure**	**Dynamic**	**Static**
Mar-2020	292100	422980	455700
Jun-2020	383100	300570	324150
Sep-2020	396300	385820	389750
Dec-2020	470200	407000	430700
Mar-2021	623300	540580	571600
Jun-2021	713800	611960	650150
Sep-2021	716500	697060	704350
Dec-2021	717100	715020	715800

Table 7.3.11
6-Month Window

		3-Month Contracts		6-Month Contracts	
Month	**Crude Oil Exposure**	**Dynamic**	**Static**	**Dynamic**	**Static**
Jun-2020	383100	431450	487750	497640	478550
Dec-2020	470200	396520	424150	400280	426500
Jun-2021	713800	529240	598450	546520	609250
Dec-2021	717100	695580	703650	690300	700350

Table 7.3.12
12-Month Window

		3-Month Contracts		6-Month Contracts		12-Month Contracts	
Month	**Crude Oil Exposure**	**Dynamic**	**Static**	**Dynamic**	**Static**	**Dynamic**	**Static**
Dec-2020	470200	444870	528800	514820	521950	529980	512900
Dec-2021	717100	588300	588300	523020	595800	564570	608150

2022 Russian Invasion of Ukraine
Table 7.3.13
3-Month Window

		3-Month Contracts	
Month	**Crude Oil Exposure**	**Dynamic**	**Static**
Dec-2021	717100	715800	715800
Mar-2022	1085000	1017710	972850
Jun-2022	1148400	1131450	1131450
Sep-2022	842600	955200	955200
Dec-2022	764400	747720	750500
Mar-2023	732800	761600	756800
Jun-2023	702500	732560	727550
Sep-2023	894300	796740	813000

Table 7.3.14
6-Month Window

		3-Month Contracts		6-Month Contracts	
Month	**Crude Oil Exposure**	**Dynamic**	**Static**	**Dynamic**	**Static**
Mar-2022	1085000	1016410	971550	968360	987800
Sep-2022	842600	938250	938250	945860	928650
Mar-2023	732800	744920	742900	733400	733300
Sep-2023	894300	826800	838050	844680	852950

Table 7.3.15
12-Month Window

		3-Month Contracts		6-Month Contracts		12-Month Contracts	
Month	**Crude Oil Exposure**	**Dynamic**	**Static**	**Dynamic**	**Static**	**Dynamic**	**Static**
Sep-2022	842600	869660	824800	829220	831450	838880	833300
Sep-2023	894300	848150	848150	845280	853450	877980	853500

7.4. Net Margin Profit/Loss

This section presents the net cash profit or loss from each hedging strategy using a margin-account framework, reflecting the actual capital impact of futures positions. Results account for initial margin deposits, margin calls, and final settlement balances. Strategies are evaluated across consistent 3-month, 6-month, and 12-month windows, allowing direct comparison of different contract lengths under each price shock.

1990 Gulf War
Table 7.4.1
3-Month Window

	3-Month Contracts	
Month	**Dynamic**	**Static**
Jun-1990	19440	12150
Sep-1990	-147920	-92450
Dec-1990	80320	50200
Mar-1991	58720	36700
Jun-1991	-9200	-5750
Sep-1991	-11680	-7300
Dec-1991	22320	13950
Mar-1992	-3520	-2200

Table 7.4.2
6-Month Window

	3-Month Contracts		6-Month Contracts	
Month	**Dynamic**	**Static**	**Dynamic**	**Static**
Sep-1990	-128480	-80300	-97920	-61200
Mar-1991	139040	86900	109680	68550
Sep-1991	-20880	-13050	-16720	-10450
Mar-1992	18800	11750	14480	9050

Table 7.4.3
12-Month Window

	3-Month Contracts		6-Month Contracts		12-Month Window	
Month	**Dynamic**	**Static**	**Dynamic**	**Static**	**Dynamic**	**Static**
Mar-1991	10560	6600	11760	7350	9590	6850
Mar-1992	-2080	-1300	-2240	-1400	-400	-250

2008 Financial Crisis
Table 7.4.4
3-Month Window

	3-Month Contracts	
Month	**Dynamic**	**Static**
Sep-2008	161760	202200
Dec-2008	249700	249700
Mar-2009	-18240	-11400
Jun-2009	-150000	-93750
Sep-2009	2320	1450
Dec-2009	-74560	-46600
Mar-2010	-31520	-19700
Jun-2010	63760	39850

Table 7.4.5
6-Month Window

	3-Month Contracts		6-Month Contracts	
Month	**Dynamic**	**Static**	**Dynamic**	**Static**
Dec-2008	411460	451900	436250	436250
Jun-2009	-168240	-105150	-150560	-94100
Dec-2009	-72240	-45150	-71760	-44850
Jun-2010	32240	20150	34000	21250

Table 7.4.6
12-Month Window

	3-Month Contracts		6-Month Contracts		12-Month Window	
Month	**Dynamic**	**Static**	**Dynamic**	**Static**	**Dynamic**	**Static**
Jun-2009	243220	346750	285690	342150	328650	328650
Jun-2010	-40000	-25000	-37760	-23600	-35920	-22450

2014 OPEC Price War
Table 7.4.7
3-Month Window

	3-Month Contracts	
Month	**Dynamic**	**Static**
Dec-2014	284000	177500
Mar-2015	27840	17400
Jun-2015	-74560	-46600
Sep-2015	111520	69700
Dec-2015	49210	35150
Mar-2016	-12480	-7800

Jun-2016	-71200	-44500
Sep-2016	1520	950

Table 7.4.8
6-Month Window

	3-Month Contracts		6-Month Contracts	
Month	**Dynamic**	**Static**	**Dynamic**	**Static**
Mar-2015	311840	194900	281840	176150
Sep-2015	36960	23100	44320	27700
Mar-2016	36730	27350	44640	27900
Sep-2016	-69680	-43550	-67840	-42400

Table 7.4.9
12-Month Window

	3-Month Contracts		6-Month Contracts		12-Month Window	
Month	**Dynamic**	**Static**	**Dynamic**	**Static**	**Dynamic**	**Static**
Sep-2015	348800	218000	326160	203850	297360	185850
Sep-2016	-32950	-16200	-23200	-14500	-17520	-10950

2020 COVID-19 Pandemic
Table 7.4.10
3-Month Window

	3-Month Contracts	
Month	**Dynamic**	**Static**
Mar-2020	130880	163600
Jun-2020	-82530	-58950
Sep-2020	-10480	-6550
Dec-2020	-63200	-39500
Mar-2021	-82720	-51700
Jun-2021	-101840	-63650
Sep-2021	-19440	-12150
Dec-2021	-2080	-1300

Table 7.4.11
6-Month Window

	3-Month Contracts		6-Month Contracts	
Month	**Dynamic**	**Static**	**Dynamic**	**Static**
Jun-2020	48350	104650	114540	95450
Dec-2020	-73680	-46050	-69920	-43700
Jun-2021	-184560	-115350	-167280	-104550

Dec-2021	-21520	-13450	-26800	-16750

Table 7.4.12
12-Month Window

	3-Month Contracts		6-Month Contracts		12-Month Window	
Month	**Dynamic**	**Static**	**Dynamic**	**Static**	**Dynamic**	**Static**
Dec-2020	-25330	58600	44620	51750	59780	42700
Dec-2021	-206080	-128800	-194080	-121300	-152530	-108950

2022 Russian Invasion of Ukraine
Table 7.4.13
3-Month Window

	3-Month Contracts	
Month	**Dynamic**	**Static**
Dec-2021	-1300	-1300
Mar-2022	-58774	-97956
Jun-2022	14275	14275
Sep-2022	112600	112600
Dec-2022	-16680	-13900
Mar-2023	28800	24000
Jun-2023	30060	25050
Sep-2023	-97560	-81300

Table 7.4.14
6-Month Window

	3-Month Contracts		6-Month Contracts	
Month	**Dynamic**	**Static**	**Dynamic**	**Static**
Mar-2022	-60074	-99256	-116640	-97200
Sep-2022	126875	126875	103260	86050
Mar-2023	12120	10100	600	500
Sep-2023	-67500	-56250	-49620	-41350

Table 7.4.15
12-Month Window

	3-Month Contracts		6-Month Contracts		12-Month Window	
Month	**Dynamic**	**Static**	**Dynamic**	**Static**	**Dynamic**	**Static**
Sep-2022	66801.3	27618.8	-13380	-11150	-3720	-9300
Sep-2023	-55380	-46150	-49020	-40850	-16320	-40800

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