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A MASTER THESIS ON

EXPLORING COMMON CHARACTERISTICS IN THE FLUCTUATIONS OF THE ECONOMIC UNCERTAINTY INDEX, GOLD AND OIL PRICES

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Abstract

The crude oil market plays a crucial role in the global economy because it is closely linked to economic growth, geopolitical events, and financial market dynamics. Oil prices are influenced by several macroeconomic factors, including global GDP growth, industrial production, and consumer demand. When the global economy expands, oil demand typically increases, which leads to higher prices. In contrast, economic recessions reduce energy consumption and cause oil prices to fall. Geopolitical tensions in oil-producing regions can also trigger sharp price fluctuations due to concerns about supply disruptions. Additionally, monetary policy and exchange rates affect oil markets, since oil is traded internationally in U.S. dollars. A strong dollar generally puts downward pressure on oil prices by making it more expensive for other countries to purchase oil. Furthermore, economic policy uncertainty can significantly impact oil markets by reducing investment and future demand expectations. As a result, oil prices often reflect both real economic activity and financial market sentiment.

Keywords:
Oil prices, global economy, supply and demand, geopolitical risk, economic policy uncertainty, energy markets, crude oil, financial markets, exchange rates, global demand.

Περίληψη

Η αγορά αργού πετρελαίου διαδραματίζει κρίσιμο ρόλο στην παγκόσμια οικονομία, επειδή συνδέεται στενά με την οικονομική ανάπτυξη, τα γεωπολιτικά γεγονότα και τη δυναμική των χρηματοπιστωτικών αγορών. Οι τιμές του πετρελαίου επηρεάζονται από διάφορους μακροοικονομικούς παράγοντες, συμπεριλαμβανομένης της αύξησης του παγκόσμιου ΑΕΠ, της βιομηχανικής παραγωγής και της καταναλωτικής ζήτησης. Όταν η παγκόσμια οικονομία επεκτείνεται, η ζήτηση πετρελαίου συνήθως αυξάνεται, γεγονός που οδηγεί σε υψηλότερες τιμές. Αντίθετα, οι οικονομικές υφέσεις μειώνουν την κατανάλωση ενέργειας και προκαλούν πτώση των τιμών του πετρελαίου. Οι γεωπολιτικές εντάσεις στις περιοχές παραγωγής πετρελαίου μπορούν επίσης να προκαλέσουν έντονες διακυμάνσεις των τιμών λόγω ανησυχιών για διαταραχές του εφοδιασμού. Επιπλέον, η νομισματική πολιτική και οι συναλλαγματικές ισοτιμίες επηρεάζουν τις αγορές πετρελαίου, καθώς το πετρέλαιο διαπραγματεύεται διεθνώς σε δολάρια ΗΠΑ. Ένα ισχυρό δολάριο ασκεί γενικά καθοδική πίεση στις τιμές του πετρελαίου, καθιστώντας την αγορά πετρελαίου πιο ακριβή για άλλες χώρες. Επιπλέον, η αβεβαιότητα της οικονομικής πολιτικής μπορεί να επηρεάσει σημαντικά τις αγορές πετρελαίου, μειώνοντας τις προσδοκίες για τις επενδύσεις και τη μελλοντική ζήτηση. Ως αποτέλεσμα, οι τιμές του πετρελαίου συχνά αντανακλούν τόσο την πραγματική οικονομική δραστηριότητα όσο και το κλίμα στις χρηματοπιστωτικές αγορές.

Λέξεις-κλειδιά:

Τιμές πετρελαίου, παγκόσμια οικονομία, προσφορά και ζήτηση, γεωπολιτικός κίνδυνος, αβεβαιότητα οικονομικής πολιτικής, αγορές ενέργειας, αργό πετρέλαιο, χρηματοπιστωτικές αγορές, συναλλαγματικές ισοτιμίες, παγκόσμια ζήτηση.

Table of contents

1. Introduction

1.1 Background and motivation

Economic policy uncertainty (EPU) has become a significant element affecting the world's financial and commodity markets in recent years. Investor sentiment, corporate investment, and asset prices are all impacted by EPU, which is defined as the uncertainty surrounding governmental economic decisions (Baker et al., 2016). Its impact is especially noticeable at times of economic hardship, geopolitical unrest, and significant policy changes, like the COVID-19 pandemic, Brexit, or the Global Financial Crisis. Market players modify their tactics in these situations to account for increased risks and volatility.

Global commodities that are particularly vulnerable to policy-related uncertainties include gold and crude oil. Oil prices are frequently volatile due to shifts in anticipated demand or interruptions in supply, reflecting broader macroeconomic conditions and geopolitical events (Hamilton, 2009; Kilian, 2008). On the other hand, gold is frequently seen as a safe-haven investment that attracts attention from investors during uncertain times (Baur and Lucey, 2010). Thus, the relationship between EPU and commodity prices offers an interesting area for research.

In order to capture co-movements and lead-lag dynamics across various investment horizons, sophisticated time-frequency analytical tools like wavelet analysis have been adopted due to the increasing complexity of financial markets (Gencay et al., 2002; Torrence and Webster, 1999). Building on the work of Albrecht et al. (2022), who investigated the impact of EPU on stock markets, this thesis turns its attention to commodities with the goal of determining if oil and gold prices exhibit comparable frequency-dependent connections and bidirectional causality. In a time of increasing global uncertainty, an understanding of these dynamics is crucial for risk management, portfolio diversification, and policymaking.

1.2 Importance of Economic Policy Uncertainty (EPU)

The importance of Economic Policy Uncertainty (EPU) in determining both financial market stability and global macroeconomic performance is becoming more widely acknowledged. Economic behavior among families, businesses, and investors is directly impacted by EPU, which is defined as the uncertainty around future government actions concerning fiscal, monetary, trade, or regulatory policies (Baker et al., 2016). Economic slowdowns are exacerbated by agents delaying investment, cutting back on consumption, and moving toward safer assets during times of increased uncertainty, such as wars, financial crises, or political upheavals (Giavazzi and McMahon, 2012; Tran, 2019).

Changes in EPU have a special effect on the financial markets. Market volatility and asset repricing are exacerbated by investors' demands for higher risk premiums in response to unpredictable policy situations (Pastor and Veronesi, 2013). According to empirical research, growing EPU is associated with higher loan spreads, lower capital spending, and decreased stock market returns (Brogaard and Detzel, 2015; Baker et al., 2016). Because the impact of EPU is not consistent across asset classes and investment horizons, time-frequency methods like wavelet analysis are necessary to understand these dynamics.

Crucially, commodities like gold and oil react differently to EPU. Expectations regarding future economic activity, supply interruptions, and geopolitical risk all have an impact on oil prices and are linked to policy choices (Kilian, 2008; Hamilton, 2009). On the other hand, gold's reputation as a safe-haven asset is strengthened by the fact that it is frequently seen as a hedge against uncertainty and tends to draw investor demand during tumultuous periods (Baur and Lucey, 2010). Therefore, risk management, portfolio diversification, and economic forecasting all depend on an understanding of the relationship between EPU and these commodities.

Furthermore, given how globalized today's markets are, EPU in one area, particularly from powerful economies like the US, may have cross-border repercussions that impact global financial stability and commodity prices (Albulescu et al., 2019). As a result, EPU is essential to comprehending modern market behavior rather than just a background variable.

1.3 Oil and gold as key global commodities

Two of the most strategically important and actively traded commodities in the world economy are gold and oil. Their significance is derived from their involvement in financial markets, macroeconomic stability, and geopolitical affairs in addition to their economic usefulness. Each has distinct traits and sensitivity to outside shocks, especially when economic policy uncertainty (EPU) is high.

The foundation of international transportation, energy production, and industrial activity is crude oil. Numerous factors, such as OPEC production decisions, geopolitical tensions, supply-demand fundamentals, and general macroeconomic trends, affect its price (Kilian, 2008; Hamilton, 2009). Oil is susceptible to both short-term shocks and long-term strategic changes since it cannot be produced or stored instantly and for free, unlike financial assets. Crucially, oil is extremely sensitive to EPU, particularly when policy changes impact expectations for economic growth, international commerce, or energy regulation (Albulescu, 2019). Price stability can be seriously upset, for instance, by fiscal stimulus or sanctions on countries that produce oil.

In contrast, gold has very little industrial application but is extremely valuable as a store of wealth and a monetary asset. It has long been seen as a safe haven in times of crisis, maintaining value when other assets lose value. Gold demand usually increases when there is financial instability, rising inflation, or geopolitical war because investors want to reduce risk (Baur and Lucey, 2010). Its price fluctuations frequently have an inverse relationship with trust in equity markets or fiat currencies. Furthermore, the price dynamics of gold are mostly driven by demand and are less vulnerable to supply chain interruptions.

Oil and gold are especially well-suited for comparative examination in the context of EPU because of their contrasting characteristics cyclical versus countercyclical, consumption-driven versus sentiment-driven. Gold reflects investor psychology and risk aversion, whereas oil often reflects how the real economy reacts to policy shocks. Economic forecasting, portfolio hedging, and asset allocation techniques all benefit from an understanding of how each responds to policy uncertainty.

Additionally, both commodities are essential to sovereign wealth fund allocations and central bank plans. Their success under various policy regimes can act as leading indicators of more general economic trends and reveal underlying changes in market expectations. Oil and gold continue to be crucial indicators of economic sentiment and global financial stability in a world characterized by frequent policy changes, pandemics, and geopolitical turmoil.

1.4 Research questions

Investigating how Economic Policy Uncertainty (EPU) affects the price dynamics of two essential global commodities specifically oil and gold across various investment horizons is the main goal of this thesis. This study investigates whether comparable frequency-dependent, bidirectional co-movements occur in commodities markets under circumstances of policy-induced uncertainty, building on recent developments in time-frequency analysis and the important work of Albrecht et al. (2022) on stock markets.

The following important research questions are developed in order to accomplish this goal:

1. What role does economic policy play? Does uncertainty impact the behavior of gold and crude oil prices?

In order to determine whether uncertainty causes price rises, declines, or increased volatility, this question aims to comprehend the overall direction and size of EPU's impact on the two commodities.

2. Do short-term and long-term investment horizons differ in how EPU affects gold and oil?

This inquiry examines whether the EPU commodity price relationship is frequency-dependent using wavelet-based techniques, exposing differences between short-term responses (like news shocks or speculation) and long-term trends (like changes in the policy regime).

3. Is there proof of a lead-lag or bidirectional causal relationship between EPU and changes in the prices of gold and oil?

In order to ascertain whether EPU drives changes in commodity prices, whether commodities can predict policy uncertainty, or whether the interaction is bidirectional, this question looks at the temporal dynamics of the relationship.

4. How is the relationship between EPU and commodity prices impacted by significant world events such as financial crises, geopolitical conflicts, and pandemics?

In order to provide insights into how these assets behave under systemic stress, this contextual question assesses whether particular historical shocks intensify or change the typical behavior of the EPU oil/gold connection.

These inquiries inform the study's empirical approach, which uses Granger causality tests and time-frequency wavelet techniques to identify subtle, time-varying patterns in the EPU commodity relationship. By providing answers, the thesis hopes to advance scholarly discussion as well as real-world applications in risk management, investment strategy, and the creation of economic policies.

1.5 Structure of the thesis

The six chapters that make up this thesis are all intended to gradually develop a thorough grasp of the connection between the dynamics of oil and gold prices and Economic Policy Uncertainty (EPU). The theoretical foundations and empirical technique used to address the research topics in the preceding section are both reflected in the structure.

- Chapter 1: Overview

This chapter explains the study's history and purpose, explains the significance of EPU, and defends the emphasis on gold and oil as important global commodities. It also outlines the main research questions and offers a thesis structure roadmap.

• Chapter 2: Review of Relevant Literature

This section reviews the body of knowledge regarding the effects of EPU on commodity and financial markets. It talks about the use of wavelet-based time-frequency analysis in capturing dynamic co-movements and emphasizes the known correlations between EPU, oil, and gold prices. The research gaps that this thesis seeks to fill are identified in the chapter's conclusion.

• Chapter 3: Data and Approach

The data sources, variables, and statistical transformations employed in the analysis are described in depth in this chapter. In order to comprehend frequency-dependent and time-varying relationships, it also explains the fundamental methodological framework, which includes the Continuous Wavelet Transform (CWT), Wavelet Coherence, Discrete Wavelet Transform (DWT), and Vector Autoregression (VAR) with Granger causality tests.

• Chapter 4: Empirical Results

The study's main conclusions are presented in this section. Through causality testing, it evaluates lead-lag correlations, separates short and long-term frequency behaviors, and investigates time-varying co-movements between EPU and oil/gold prices. Additionally, it places the findings in the perspective of significant world events like the COVID-19 pandemic, Brexit, and the 2008 financial crisis.

• Chapter 5: Discussion

This chapter discusses the significance of the empirical findings for scholars, policymakers, and market participants after interpreting them in the context of the body of current literature. Additionally, it assesses EPU's applicability to macroeconomic forecasts and investment strategies.

- Chapter 6: Conclusions

The thesis's main contributions are outlined in the concluding chapter, which also notes the thesis's shortcomings and suggests further lines of inquiry into commodities markets and uncertainty.

2. Literature Review

2.1 Economic Policy Uncertainty and financial markets

The concept of Economic Policy Uncertainty (EPU) has gained prominence in the field of financial economics, particularly since the global financial crisis of 2008 revealed how susceptible markets are to shocks brought on by policy. EPU introduces an element of ambiguity that greatly influences investor expectations and behavior. It is defined as the lack of certainty regarding future government actions affecting fiscal, monetary, regulatory, or trade-related choices. Baker et al. (2016) claim that EPU lowers consumption, hires fewer people, delays investments, and affects firm-level decision-making. Additionally, it makes market participants more risk averse, which raises volatility, widens credit spreads, and devalues stocks. Both behavioral biases like ambiguity aversion, in which agents overreact to perceived threats because they lack knowledge, and rational reactions to policy uncertainty are reflected in these dynamics.

Strong correlations between EPU and financial market performance have been found empirically in developed economies, particularly the US. Baker et al. (2016) constructed the widely used EPU index by tracking the frequency of terms related to uncertainty in major newspapers. They discovered that lower equity prices, less firm investment, and less hiring activity are all correlated with higher EPU levels. Building on this foundation, Pastor and Veronesi (2013) argued that political uncertainty raises risk premia as investors demand compensation for bearing additional ambiguity regarding future policy. This is consistent with asset pricing theory, which holds that the valuation of risky assets is directly impacted by uncertainty about future cash flows or discount rates. Notably, EPU is a priced risk factor in equity markets, according to Brogaard and Detzel (2015), who found that portfolios more exposed to EPU underperform at times of increased uncertainty. According to their research, EPU has long-term effects on expected returns and market efficiency in addition to short-term volatility.

Further evidence that EPU has worldwide spillover effects comes from cross-country investigations. In his investigation of EPU and market uncertainty in the G7 economies, Smales (2020) demonstrated that, almost universally, financial market volatility increases in line with policy uncertainty. Using daily and monthly data, the study demonstrated that implied volatility measures, such as the VIX, are strongly and positively correlated with EPU. Interestingly, the most noticeable spillover effects on other G7 markets were seen in the US and Japan because of their economic size and policy clout. These results demonstrate how EPU in one nation, particularly a large economy, can spread internationally, thereby enhancing the interdependence of international financial systems. Using more sophisticated econometric models, Smales (2019) expanded on this work and confirmed the statistically significant effect of U.S. policy uncertainty on foreign bond and equities markets, highlighting the externalities linked to domestic policy ambiguity.

The impact of EPU is not limited to developed markets. Emerging nations often have exacerbated effects due to their greater reliance on foreign investment, relatively weaker institutional frameworks, and increased vulnerability to global macroeconomic shocks. For example, Akben-Selcuk (2024) looked at more than 5,500 firm-year observations from nine emerging markets between 2011 and 2022, including Brazil, India, Mexico, and Russia. Higher EPU levels are associated with statistically significant drops in firm financial performance as determined by return on assets (ROA), according to the study. The negative association persisted in all models even after taking firm-specific measures like leverage, cash holdings, and capital expenditures into consideration. Accordingly, EPU appears to have a significant and enduring impact on business outcomes, frequently leading managers and investors in emerging markets to take defensive measures that could impede innovation and growth. Guo et al. (2020) and Feng et al. (2023) offered comparable evidence in the case of Chinese enterprises, supporting the idea that EPU is a worldwide driver of market stability and corporate performance.

Recent research has started to look into the wider implications of EPU for the operation of the financial system, going beyond asset pricing and firm performance. Aman et al. (2024) discovered that EPU considerably reduces financial system efficiency (FSE), especially in regimes with high levels of uncertainty, after analyzing data from 22 countries over a 20-year period. Their study, used FIE and FME. While their examination indicated that increased EPU results in resource misallocation, weakened intermediation and inefficient capital allocation.These effects were stronger in times of global crises and political turmoil.". The paper also reinforced these findings by presenting solid sensitivity analysis with variations on EPU indices as well as econometric techniques such as dynamic system GMM estimators.

It is also well-established that the consequences of EPU vary between sectors and asset types. Compared to bonds, equities typically show higher reactions to policy uncertainty, especially in highly regulated industries like healthcare, utilities, and defense. Pastor and Veronesi (2012) emphasized how industries that depend on government contracts or regulations are disproportionately impacted by political events. Depending on whether EPU is viewed as deflationary or inflationary, government bond yields may react differently. For example, flight-to-safety behavior may cause bonds to climb during periods of fiscal uncertainty; on the other hand, rates may rise due to expected central bank tightening if policy uncertainty signals inflationary risk. According to Fadekemi et al. (2024), bond market movements are more muted and dependent on the type of uncertainty, but stock market volatility continuously climbs with EPU. Additionally, in response to elevated default risk perceptions and decreased investor interest for risk-bearing assets, credit markets raise spreads.

In conclusion, the empirical data consistently shows that EPU plays a significant role in determining the results of financial markets. In both developed and emerging economies, it has an impact on asset valuation, corporate strategy, investor behavior, and systemic efficiency. In addition to being statistically significant, these impacts have economic significance, especially during times of crisis or political upheaval. Increased volatility, changed capital flows, and asset repricing are some of the ways that financial markets react to EPU, frequently making macroeconomic instability worse. Crucially, EPU is also endogenous, meaning that market responses can magnify it and produce feedback loops that increase uncertainty. This emphasizes the necessity of transparent, reliable, and stable policymaking, particularly in a globalized financial world where shocks spread quickly across national boundaries.

2.2 EPU and commodity markets

There are several macroeconomic factors that affect commodities market volatility, but in recent years, Economic Policy Uncertainty has emerged as a significant factor. Given how sensitive commodities like gold and oil are to shifts in the economy, policy-driven uncertainty can both cause and indicate volatility. As a vital component of industrial and energy production, oil reacts to trade policy, geopolitical risk, and economic growth expectations. In contrast, gold serves as a store of value and has long been regarded as a hedge against uncertainty and inflation. Therefore, for investors, managers, and policymakers hoping to predict market behavior and create successful risk mitigation methods, it is essential to comprehend the relationship between EPU and these commodities.

Variations in EPU can have a substantial impact on the prices of gold and oil, according to a number of empirical research. Ahmed and Sarkodie (2021) showed that commodity prices, such as those of gold and oil, respond differently to EPU under regimes with high and low volatility using a Markov regime-switching model. Their findings support the idea that gold and other precious metals are relatively stable investment assets during systemic stress, even though most commodities react substantially to changes in both COVID-19 shocks and EPU. This implies that the effect of EPU on commodities varies depending on the intrinsic qualities and applications of each item.

Xiao et al. (2022) extended this line of research by employing a two-regime Markov switching (MS(2)) model to examine commodities markets during the COVID-19 pandemic. According to their findings, during times of extreme volatility, EPU had a more noticeable effect on the energy and metal sectors' volatility. Crucially, their results showed that gold's reaction was more strongly linked to changes in inflation expectations and policy pronouncements, whereas COVID-related events had a more direct impact on oil. This is consistent with earlier research that highlights how gold serves as a gauge for macroeconomic imbalances and systemic financial stress, reflecting changes in investor sentiment more broadly than sudden demand-supply shocks. Because of this, EPU typically has a delayed but notable impact on gold, particularly during protracted periods of policy ambiguity or uncertainty.

EPU's impact on oil markets is more complex. Soni (2023) used a wavelet-based Granger causality framework to investigate the relationships between EPU and important financial assets, such as gold and oil, in their analysis of Indian financial markets. They came to the conclusion that long-term persistence in EPU severely hindered market participants' capability to secure favorable oil prices, whereas short- and medium-term variations in EPU had little predictive effect over oil price discussions. The idea that oil, being a commodity driven by consumption, responds more strongly to short-term policy changes that affect trade, regulation, or economic production is supported by this distinction between short- and long-term effects. However, sustained EPU over long periods of time might change assumptions of structural demand, which in turn affects pricing patterns and production plans.

The correlation between gold and EPU, on the other hand, seems to be more steady and constant across time. According to Soni et al., gold works well as a hedge during high EPU regimes, especially when inflationary expectations are present. Gold's safe-haven quality makes it a popular asset in times of crisis, such as pandemics, financial meltdowns, and geopolitical unrest. In support of this, Du and Zhang (2024) investigated the EPU-commodity link in China using a quantile autoregressive distributed lag (ARDL) technique. Their findings showed that EPU had a major detrimental effect on gold prices throughout the pandemic, suggesting that although demand for gold as a safe haven rose, price increases may have been restrained by speculative pressure and central bank policy reactions. Interestingly, they could not find any substantial impact of EPU on oil during the same period. This is probably because OPEC+ interventions and concurrent supply-side disruptions overpowered signals relating to policy.

Keshav Singh (2022) offers a more comprehensive viewpoint on how EPU affects commodity indices globally. His empirical research demonstrated that, while not consistently across all categories, EPU has a negative impact on a number of commodity price indices, including gasoline, fossil fuels, industrial raw materials, and agriculture. The conclusion that gold is somewhat immune to policy noise and is primarily influenced by monetary dynamics and investor psychology is supported by the noteworthy fact that the effect of EPU on gold and precious metals was statistically negligible. The significance of distinguishing commodities according to their economic role and market structure is highlighted by this study, which calls into question the notion that all commodities are equally susceptible to EPU.

These findings have ramifications that go beyond scholarly interest. When the EPU is high, investors practically reorganize their portfolios, moving money from riskier or consumption-linked assets like oil to safe-haven assets like gold. Historical evidence supports this reallocation, demonstrating that at times like the global financial crisis, Brexit, and the COVID-19 epidemic, gold prices rose sharply while oil prices fell sharply as a result of uncertain demand. Furthermore, these interactions can teach policymakers valuable insights. To lessen market anxiety, for example, increased transparency and forward guidance in economic planning may be promoted by acknowledging the destabilizing impact of policy uncertainty on commodity markets, particularly oil.

The cyclical nature of the EPU and its relationship to macroeconomic and geopolitical shocks are further significant factors. According to research by Ahmed and Sarkodie (2021) and Xiao et al. (2022), commodity markets react more forcefully to EPU in times of crisis than in times of calm. This finding points to a nonlinear link that calls for investors and regulators to switch from static risk management approaches to dynamic ones. A viable methodological foundation for capturing these frequency-dependent interactions and lead-lag effects throughout time is provided by wavelet-based techniques, as those employed by Soni et al. A more sophisticated understanding of how EPU affects commodities during both short-term shocks and long-term structural changes is made possible by these techniques.

In summary, the relationship between commodities markets and economic policy uncertainty is intricate, multidimensional, and heavily context-dependent. Gold acts more as a long-term hedge against systemic instability and inflationary pressures, whereas oil largely reacts to short-term demand shocks and geopolitical upheavals. According to the empirical data now available, EPU influences these commodities' direction and volatility significantly, albeit through different processes. Our capability to identify and analyze these dynamics has greatly increased with the application of sophisticated econometric methods such as regime-switching models and wavelet analysis. Ultimately, the study of EPU in commodities markets is not only pertinent but also necessary for well-informed investment and policy decisions due to the changing nature of global economic uncertainty, which is made worse by pandemics, wars, and political instability

2.3 Oil price dynamics: macroeconomic and geopolitical determinants

One of the most important and unstable aspects of the global economy is the crude oil market, where supply-demand mismatches, geopolitical conflicts, and a complex web of macroeconomic factors all affect pricing. Crude oil's dual status as a fundamental commodity and a financial asset is at the core of the dynamics of oil prices. It reacts to interest rate policy, currency movements, inflation predictions, and investor emotion as a financial asset. Physical demand from consumers, transportation, and industry, as well as production choices made by countries that export oil, are what drive it as a commodity. Policymakers, energy economists, and central banks, whose budgetary decisions are closely linked to the stability of the world's oil markets, must all have a thorough understanding of the factors that influence changes in the price of oil. Selmi, Hammoudeh, and Wohar (2022) claim that cartel-driven supply manipulations, market expectations, and geopolitical turmoil are the main causes of spikes in crude oil prices, all of which increase the volatility that exists in oil markets.

Global economic growth is one of the macroeconomic variables that affects oil prices most consistently. Rising oil demand is usually linked to periods of strong GDP development, especially in energy-intensive economies like China, the US, and India. Despite declining in more energy-efficient civilizations, the elasticity of oil demand to GDP is still substantial on a worldwide scale. Regression analysis is used by Alredany (2018) to show how macroeconomic factors like industrial output, global GDP, and consumer confidence indices have a significant influence on crude oil prices. On the other hand, oil consumption declines during recessions or other times of economic contraction, which pushes oil prices lower. Examples of how global economic shocks can result in large declines in oil demand and price collapses include the 2008 financial crisis and the COVID-19 pandemic's economic shutdowns.

The dynamics of oil prices are also greatly influenced by interest rates and monetary policy. Through changes in interest rates and the availability of liquidity, central banks particularly the US Federal Reserve have an indirect impact on oil prices. Generally speaking, lower interest rates result in a weaker dollar, which lowers the price of oil, which is valued in USD, for holders of other currencies, increasing demand. Rising interest rates, on the other hand, boost the dollar and lessen inflationary pressures, which can lower the price of commodities like oil. Abdel-Latif and El-Gamal (2020) discovered that oil prices are significantly positively impacted by global financial liquidity, as measured by real interest rates and quantitative easing policies. Their analysis demonstrated how higher speculative flows into oil futures as a result of post-2008 expansionary monetary policy increasingly decoupled prices from the fundamentals of the physical market.

Sharp increases in oil prices have historically been caused by geopolitical conflicts, especially in oil-rich countries like the Middle East, North Africa, and Eastern Europe. The Russian invasion of Ukraine, the Gulf War, and the Iranian Revolution are a few examples of how geopolitical instability can cause real or perceived supply interruptions, which in turn can exacerbate investor concern and speculative trading. According to Selmi, Hammoudeh, and Wohar (2022), geopolitical events are one of the main causes of sudden spikes in the price of oil, frequently outweighing the short-term effects of macroeconomic news. The oil market experiences risk premiums as a result of these geopolitical shocks, which forces traders to protect themselves from potential supply shortages. Eissa, Al Refai, and Chortareas (2025) offer more proof that changes in oil prices in the Middle East and Africa regions that contribute a sizable portion of the world's oil supply have a high correlation with geopolitical risk indices. They found that conflict-induced spikes in oil prices have a detrimental influence on stock markets in these areas, illustrating the dual macro-financial effects of geopolitical unpredictability.

Price formation has become more difficult due to structural shifts in oil production patterns in addition to conventional geopolitical challenges. The global supply picture has changed as unconventional oil sources, including shale oil in the US, have become more popular. Oil markets became more sensitive to real-time supply fluctuations and financial speculation as a result of the U.S. shale revolution, which drastically diminished OPEC's market dominance. Dey, Edwards, and Das (2020) demonstrated how fundamental changes in oil production technology and supply capacity might result in high price regimes using a nonstationary extreme value approach. These high-price regimes are maintained by long-term changes in cost structures and production economics as well as by transient shocks. According to their results, nonlinear oil price behaviors may result from market expectations of production ceilings or disruptions, particularly when there are refining bottlenecks or tight inventories.

Furthermore, investor behavior and market expectations have a greater impact on the dynamics of oil prices, particularly in the age of algorithmic trading and the financialization of commodities. Investors can bet on changes in the price of oil through futures markets, oil exchange-traded funds (ETFs), and other derivative instruments. However, this can occasionally increase volatility above levels supported by physical fundamentals. Abdel-Latif and El-Gamal (2020) noted that short-term fluctuations in oil prices from supply-demand equilibrium are frequently explained by investor behavior, which is influenced by financial liquidity and geopolitical storylines. The relationship between the volatility of the oil price and the volume of speculative trading highlights how oil is becoming a riskier asset that is more susceptible to changes in mood and macro-financial cycles.

Beyond supply and demand fundamentals, currency exchange rates, especially the strength of the U.S. dollar serve as another major determinant of oil prices. Since crude oil is globally traded in dollars, fluctuations in the USD directly affect oil affordability for non-dollar economies. A strong dollar typically exerts downward pressure on oil prices by making oil more expensive for foreign buyers, while a weaker dollar supports price increases. Alredany (2018) confirmed the inverse relationship between oil prices and the U.S. dollar index in his multivariate regression model, suggesting that foreign exchange markets should be integrated into oil pricing models to accurately forecast trends. Furthermore, when oil prices decline as a result of a strong dollar, countries that export oil and have dollar-pegged currencies, such those in the Gulf Cooperation Council (GCC), face budgetary strain, which exacerbates macroeconomic vulnerabilities.

The strategy and unity of oil-exporting nations, especially through the Organization of the Petroleum Exporting Countries and its allies (OPEC+), is a significant structural determinant in oil pricing. In the past, controlled production quotas have been essential for controlling the world's oil supply and setting prices. However, the efficacy of OPEC policies is frequently compromised by intra-group conflicts, changing country interests, and compliance problems. According to Selmi, Hammoudeh, and Wohar's (2022) analysis of cartel behavior, non-OPEC supply, market skepticism, and growing global energy source diversification all lessen the long-term effects of OPEC decisions, even though they can cause notable price reactions. Furthermore, as alternative energy sources become more popular, OPEC's significance may eventually be undermined by the emergence of climate change policies, energy transition investments, and carbon pricing mechanisms.

To make things even more complicated, external shocks like pandemics, natural disasters, and interruptions in the global supply chain can also affect oil prices. For example, the COVID-19 pandemic caused an unheard-of decline in oil demand, which led to the first-ever negative turn in crude futures in April 2020. These black swan events expose the shortcomings of conventional forecasting techniques and bring tremendous uncertainty to the oil markets. In order to capture extreme value behavior and tail risks in oil prices, especially during times of crisis, Dey, Edwards, and Das (2020) underlined the necessity of nonlinear models. Deeper understanding of the probability distribution of significant fluctuations in oil prices, which are becoming more frequent in a volatile global environment, is made possible by their methodological breakthrough in using extreme value theory.

Lastly, oil markets are subject to long-term structural challenges as a result of the shift to renewable energy and decarbonization objectives. In the upcoming decades, it is anticipated that the demand for oil will level off or even decrease as governments make commitments to achieve net-zero emissions and the use of electric vehicles increases. Long-term downward pressure on oil prices may result from this energy transition, but it also causes transitional instability as markets adapt to shifting demand trends, regulatory uncertainties, and technical advancements. According to Eissa (2025), market participants find it difficult to balance short-term supply constraints with long-term demand destruction, which makes investors confused about energy policy changes and leads to the volatility of oil prices. Furthermore, the energy transition's geopolitical ramifications can cause alliances and conflicts pertaining to oil to change their focus, rearranging the conventional factors that determine oil prices.

2.4 Gold as a safe-haven asset

Gold has been valued as a store of wealth and a sign of financial stability since the beginning of civilization, in addition to being a metal for decoration. The significance of gold has only increased in recent decades due to macroeconomic volatility, geopolitical upheaval, and global financial turmoil. Gold's function as a possible "safe haven" an asset that retains or improves its value during market downturns and systemic risk events has been reexamined in economic literature, particularly since the start of the global financial crisis in 2007–2008. With the help of financial theory, historical trends, and new empirical data, this chapter explores the macroeconomic and geopolitical factors that influence the dynamics of the gold price.

The fact that gold has historically performed well during financial crises is a major factor in its reputation as a "safe haven" asset. In their well-known test of this theory, Baur and Lucey (2009) defined a safe haven as an asset that, during periods of market stress, is either uncorrelated or negatively associated with another asset or portfolio. According to their research, gold held its value through market meltdowns in wealthy nations including the US, Germany, and the UK. To elaborate, McCown and Zimmerman (2006) highlighted gold's ability to hedge against inflation and its traits as a "zero beta asset," which means it doesn't bear systemic market risk. In a similar vein, Capie et al. (2005) demonstrated that gold serves as a currency hedge during financial crises since it is a powerful hedge against the devaluation of the US dollar.

Expectations for inflation, interest rates, exchange rates, stock market performance, and the uncertainties surrounding economic policy are some of the macroeconomic factors that influence gold prices. Since gold is a non-yielding asset, its value usually increases when real interest rates are low or even negative. Due to concerns about currency devaluation and rising inflation, investors frequently turn to gold when central banks implement expansive monetary policies, particularly quantitative easing. Gold responds to inflation, both anticipated and actual, according to research. According to Zhu, Fan, and Tucker (2017), gold served as an inflation hedge mainly during times of high inflation, particularly before 1997 in the UK and before 2003 in the US. But during times of low inflation, its efficacy diminished, underscoring the property's conditional nature.

Furthermore, as gold is priced in U.S. dollars internationally, changes in exchange rates have a significant impact on changes in the price of gold. Demand rises when gold becomes more affordable in other currencies due to the dollar's depreciation. This trend was explained by Sjaastad and Scacciavillani (1996), who claimed that the domestic price of gold is impacted by any shift in the trade-weighted exchange rate. Because of this connection, nations with little control over the gold market must modify their own pricing to match changes in global exchange rates.

A major factor in determining market attitude and expectations for gold is monetary policy. Interest rate targeting, forward guidance, and quantitative easing (QE) all have an impact on inflation projections and the perceived stability of fiat currencies. Zhu et al. (2017) conducted event-study analyses on QE announcements and discovered that these programs, particularly those started by the European Central Bank and the Federal Reserve, generally resulted in higher gold prices. This demonstrates how sensitive gold is to changes in macropolicies and investor behavior in the face of uncertainty.

Gold acts as a hedge against market disruptions brought on by war, sanctions, and global unrest in geopolitical circumstances. According to Tronzano (2020), conditional correlations between gold and other asset classes increased after significant financial crises and geopolitical upheavals, suggesting a definite flight to safety. Particularly in international portfolios, investors have a tendency to diversify away from stocks and toward gold. These changes frequently coincide with heightened price volatility for gold, highlighting the metal's dual characteristics as a reactive financial tool and a reliable store of value.

Sathyanarayana and Mohanasundaram (2025) highlight how reserve diversification and central bank policies are increasingly influencing the dynamics of the gold market. In order to reduce their exposure to dollar-based dangers and maintain economic sovereignty in the face of trade disputes and currency manipulations, many nations particularly emerging economies have expanded their gold reserves. The long-term understanding of gold's value in maintaining national wealth and stabilizing foreign exchange reserves is shown in this strategic diversification.

Another topic of great interest is the relationship between gold and the stock market. In times of stock market decline, as the global financial crisis of 2008 or the COVID-19 pandemic of 2020, gold prices usually rose as investors sought safety. Baur and McDermott (2010) carefully investigated this link and discovered that gold's significance as a safe haven was particularly noticeable during periods of significant volatility across global market indices. Concurrent macroeconomic policies, market sentiment, and liquidity limitations can all have an impact on this relationship, which is not absolute.

Curiously, gold's reputation as a safe haven is frequently stronger in industrialized areas than in developing ones. According to Baur and Lucey (2009), emerging market reactions are more varied and impacted by regional economic systems, whereas investors in established markets react more strongly to shocks by reallocating to gold. This disparity may result from varying degrees of institutional framework trust, market maturity, and access to global gold markets.

Our comprehension of gold's behavior has been considerably enhanced by recent developments in behavior analysis and financial technology. Although gold is still an essential component of the global financial architecture, new developments like blockchain-enabled gold trading, AI-based price modeling, and the emergence of central bank digital currencies (CBDCs) are changing the gold ecosystem, according to Sathyanarayana and Mohanasundaram (2025). These developments could have an impact on gold's involvement in diversified investment strategies, liquidity, and price discovery process.

From the standpoint of behavioral finance, herd mentality and investor psychology have a big impact on changes in gold prices. During emergencies, demand spikes are fueled by fear and uncertainty, which drives up prices regardless of their intrinsic value. Research on financial contagion (Forbes and Rigobon, 2002) and flight-to-quality (Hartmann et al., 2004) supports this viewpoint by highlighting gold's dual role as a rational hedge and an emotional refuge.

In summary, a complex network of macroeconomic variables, monetary policies, geopolitical events, and investor emotion all have an impact on the dynamics of gold's price. Its long-standing position as a safe haven asset is well-established, especially during times of crisis in industrialized economies. However, this position is conditional, context-dependent, and increasingly influenced by technological advances and changing market systems. Understanding these multiple variables is critical for policymakers, investors, and scholars looking to manage financial markets with better resilience.

2.5 Time–frequency analysis and wavelet methods in financial research

One of the most difficult analytical difficulties in financial and commodity markets is identifying dynamic relationships those that change over time and across investment horizons. Traditional time series models, such as autoregressive (AR) models, vector autoregressions (VAR), or GARCH frameworks, typically assume stationary behavior and fixed parameter structures, making it difficult to detect nonlinear dependencies, structural breaks, or horizon dependent co-movements. However, financial variables such as commodity prices, uncertainty indices, and exchange rates are frequently non-stationary and sensitive to regime upheavals, making traditional techniques potentially insufficient or misleading for long-term, crisis-prone data. Time-frequency analysis, particularly wavelet-based approaches, is a strong tool in empirical financial economics (Aguiar Conraria & Soares, 2014; Vacha & Baruník, 2012).

Wavelet analysis allows for the decomposition of a time series into temporal and frequency-localized components. This dual localization allows one to examine not only when co-movements or volatility spikes occur, but also at what frequency which generally corresponds to the investment horizon (short-term traders vs. long-term investors). This capability makes wavelet methods particularly well-suited for studying the impact of macroeconomic variables such as economic policy uncertainty on commodity prices such as oil and gold, which can be immediate and transient or persistent and structural (e.g., changing long-term inflation expectations or shifts in demand). Wavelets help keep the original series' entire informational value by preserving both high-frequency variations and low-frequency trends without aggressive pre-filtering (differencing or detrending).

The fundamental mathematical representation of wavelet analysis is the Continuous Wavelet Transform (CWT). The CWT of a time series $x(t)$is defined as:

$$W_x(u,s) = \int_{-\infty}^{\infty} x(t)\,\psi^*\left(\frac{t-u}{s}\right) dt$$

where $x(t)$is the time series, ψ represents the mother wavelet, $s$is the scale parameter (which corresponds to frequency), u is the time translation parameter, and $*$ denotes the complex conjugate. Through this transformation the original series is decomposed across different time periods and frequencies, allowing the identification of localized oscillations and structural patterns.

Wavelet coefficients capture localized oscillations or trends at different scales and times, resulting in a two-dimensional (time × scale) representation of the data. From these coefficients the wavelet power spectrum (WPS) can be derived, which measures the local variance of a time series at a given time and scale:

$$WPS(u,s) = |\, W_x(u,s)\,|^2$$

The wavelet power spectrum therefore highlights periods of increased volatility or variability at specific frequencies.

In addition to analysing individual time series, wavelet techniques can also be used to investigate the relationship between two variables. The wavelet coherence (WTC) provides a localized correlation measure in the time-frequency domain. It is mathematically defined as:

$$R^2(u,s) = \frac{|\ S(s^{-1}W_{xy}(u,s))\ |^2}{S(s^{-1}\ |\ W_x(u,s)\ |^2)\ S(s^{-1}\ |\ W_y(u,s)\ |^2)}$$

where $W_{xy}(u,s)$represents the cross-wavelet transform between the two time series and $S(\cdot)$denotes a smoothing operator applied in both time and scale dimensions. The wavelet coherence coefficient ranges between 0 and 1, where values close to 1 indicate strong co-movement between the variables at a specific time and frequency.

To further examine the direction of the relationship between variables, the phase difference is calculated. The phase difference between two series is given by:

$$\phi_{xy}(u,s) = \tan^{-1}\left(\frac{\mathrm{Im}(W_{xy}(u,s))}{\mathrm{Re}(W_{xy}(u,s))}\right)$$

where Im and Re denote the imaginary and real parts of the cross-wavelet transform respectively. The phase difference provides information about lead-lag relationships, indicating whether one variable leads or lags the other at specific frequencies.

Baruník, Kočenda, and Vacha (2013) offer a strong empirical example. In their paper "Gold, Oil, and Stocks," they used wavelet time-frequency analysis to look at dynamic correlations between gold, oil, and stock returns using intra-day and daily data from 1987 to 2012. They discovered that a prominent characteristic is correlation heterogeneity across investment horizons: correlations differ significantly based on the horizon (long vs. short). It's interesting to note that correlations between all three assets became more uniform across scales during the 2008 financial crisis, suggesting that the advantages of diversification across horizons may disappear during times of crisis (Baruník, Kočenda ,Vacha, 2013). The horizon-dependent heterogeneity and temporal shifts linked to structural fractures would be missed by typical covariance or correlation measurements averaged over time, as this case illustrates perfectly.

The application of wavelet coherence to energy commodities provides another example. In their work "Co movement of energy commodities revisited: Evidence from wavelet coherence analysis," Vacha & Baruník (2012) used wavelet coherence on a series of energy commodities, including natural gas, heating oil, gasoline, and crude oil, over an extended period of time. In the time frequency domain, their findings revealed dynamic, time-varying associations. There were times when the commodities moved closely together, and times when they moved at different scales. Conventional, time-averaged correlation analysis would not detect these patterns (Vacha & Baruník, 2012).

While the continuous wavelet transform provides a detailed time-frequency representation, the Discrete Wavelet Transform (DWT) allows the decomposition of a time series into a finite set of frequency bands corresponding to different investment horizons. The mathematical representation of this decomposition is:

$$x_t = \sum_{j=1}^{J} D_j\,(t) + S_J(t)$$

where $D_j(t)$represents the detail components at scale j, capturing fluctuations at specific frequencies, and $S_J(t)$represents the smooth long-term component. This multiresolution decomposition enables the separation of short-, medium-, and long-term dynamics in financial time series.

Wavelet-based approaches are frequently combined with traditional econometric techniques in order to strengthen the robustness of empirical results. One commonly used framework is the Vector Autoregression (VAR) model, which captures the dynamic interaction between multiple time series. A VAR(p) model can be expressed as:

$$Y_t = c + A_1 Y_{t-1} + A_2 Y_{t-2} + \ldots + A_p Y_{t-p} + \varepsilon_t$$

where $Y_t$represents the vector of endogenous variables, $A_i$are coefficient matrices, $c$is a vector of constants, and $\varepsilon_t$is a vector of error terms.

Within this framework, Granger causality tests are used to determine whether past values of one variable help predict another variable. Variable $x$is said to Granger-cause variable y if:

$$Var(y_t \mid y_{t-1}, \ldots, y_{t-p}, x_{t-1}, \ldots, x_{t-p}) < Var(y_t \mid y_{t-1}, \ldots, y_{t-p})$$

This hypothesis is tested through F-tests on the joint significance of the lagged coefficients of x.

Wavelet techniques have been extended to multivariate analyses beyond univariate or bivariate research. For instance, Kahraman, Maras, and Serletis (2016) broke down the co-movement of four metal prices (steel, aluminum, copper, and zinc) into multiple scales using a Multiple Wavelet Coherence (MWC) framework and a VARMA model. This allowed them to find both scale-specific interactions and common trends. They then employed VARMA to forecast, demonstrating that, in comparison to traditional models, wavelet-based decomposition improves forecasting performance (Kahraman et al., 2016). This demonstrates how useful wavelet multiresolution analysis is for both descriptive and predictive modeling in commodity markets.

Wavelet-based multivariate analysis has been further developed from a theoretical perspective. Researchers can examine complicated joint dynamics among several assets and move beyond basic pairwise connections by extending CWT to partial wavelet coherency (controlling for third variables) and MWC, as described in the methodological survey of Aguiar Conraria & Soares (2014). When one believes that observed co-movements may be caused by shared external factors (such as interest rates, exchange rates, and global macroeconomic shocks) rather than direct bilateral links, this extension is crucial.

Wavelet coherence has been used in more recent empirical research to examine the connections between commodity prices and economic policy uncertainty over extended periods of time and across several crises. The paper by Arouxet, Bariviera, Pastor, and Vampa (2023) is a noteworthy contribution. It covers the period from 1997 to 2022 and looks at time-frequency co-movements between a wide range of commodity futures and an EPU index, capturing multiple crises (global financial crisis, regional political upheavals, a global pandemic). According to their findings, the magnitude and timing of comovements between EPU and commodities differ greatly based on the type of crisis: for some crises, comovements become more intense at particular scales and times. This emphasizes the significance of using a time-frequency perspective when researching the relationship between uncertainty and commodities (Arouxet et al., 2023).

Furthermore, new research combines machine learning frameworks with wavelet techniques to improve predictability. Doroshenko et al. (2025), for example, use wavelet coherence analysis in conjunction with LSTM neural networks and an information-theoretic divergence metric (wavelet-based Kullback–Leibler divergence) to evaluate the impact of financial and policy uncertainty on the pricing of metal and energy commodities. A one-size-fits-all model is inadequate, and time-frequency analysis is still a useful descriptive tool even when combined with contemporary predictive modeling, as their hybrid method emphasizes that different commodities react differently to uncertainties (Doroshenko et al., 2025).

In light of these achievements, wavelet approaches provide a number of benefits over conventional econometric methods when it comes to commodities and uncertainty:

• Preservation of non-stationarity and structural breaks: Since wavelet transforms don't call for detrending or differencing, all frequency components including high-frequency noise and low-frequency trends are retained, along with long-term data.

• Time-varying and scale-dependent correlations: Traditional correlation or cointegration analyses, which presume continuous links, tend to mask dynamic co-movements that may change across time and investment horizons. Wavelet coherence reveals these co-movements.

• Flexibility and model-free nature: Compared to VAR or cointegration models, wavelet approaches make fewer parametric assumptions and are essentially model-free. This lowers the possibility of model misspecification in macrofinancial contexts that are unstable or complicated.

• Multivariate extensions: Partial coherence, or MWC, preserves interpretability while capturing complex relationships by permitting the addition of multiple assets or the management of confounding variables.

• Improvement of forecasting in combination with parametric models: Kahraman et al. (2016) shown that forecast performance can be improved by employing parametric models after first separating data by scale. Similarly, the combination of wavelet decomposition and machine learning creates new opportunities for predicting the response of commodities to macroeconomic shocks or uncertainty (Doroshenko et al., 2025).

However, wavelet approaches have drawbacks and difficulties that need to be carefully taken into account. First, a certain amount of subjectivity is introduced by the selection of the mother wavelet, decomposition stages, and boundary conditions. Different decisions could produce different results, which could impact the interpretability and comparability of different studies. Second, it might be difficult to interpret phase differences (lead-lag relationships), particularly if they change over time or between scales. It is important to avoid overinterpreting transitory alignments without doing robustness checks. Third, unless combined with structural economic models or other econometric tests (e.g., VAR, Granger causality, structural breaks testing), wavelet-based analysis may not uncover underlying economic mechanisms because it is primarily descriptive. For instance, it may not explain why uncertainty affects gold but not oil, or why comovements strengthen during some crises but not others.

Lastly, the use of multivariate extensions or fine-scale decompositions may increase computational and data needs. Given these limitations, the most sensible approach is frequently a hybrid methodological strategy that combines wavelet-based techniques with conventional econometric testing and economic reasoning. Accordingly the research employs the following three-pronged approach: first the use of CWT to calculate wavelet coherence (and possibly partial coherence) between the EPU index and commodity prices (oil and gold) in order to identify co-movement and potential directionality in time–frequency space, second, break down series into short-, medium-, and long-term components in order to isolate frequency-specific dynamics; and third, use of scale-by-scale Granger causality tests on these decomposed components to test predictive relationships in the time domain.

Specifically, if uncertainty "Granger-causes" changes in commodity prices at particular frequencies, and whether this causal relationship is constant throughout time or changes depending on the economic system.

To account for confounding impacts, we can choose expand the study by adding control variables (such as interest rates, inflation, and exchange rates) or more assets (such as stock indices or volatility indices). We can even use multivariate wavelet coherence or multiple wavelet coherence frameworks.

This hybrid technique grounds results in predictive econometric tests and economic interpretation, while allowing the investigation to benefit from the descriptive richness of wavelet approaches capturing when and at what horizon associations peak. Following the example provided by Baruník et al. (2013), Vacha & Baruník (2012), Arouxet et al.

(2023), Kahraman et al. (2016), and others, it also conforms to best standards in empirical finance and commodity research.

In conclusion, time-frequency wavelet techniques offer a strong, adaptable, and sophisticated framework for examining intricate, changing interactions in commodity and financial markets. They overcome many of the limitations of traditional time-series methods by accommodating non-stationarity, structural breaks, and multi-horizon dynamics. They provide a complete arsenal for examining the effects of macroeconomic uncertainty, such as that represented by an EPU index, on commodity prices like gold and oil over time and across scales, when paired with discrete decompositions and conventional causality or econometric tests. This hybrid wavelet econometric approach promises more insight and robustness than traditional approaches alone for studies of the uncertaintycommodity nexus.

2.6 Research gap and contribution of the study

Significant theoretical and empirical gaps still exist regarding the frequency-dependent and temporal dynamics of economic policy uncertainty's (EPU) impact on commodity prices, especially for gold and oil, despite an expanding body of research examining the relationship between EPU and financial markets. By incorporating time-frequency approaches, expanding current frameworks into uncharted analytical areas, and offering sophisticated insights into asset behavior over a range of investment horizons, this study fills these gaps. By using a hybrid technique that blends wavelet analysis with causality testing, it also makes a methodological contribution by providing a more thorough understanding of the EPU commodity nexus than is possible with traditional models.

The following research gaps were identified in the thesis.

1. EPU literature pays little attention to commodities.

   Most of the current research has focused on how EPU affects corporate investment, stock markets, and macroeconomic aggregates. More EPU has been shown to result in worse equity returns, more volatility, and deferred investment in seminal works like Baker et al. (2016) and Brogaard & Detzel (2015). But commodities, particularly gold and oil, have gotten comparatively little attention. Instead of being the main focus of the study, they are frequently handled as secondary effects or control variables.

   Given their unique roles in energy markets, monetary systems, and macroeconomic hedging, this provides a crucial blind spot in our knowledge of how policy uncertainty impacts global commodity prices.

2. Insufficient distinction between investment horizons.

The majority of earlier research on EPU impacts used static or linear models, such as VARs, GARCH-type models, or linear regressions, and assumed homogeneous effects over time. Although helpful, these methods overlook the potential that EPU has varying effects on commodities over short-, medium-, and long-term timeframes. Long-term pricing patterns are impacted by ongoing uncertainty regarding regulation, climate policy, or fiscal planning, while short-term price changes may be the result of speculative trading based on geopolitical rumors. These complex dynamics are impossible to separate using conventional techniques. This makes it more difficult to provide investors, legislators, and risk managers working on various time horizons with useful insights.

3. Inadequate wavelet-based time-frequency research on EPU-commodity correlations.

In financial econometrics, wavelet analysis has been popular (Gencay et al., 2002; Vacha & Baruník, 2012), but few research have addressed the precise relationship between EPU and individual commodities using time-frequency approaches. Wavelet coherence and Markov regime-switching models have been used by exceptions like Soni et al. (2023) and Xiao et al. (2022), but these applications are still rare and frequently do not concentrate only on oil or gold. Furthermore, even less focus is placed on determining whether these commodities show asymmetric or bidirectional causality with EPU across scales, which is a crucial concern for locating feedback loops in macrofinancial systems.

4. A lack of appreciation for crisis-specific conduct.

Global crises like the 2008 Financial Crisis, the COVID-19 pandemic, or geopolitical shocks like Brexit and the Russia-Ukraine war cause structural changes in many macro-financial interactions. However, there is a dearth of research that systematically investigates the behavior of the EPU commodity price relationship during and outside of crisis moments, particularly in a scale-dependent manner. Since perceived tail risks or systemic uncertainty frequently cause commodity markets to respond rapidly, the lack of event-based, time-frequency research represents a methodological and practical gap.

5. Multiscale causality methodological flaws.

Granger causality in a VAR or VECM framework is usually the basis for causality testing in the EPU literature, which is still mostly limited to time-domain methods. These models are unable to discern whether causality is present in long-term patterns or just in short-term volatility. EPU commodity research has not yet fully embraced recent developments in wavelet-based Granger causality testing. This disregard restricts how results can be interpreted statistically and economically.

Six significant contributions are made by this thesis in the areas of methodology, theory, and empirical research:

1. Turns the attention of analysis to commodities.

Despite the macroeconomic significance of gold and oil, the study's focus on these commodities draws attention to how EPU affects non-equity asset classes, an area that is frequently disregarded. Oil, with its economic and geopolitical importance, and gold, with its monetary qualities, offer opposing case studies of how various assets react to uncertainty.

2. Introduces EPU-commodity research to time-frequency analysis.

This work is one of the first to evaluate the EPU commodity relationship over time and frequency using wavelet coherence and Continuous Wavelet Transform (CWT) techniques. When and at what investment horizon EPU has the greatest impact is shown by this dual localization, which is a dimension that linear models overlook. Additionally, it makes it possible to identify dynamic lead-lag correlations, which helps to clarify if market reactions predict policy changes or whether EPU is a leading indicator of commodity prices.

3. Uses a hybrid approach that combines causality and wavelet methods.

Apart from CWT, the research isolates frequency-specific components of each series using the Discrete Wavelet Transform (MODWT) and then conducts Granger causality testing on a scale-by-scale basis. This integrated methodology improves granularity and robustness: findings are more confident if wavelet coherence and causality tests produce convergent results. Additionally, it provides a blueprint for upcoming research on multi-scale financial interactions.

4. Provides crisis-sensitive insights.

By anchoring the analysis to major global events including the 2008 GFC, COVID-19, Brexit, and recent energy shocks examines how EPU commodity dynamics behave during systemic crises. Time–frequency heatmaps and event-linked phase differences help identify when markets become more (or less) synchronized with uncertainty, providing valuable insights for crisis forecasting, asset allocation, and risk management.

5. Improves comprehension of the behavior of different assets.

Comparisons between a cyclical commodity (oil) and a counter-cyclical safe-haven asset (gold) are made possible by the dual focus on the two commodities. The study examines whether divergent responses occur or if EPU has symmetric impacts on both assets. Theoretical knowledge of how uncertainty spreads across various asset classes with various economic functions is strengthened by this comparative lens.

6. Aids in the implementation of investment strategy and policy.

Central banks, institutional investors, and monetary authorities can all benefit from the study's conclusions. For example, gold might be a more dependable hedge in strategic asset allocation if EPU is shown to have higher long-term coherence with gold prices. In contrast, energy traders and hedging choices may be affected if oil mostly responds in the short term. Results can also be used by policymakers to predict how the market will respond to ambiguity brought on by pronouncements about trade or fiscal policy.

To sum up, this study closes a number of important gaps in the body of knowledge about financial market behavior and economic policy uncertainty. By (1) reorienting the empirical focus from stocks to important global commodities, (2) using cutting-edge time-frequency and wavelet-based methodologies to reveal dynamics unique to a given horizon, (3) adding scale-sensitive causality tests to strengthen inferential validity, and (4) placing findings within global crisis events to give them practical significance, it advances the field. By filling up these gaps, the study offers a methodological framework that may be repeated or expanded upon in subsequent research, while also adding unique insights to the developing body of knowledge on uncertainty, asset pricing, and commodities markets.

2.7 Interactions between Oil and Gold Markets under Economic Uncertainty

Due to the strategic significance of both commodities in international markets, the relationship between the oil and gold markets has been extensively studied in the literature on financial economics. One of the most significant energy resources and a crucial component of global manufacturing, transportation, and industrial operations is oil. In contrast, gold has historically been regarded as a store of value and a financial asset that can be used as a hedge against market volatility, inflation, and currency depreciation. The relationship between oil and gold prices reveals intricate mechanisms involving macroeconomic factors, financial market expectations, and geopolitical developments due to their distinct economic responsibilities (Baffes, 2007; Reboredo, 2013).

A substantial amount of research indicates that changes in oil prices may have an impact on gold prices via a number of transmission pathways. Inflation is one of the main processes. Rising oil prices typically result in greater production and transportation costs, which raise the economy's overall price levels. As a hedge against declining purchasing power, investors frequently raise their demand for gold in response to rising inflation forecasts (Baffes, 2007). In this situation, changes in the price of gold may be indirectly caused by shocks to the price of oil through monetary policy reactions and inflationary pressures.

The exchange rate, namely the value of the US dollar, is another significant conduit connecting the oil and gold markets. Because both commodities are usually traded in U.S. dollars on international markets, changes in the value of the dollar can affect the price of both gold and oil at the same time. Commodities become comparatively less expensive for investors using other currencies as the U.S. dollar weakens, boosting demand globally and driving up prices. Because of this, currency dynamics frequently cause co-movements in the prices of gold and oil (Sari, Hammoudeh, & Soytas, 2010).

The relationship between oil and gold prices is significantly shaped not just by macroeconomic considerations but also by investor behavior and financial market uncertainties. Investors sometimes adjust their portfolios during times of economic instability or financial volatility by boosting their holdings of safe-haven assets like gold and decreasing their exposure to risky assets. Because oil prices are often more sensitive to economic activity and global demand conditions, this behavior may cause the oil and gold markets to diverge (Baur & Lucey, 2010). As a result, during economic downturns, gold prices may rise as a result of increased demand for financial security, while oil prices may decline.

Another element that can have a big impact on how the oil and gold markets interact is Economic Policy Uncertainty (EPU). High levels of policy uncertainty can cause volatility in commodities markets and disrupt the connections between various asset classes. These can be caused by unclear government policies, regulatory changes, fiscal instability, or geopolitical conflicts. Increases in policy uncertainty can cause spillover effects between oil prices and other financial assets, such as gold, according to research by Kang, Ratti, and Vespignani (2017). These spillovers show how investor expectations, capital flows, and commodity price dynamics are shaped by uncertainty.

Furthermore, empirical evidence suggests that the relationship between oil and gold has changed throughout time. Instead, it varies depending on different economic regimes and market conditions. For example, during financial crises or periods of geopolitical unrest, gold's safe-haven properties become more apparent, which reduces the correlation between oil and gold prices. However, during periods of great economic growth and stable financial markets, oil and gold may exhibit stronger positive connections due to shared macroeconomic factors including inflation and currency volatility (Reboredo, 2013).

Research utilizing time-frequency analysis and wavelet coherence has shown that the oil-gold link can vary greatly over different investment horizons. Short-term price swings may be dominated by speculative trading, mood in the financial markets, and unexpected geopolitical developments. Long-term co-movement between these commodities is typically shaped more by macroeconomic factors including inflation, economic growth, and energy consumption (Tiwari, Dar, Bhanja, & Shahbaz, 2013). These results emphasize how crucial it is to take into account both temporal and frequency aspects when examining interactions in the commodity market.

It is crucial for investors, governments, and financial institutions to comprehend how the oil and gold markets interact. Understanding how these commodities move together can help investors make better judgments about risk management and portfolio diversification. While oil-related assets are intimately linked to economic growth and energy consumption, gold is frequently included in investment portfolios as a hedge against inflation and financial market instability. Investors can therefore better control their exposure to macroeconomic risks by examining the dynamic link between various commodities (Baur & McDermott, 2010).

From a policy standpoint, studying the relationships between oil and gold can also shed light on how commodities markets are impacted by geopolitical unrest and uncertainty in the world economy. Understanding how shocks in one market might spread to another can help policymakers keep an eye on financial stability, energy security, and inflation threats. This is especially important during times of increased global uncertainty, as commodity markets can become extremely intertwined and volatile.

Overall, research suggests that a mix of macroeconomic principles, financial market dynamics, and geopolitical events influence the relationship between oil and gold prices. These relationships have been reinforced by the growing influence of financial investors and the increasing integration of international commodity markets. As a result, researching the relationship between oil and gold using sophisticated econometric methods can provide light on how uncertainty spreads throughout commodities markets and how gold functions as a safe haven for investors during unstable economic times.

3. Data and Methodology

3.1 Data Sources and Variable Description

With an emphasis on crude oil and gold, this study investigates the connection between commodities markets and economic policy uncertainty. For this, three primary time series which originate from extensively utilized and globally recognized databases are used.

The Baker, Bloom, and Davis database is used to create the Economic Policy Uncertainty Index (EPU), which is based on press uncertainty and the frequency of phrases relevant to economic policy. This indicator is thought to be suitable for researching how uncertainty affects financial markets and has been widely utilized in the literature as a gauge of institutional and political uncertainty.

The price of Brent crude, a global benchmark for energy markets, is a representation of the price of oil. Because of its great liquidity and significance for worldwide economic activity, Brent is frequently utilized in international literature.

The spot price of gold (LBMA Gold Price), which represents the actual trading price in the market, is used to calculate the price of gold. Gold has long been seen as a safe haven, and its behavior during periods of heightened uncertainty is a major topic of study in the financial literature.

3.2 Sample Period and Frequency of Observations

Depending on the availability of each series, the study is based on monthly data spanning from the early 1990s to the most recent observation. The monthly frequency was chosen because of the monthly construction of the EPU index and the study's goal of taking both short- and long-term investment perspectives into account.
By using monthly data, it is possible to minimize the excessive noise that is frequently seen in daily time series while still having enough observations to use multivariate models and sophisticated time-frequency analysis techniques.
To guarantee a uniform sample of observations and comparability of outcomes, all time series are time-aligned.

3.3 Data Transformations

All value series are transformed into log returns prior to using the empirical techniques. Because it brings time series closer to stagnation and enables changes to be expressed as percentage changes, this transformation is often used in financial analysis.

The definition of log returns is **rt=ln(Pt)−ln(Pt−1).**
where Pt is the variable's value during time t.

There are three primary reasons for choosing log-returns. First of all, it lessens the impact of heteroskeletality and price extremes. Second, it facilitates the comparison of variables with various measurement units. Thirdly, it qualifies the series for use with both VAR templates and wave methods. The Augmented Dickey–Fuller check is used to verify that all return rows are level-stationary and to check for stagnation of the modified rows.

3.4 Methodological Framework

A multi-level methodological framework that blends time-frequency methodologies and conventional econometric techniques is used to examine the connection between economic policy uncertainty and commodity markets.

3.4.1 Continuous Wavelet Transform (CWT)

Analysis of a time series in both time and frequency is possible due to the continual change of waves. CWT makes it possible to identify time-varying patterns, in contrast to standard time series approaches that presume stable relationships throughout the sample. The behavior of oil and gold yields across various time horizons and during various periods of economic uncertainty is examined in the current study using CWT.

Mathematically, the Continuous Wavelet Transform of a time series $x(t)$is defined as:

$$W_x(u,s) = \int_{-\infty}^{\infty} x(t)\, \psi^* \left(\frac{t-u}{s}\right) dt$$

Where:

- $x(t)$represents the original time series,
- $\psi$is the mother wavelet,
- $s$denotes the scale parameter, which is inversely related to frequency,
- $u$represents the time translation parameter, and
- $*$ denotes the complex conjugate.

This transformation decomposes the time series into localized time–frequency components, allowing the identification of cyclical patterns and structural changes across different investment horizons.

The local variance of the series can be measured through the Wavelet Power Spectrum, defined as:

$$WPS(u,s) = | W_x(u,s) |^2$$

which indicates the concentration of volatility at specific times and frequencies.

3.4.2 Wavelet Coherence and Phase Difference

By enabling the investigation of co-motion between two time series in both time and frequency, wavelet coherence expands CWT. Across various investment horizons, wavelet coherence serves as a local correlation metric, exposing times of high or low correlation. The phase difference, which reveals the direction of the lead-lag relationship, is given special attention. Phase difference arrows, in particular, allow one to determine if changes in commodity prices are preceded by economic policy uncertainty or vice versa.

Wavelet coherence between two time series $x(t)$and $y(t)$is defined as:

$$R^2(u,s) = \frac{| S(s^{-1}W_{xy}(u,s)) |^2}{S(s^{-1} | W_x(u,s) |^2)\, S(s^{-1} | W_y(u,s) |^2)}$$

where

- $W_{xy}(u,s)$is the cross-wavelet transform,
- $S(\cdot)$represents a smoothing operator in time and scale.

The coefficient $R^2(u,s)$ranges between 0 and 1, where higher values indicate stronger co-movement between the variables.

The phase difference, which reveals the direction of the lead-lag relationship, is given special attention. The phase difference is defined as:

$$\phi_{xy}(u,s) = \tan^{-1}\left(\frac{\mathrm{Im}(W_{xy}(u,s))}{\mathrm{Re}(W_{xy}(u,s))}\right)$$

where Im and Re denote the imaginary and real parts of the cross-wavelet transform. Phase difference arrows allow one to determine whether changes in commodity prices are preceded by economic policy uncertainty or vice versa.

3.4.3 Discrete Wavelet Transform

Discrete wave transformation, namely the MODWT method, is used for robustness. Time series can be divided into distinct frequency levels using this strategy, which correspond to short-, medium-, and long-term investment perspectives.
The consistency of the wavelet coherence results at various levels of analysis is checked by looking at the correlations between the components at each scale.

The discrete wavelet decomposition of a time series $x_t$can be written as:

$$x_t = \sum_{j=1}^{J} D_j\,(t) + S_J(t)$$

where

- $D_j(t)$represents the detail components at scale j, capturing fluctuations at specific frequencies,
- $S_J(t)$represents the smooth component, capturing the long-term trend.

This decomposition allows the separation of the time series into components associated with different investment horizons. The consistency of the wavelet coherence results at various levels of analysis is checked by examining the correlations between the components at each scale.

3.4.4 VAR Framework and Granger Causality Tests

Lastly, the direction of causality in the time domain is examined using a multivariate vector autoregression (VAR) model. The AIC, HQ, SC, and FPE criteria are used to determine the ideal lag length. Granger causality checks are performed in the context of VAR, allowing one to investigate if historical EPU values contain information that can be used to forecast oil and gold yields and vice versa.

A VAR(p) model can be expressed as:

$$Y_t = c + A_1 Y_{t-1} + A_2 Y_{t-2} + \ldots + A_p Y_{t-p} + \varepsilon_t$$

where

- Y_t is the vector of endogenous variables (EPU, oil returns, gold returns),
- A_i are coefficient matrices,
- c is a vector of constants,
- ε_t is a vector of white-noise error terms.

The AIC, HQ, SC, and FPE criteria are used to determine the optimal lag length.

Within the VAR framework, Granger causality tests are applied in order to determine whether past values of one variable contain predictive information about another variable. Variable x is said to Granger-cause variable y if:

$$Var(y_t \mid y_{t-1}, \ldots, y_{t-p}, x_{t-1}, \ldots, x_{t-p}) < Var(y_t \mid y_{t-1}, \ldots, y_{t-p})$$

This hypothesis is tested through F-tests on the joint significance of the lagged coefficients of x.

3.5 Interpretation of Lead–Lag Relationships

An integrated approach to the investigation of lead-lag connections is made possible by the combination of wave techniques and VAR. Wave approaches show the dynamic character of these relationships over various time periods, whereas Granger tests shed light on short-term linear causality. This method advances our knowledge of the mechanisms underlying the transmission of uncertainty and allows us to differentiate between the short-term and long-term impacts of economic policy uncertainty on commodities markets.

3.6 Software implementation

All empirical analyses were conducted using the R statistical software environment. R provides extensive libraries for time-series analysis and wavelet-based methods, making it particularly suitable for time–frequency econometric research.

Wavelet analysis, including the Continuous Wavelet Transform (CWT) and Wavelet Coherence, was implemented using specialized R packages designed for time-frequency decomposition. The Discrete Wavelet Transform (DWT) was applied to decompose the series into multiple frequency components corresponding to different investment horizons.

Furthermore, econometric analysis including the Vector Autoregression (VAR) model and Granger causality tests was performed using standard time-series packages available in R. These tools allow the estimation of multivariate dynamic models and the statistical testing of predictive relationships between economic policy uncertainty and commodity returns.

The use of R ensures transparency, reproducibility, and flexibility in implementing advanced econometric techniques and visualizing time-frequency relationships.

4. Methodology

4.1 Data section

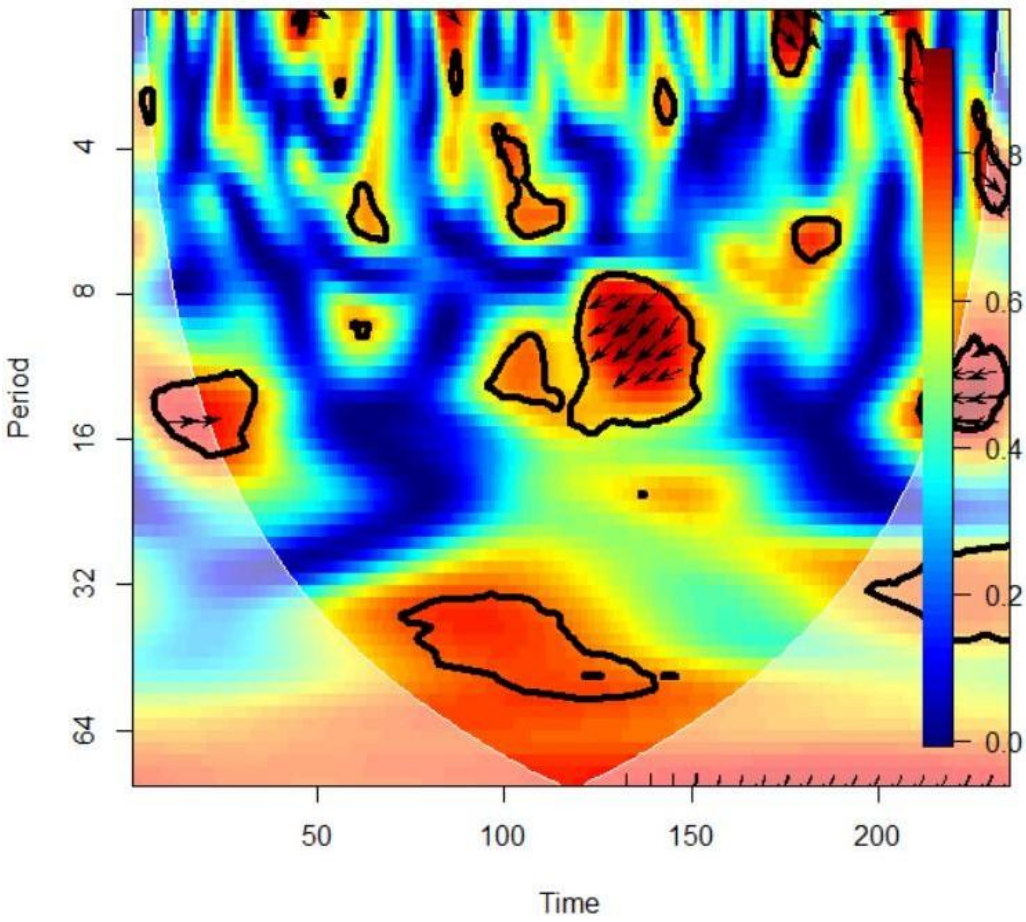
A preliminary study of the converted return time series was carried out before the primary empirical methods were applied. The volatility of the gold and oil markets differs significantly, according to descriptive statistics, and the economic policy uncertainty index fluctuates a lot. The use of time-frequency approaches to investigate dynamic linkages is supported by the fact that time series reveal times of elevated volatility that align with recognized bouts of geopolitical and economic unrest.
In order to guarantee stationarity and enable insightful comparisons across various scales, all price series are converted into logarithmic returns. The wavelet and VAR-based analysis then make use of the converted series.

Variable	Mean	Std_Dev	Min	Max
EPU_lr	-0.000498911	0.2482473030889	-0.652111305170519	1.07
Oil_lr	0.00522284080005564	0.0957311347198	-0.310955370495573	0.46
Gold_lr	0.00356330574484379	0.0417073233683	-0.184491464821565	0.16

4.2 Continuous Wavelet Coherence Analysis

There is significant temporal and frequency fluctuation in the wave coherence between oil yields and economic policy uncertainty. High coherence periods are primarily found in medium and long-term horizons, indicating that taking into account lower frequencies strengthens the link between the two variables. Short-term horizons, on the other hand, show limited and fractured cohesiveness, which suggests weaker or fleeting co-motion.

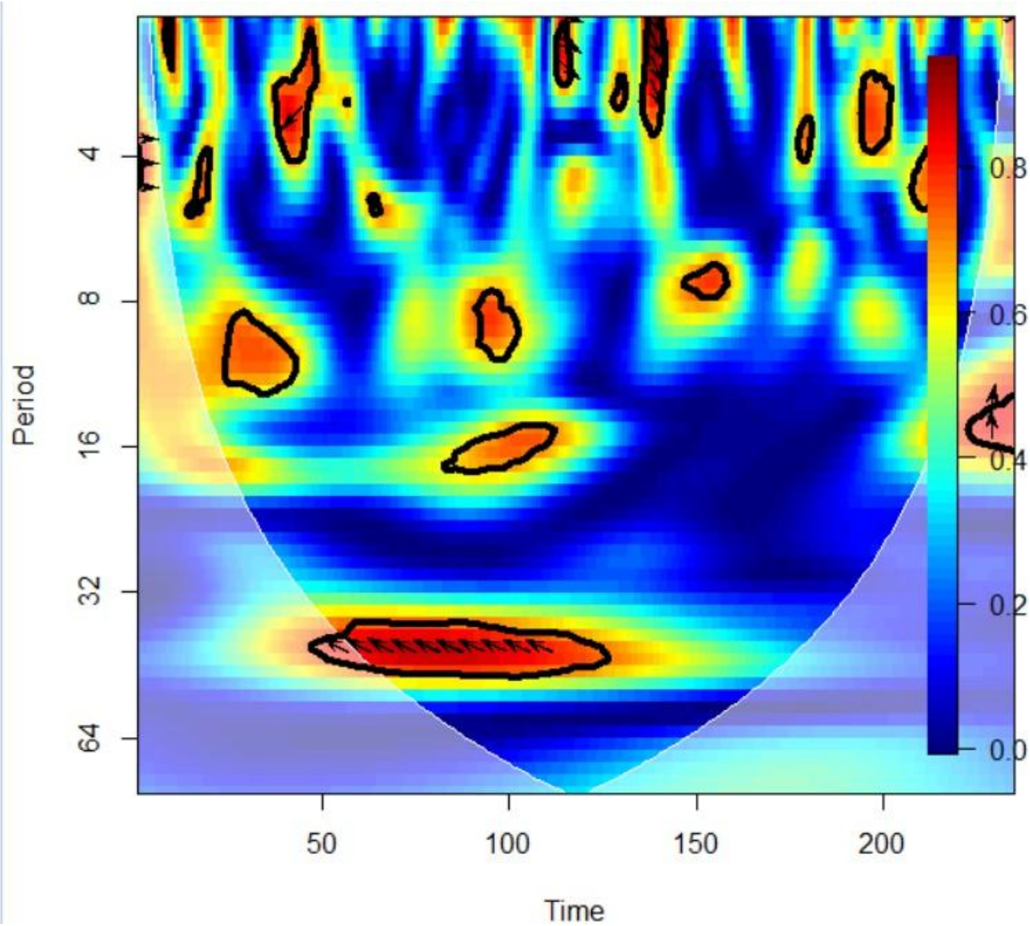
Figure 1: Wavelet Coherence between Oil Returns and EPU index



The wavelet coherence between oil prices and Economic Policy Uncertainty (EPU) is shown in Figure 1. Time-varying co-movements across several frequency bands are revealed by the results. The relationship between EPU and oil prices is neither consistent nor uniform throughout time, as seen by the strong coherence seen within certain sub-periods, especially at medium- and long-term horizons. The phase difference arrows indicate that, particularly at lower frequencies, EPU leads changes in the price of oil in a number of events, underscoring the influence of policy-related uncertainty on commodity price dynamics.

Wavelet coherence results for the link between EPU and gold yields indicate that consistency is primarily concentrated at low frequencies, or long-term investment horizons. The lack of consistency at higher frequencies, on the other hand, indicates that the relationship between uncertainty and gold prices predominantly takes the form of longer-lasting and more persistent mechanisms.

Figure 2: Wavelet Coherence between Gold Returns and EPU index



The wavelet coherence between EPU and gold prices is shown in Figure 2. Significant consistency is seen in the analysis, mostly over longer time horizons, which is in line with gold's function as a safe-haven asset. Phase arrows show alternating lead-lag correlations, with EPU seemingly driving gold price variations in some episodes and gold prices occasionally leading EPU during times of increased uncertainty.

4.3 Discrete Wavelet Transform (Robustness Analysis)

The logarithmic returns were subjected to a discrete wavelet transform in order to evaluate the robustness of the wavelet coherence results. While gold shows a consistently positive association with EPU, especially at medium and long-term scales, the scale-by-scale correlations show that the relationship between economic policy uncertainty and oil prices gets stronger in absolute terms at longer horizons. The scale-dependent dynamics found in the CWT analysis are supported by these results.

EPU – Oil (DWT)

Discrete wave transformation analysis demonstrates that there is a scale-dependent link between EPU and oil yields. Both the sign and size of the correlations vary, with the long-term components showing the highest absolute values. This result implies that political unpredictability's impact on oil is not constant over time but rather increases with longer investment horizons.

Scale	Corr
d1	0.192884
d2	0.105849
d3	-0.04375
d4	-0.03713
d5	-0.2776
d6	-0.37737

The association between oil price returns and economic policy uncertainty (EPU) varies over different time scales, according to the discrete wavelet transform. The association is favorable but somewhat modest for short-term horizons (d1–d2). The connection turns negative as the analysis shifts to medium-term scales (d3–d4), indicating a decoupling of changes in oil prices from policy uncertainty. Interestingly, the correlation becomes stronger in absolute terms and stays negative over long-term horizons (d5–d6), suggesting that prolonged periods of high policy uncertainty are linked to reduced returns on oil prices. The long-term dynamics found in the continuous wavelet coherence analysis are supported by these results.

EPU – Gold (DWT)

The correlations derived from the DWT for gold are positive on most scales and progressively get stronger as the time horizon increases; the sign's stability and the rise in correlation intensity at low frequencies suggest that the relationship between economic policy uncertainty and gold yields compared to oil is more stable and long-lasting.

Scale	Corr
d1	0.119472
d2	0.047645
d3	0.213173
d4	0.099948
d5	-0.08945
d6	0.134811

Across the majority of scales, the DWT-based correlations for gold prices show a consistently positive relationship with economic policy uncertainty. At short-term horizons (d1–d2), the association is rather weak; however, at medium- and long-term scales (d3–d6), it gets stronger. Given that higher degrees of economic policy uncertainty are typically linked to higher gold returns over longer investment horizons, this pattern is consistent with gold's function as a safe-haven asset. Overall, the conclusions drawn from the wavelet coherence analysis are strongly supported by the DWT results.

4.4 VAR Framework and Granger Causality Tests

The logarithmic return series of the prices of gold, oil, and EPU were subjected to enhanced Dickey-Fuller tests. The use of a VAR framework for Granger causality analysis is validated by the results, which show that all series are stationary at standard significance levels.

Criterion	Selected_L
AIC(n)	1
HQ(n)	1
SC(n)	1
FPE(n)	1

The Final Prediction Error (FPE), the Schwarz Criterion (SC), the Hannan–Quinn (HQ), and the Akaike Information Criterion (AIC) were used to determine the ideal lag time for the VAR model. Every criterion consistently showed one lag. As a result, a VAR(1) specification was used.

Granger causality test results show that there is a statistically significant unidirectional causal relationship between economic political uncertainty and oil and gold yields. However, there is no evidence of a causal relationship between the goods' returns and the EPU. This result supports the theory that economic political uncertainty functions as an external element in commodity markets and is consistent across all levels of significance evaluated.

Direction	F_statistic	p_value	Conclusion
EPU вт' Oil	5.222218	0.005611	YES
Oil вт' EPU	0.502538	0.605214	NO
EPU вт' Gold	5.222218	0.005611	YES
Gold вт' EPU	0.702273	0.495812	NO

Causality between EPU and Oil Returns

The results show a statistically significant Granger causal relationship between EPU and oil returns (F-statistic = 5.22, p-value = 0.0056). This finding implies that historical realizations of economic policy uncertainty provide valuable information for forecasting future changes in oil prices.
On the other hand, there is no indication of reverse causality between oil returns and EPU (p-value = 0.6052). This asymmetry suggests that changes in oil prices do not consistently affect how policy uncertainty develops.

5. Causality between EPU and Gold Returns

The correlation between EPU and gold returns exhibits a similar causal pattern. The findings show that there is a statistically significant unidirectional causal relationship between EPU and gold returns (F-statistic = 5.22, p-value = 0.0056), but the opposite relationship is not significant (p-value = 0.4958).

5.1 Comparison between Oil and Gold

Despite perhaps using distinct transmission routes, the causality results show that both the gold and oil markets react to policy uncertainty. While gold returns convey investors' risk-hedging behavior, oil returns reflect uncertainty through predictions of economic growth and energy demand.
Notwithstanding these structural variations, the causal relationship between the two commodities is the same: commodity returns are driven by economic policy uncertainty rather than the other way around. This consistent pattern lessens the possibility that the outcomes are the product of peculiar market dynamics and increases the findings' robustness.

In order to lay the groundwork for the more in-depth discussion that takes place in the subsequent subchapters, this subchapter summarizes and interprets the key empirical findings that were presented in Chapter 4. Highlighting the key trends that emerge from the combined use of time-frequency approaches and econometric causality controls, as well as elucidating the ways in which economic political uncertainty impacts the gold and oil markets, is the goal rather than reproducing the statistical findings.

Overall, the analysis's findings demonstrate that there is neither a stable nor consistent relationship between economic policy uncertainty (EPU) and commodity prices across time. On the other hand, it exhibits significant frequency dependency and temporal variability, confirming the value of wave approaches in the analysis of intricate macrofinancial linkages. Wave coherences show that while short-term links seem weaker and less reliable, the strongest co-movements between EPU and the prices of gold and oil are mostly found in medium- and long-term investment horizons.

The two commodities' distinct responses to political and economic instability constitute a second important discovery. Oil and EPU primarily have a negative association at low frequencies, indicating that lower oil output are linked to extended periods of increasing uncertainty. On the other hand, gold and EPU continuously show a positive link that gets stronger as the analysis time horizon grows. This asymmetry implies that while political uncertainty affects both commodities, the transmission mechanisms are essentially distinct from one another.

The preceding conclusions are further supported by discrete waveform transformation (DWT/MODWT) analysis, which provides strong evidence for the results' robustness. The correlations between EPU and oil vary in sign and intensity, with long-term components showing the strongest associations, according to the decomposition of time series at various scales. On most scales, however, correlations for gold stay positive, indicating a more steady and consistent reaction to the uncertainty of economic policy.

The Granger causality tests in the context of the VAR model demonstrate the EPU's unidirectional causality towards the yields of both gold and oil, which is particularly significant. The lack of reverse causality implies that commodities markets adapt to the development of economic uncertainty policy rather than systematically influencing it. This finding supports the idea that EPU functions as an exogenous macroeconomic agent that influences markets through risk perception, investment behavior, and expectations.

5.2 The role of economic uncertainty in commodity price formation: a comparison with the relevant literature

In addition to providing fresh, more thorough evidence about the frequency and temporal nature of these effects, Chapter 4's findings mainly support the body of worldwide research on the subject of economic political uncertainty (EPU) as a major determinant of commodities markets. According to the analysis, the EPU mainly acts as an exogenous macroeconomic shock that affects the gold and oil markets through perceptions of risk, investment behavior, and expectations.

The findings of Kilian (2008) and Hamilton (2009), who contend that expectations for future economic activity have a significant impact on oil prices, are consistent with the negative association between economic policy uncertainty and oil yields, particularly over medium and long-term horizons. These expectations decline in a setting of increased political unpredictability, which lowers anticipated demand and puts pressure on oil prices. The study by Albulescu et al. (2019) comes to similar conclusions, indicating that EPU has a negative impact on energy markets, particularly when uncertainty increases over time.

However, the current study's results are consistent with those of Soni et al. (2023), who also used wave techniques to discover that the influence of EPU on oil is much stronger at lower frequencies and weaker in the short term. This result supports the theory that oil responds more to long-term, structural shifts in uncertainty than to brief news or political shocks.

On the other hand, Chapter 4's findings support gold's status as a safe haven during periods of increased economic policy uncertainty. The classic research by Beckmann et al. (2015) and Baur and Lucey (2010), which show that gold maintains or increases in value during periods of political and economic upheaval, are consistent with the positive and enhanced long-term link between EPUs and gold yields. The findings also align with those of Tronzano (2020) and Xiao et al. (2022), who note that the main reason for the increase in demand for gold is when uncertainty becomes systemic and impacts long-term investor expectations.

The current study, however, deviates somewhat from other studies, including Singh's study (2022), that discover a weak or non-statistically significant correlation between EPU and gold throughout specific time periods or geographical settings. This discrepancy can be explained by the methodological approach: whereas the majority of earlier research is based on time-stable models, the current analysis's use of wave methods enables the revelation of relationships that primarily occur at particular frequencies and times of extreme uncertainty.

Lastly, the results of Pastor and Veronesi (2013) and Brogaard and Detzel (2015), who contend that political uncertainty influences markets as a factor that raises risk premia, independent of individual market movements, are in line with the EPU's finding of unidirectional causality towards commodity prices. The lack of reverse causality distinguishes the current study from studies that indicate the existence of bidirectional links only under extremely particular crisis settings and supports the idea that EPU is an external macroeconomic element.

5.3 The oil market's reaction to economic political uncertainty: interpretation and comparison with the literature

The results of Chapter 4 demonstrate that the oil market responds to economic political uncertainty (EPU) in a distinct and systematic manner, with significant variations based on the time horizon of investigation. According to the wave analysis, the highest correlations between EPUs and oil yields are mostly observed over medium- and long-term investment horizons; in the short term, however, the association is weak or dispersed. This pattern implies that the oil market is largely impacted by protracted periods of uncertainty that mold expectations for future economic activity rather than by brief political shocks or news developments.

The observed inverse correlation between EPUs and low-frequency oil yields is mainly consistent with the basic research on the dynamics of oil prices. According to Kilian (2008) and Hamilton (2009), expectations regarding future global demand and economic growth have the biggest impact on oil prices. These expectations sometimes worsen during periods of increased political unpredictability as individuals and businesses put off investments and consumption, which lowers the anticipated demand for energy. The current study's findings support this strategy by demonstrating that when uncertainty becomes structural rather than transient, its impact on oil becomes more significant.

Similar findings come from research by Albulescu et al. (2019), who discover that energy markets are adversely impacted by economic political uncertainty, particularly when that uncertainty is connected to trade policies, regulatory actions, or geopolitical conflicts. These results are further supported by this investigation, which demonstrates that the detrimental impact of EPU on oil is not time-stable but rather amplified at particular frequencies that conventional temporal models are unable to fully capture.

The work by Soni et al. (2023), which uses wavelet-based Granger causality to determine that EPU has a minimal impact on oil in the short term but gains strong predictive power over medium and long-term horizons, is likewise consistent with the differentiation of outcomes by time horizon. This result supports the idea that oil, a cyclical commodity that is closely related to the actual economy, reacts mostly to ongoing shifts in uncertainty that have an impact on production plans and demand patterns.

The current study's findings, however, diverge somewhat from those of studies that affirm the presence of transient or reciprocal connections between EPUs and oil, especially during times of extreme geopolitical unrest. For instance, some research indicates that abrupt shifts in oil prices, particularly in economies that produce the commodity, can increase political unpredictability. However, no statistically significant reverse causal relationship between oil and EPU is shown in the current study, indicating that political uncertainty precedes and is not influenced by changes in the oil market in the sample and environment under investigation.

Overall, Chapter 4's findings confirm that macroeconomic and political uncertainty are received by the oil market, with effects primarily appearing over medium- and long-term timeframes. The results of the current study provide a more thorough, often sensitive interpretation of the relationship between economic policy uncertainty and oil prices, while also being highly consistent with established theoretical and empirical approaches, according to a comparison with the pertinent literature.

5.4 Gold as a safe haven in a context of economic political uncertainty

According to Chapter 4's findings, gold has a consistent and long-lasting positive correlation with economic political uncertainty (EPU), especially over medium- and long-term investment horizons. This finding supports the idea that gold is a safe-haven asset and confirms that investors seek it out when political and institutional uncertainty rises.

The classic findings of Baur and Lucey (2010), who demonstrate that gold serves as an effective haven during periods of extreme financial and political instability, are mostly consistent with the positive association between EPU and gold yields, which is increased at low frequencies. Similar to this, Beckmann et al. (2015) note that gold's function as a safe haven is increasingly prominent during systemic crises, which is in line with the long-term strengthening of the EPU-gold association identified in this study.

The application of wave methods enables us to observe that, even in the near term, gold's response to economic and political instability is not instantaneous. Rather, as uncertainty grows more persistent and influences investors' long-term expectations regarding inflation, currency stability, and the legitimacy of economic policy, the relationship is progressively getting stronger. This result is in line with research by Tronzano (2020) and Xiao et al. (2022), who contend that gold reacts more to systemic risk situations than to short-term variations in uncertainty.

The current study's findings, however, deviate somewhat from studies like Singh's (2022), which found no statistically significant relationship between EPU and gold prices. This distinction can be ascribed to the methodological approach as well as the various time periods of analysis. The current analysis demonstrates that the EPU–gold association is primarily evident at particular frequencies and times of high uncertainty, which may be "smoothed out" in temporal averages, in contrast to the majority of earlier research, which was based on linear models with fixed parameters.

Furthermore, the idea that gold serves as a reactive rather than a formative component of political uncertainty is supported by the lack of reverse causation from gold's yields to the EPU. This finding supports the claim made by Pastor and Veronesi (2013) that safe haven assets absorb uncertainty without changing it.
Overall, Chapter 4's conclusions support gold's function as a long-term political risk hedge. Gold's behavior can be better understood by considering the frequency and length of uncertainty, which provide a more nuanced and accurate interpretation than conventional methods.

5.5 Interpretation of lead-lag relationships and market reactions

The unidirectional causal relationship between economic political uncertainty and gold and oil yields is one of the most significant conclusions in Chapter 4. While no reverse causality is seen, Granger causality studies demonstrate that historical EPU values include information to forecast future commodity returns. This finding is especially significant for comprehending how political unpredictability functions as a primary macroeconomic driver.

Pastor and Veronesi's (2012, 2013) theoretical methods, which contend that political uncertainty raises risk premia and influences markets through expectations for future policy actions, are consistent with the relationship's unidirectional nature. In this case, commodity markets reflect changes in risk perception and macroeconomic outlook by incorporating uncertainty into their prices rather than shaping it.

The leading effect of EPU is more noticeable at low frequencies, according to wave analysis results, which provide more depth in the interpretation of lead–lag interactions. According to this research, political unpredictability influences markets more gradually through the change of investor expectations than through sudden news shocks. The findings of Soni et al. (2023) and Arouxet et al. (2023), who discover that the leading-lagging variable correlations between EPUs and markets primarily appear in medium and long-term investment horizons, are similar.

The results of the current analysis do not corroborate the existence of reciprocal correlations between commodity prices and political uncertainty, despite several studies supporting this idea, especially during periods of severe geopolitical crises. The lack of reverse causation between gold or oil and the EPU indicates that markets do not consistently affect the degree of political uncertainty in the sample under study. This finding sets this study apart from studies that focus on certain economies or eras where commodities revenues are heavily relied upon.

It's also crucial to distinguish between the lead-lag processes in gold and oil. Gold reacts through the impression of danger and the desire for protection, whereas oil predominantly responds through the real economy and demand expectations. The generalizability of effects is improved by the fact that both commodities show a similar pattern in the direction of causality despite these variations.
Overall, the examination of lead-lag correlations demonstrates that one of the main driving forces behind commodities markets is political and economic uncertainty. A deeper comprehension of the temporal mechanics of uncertainty transmission is made possible by the combination of wave methods and causality tests, which emphasizes the critical role that expectations and the length of uncertainty play in determining the price of gold and oil.

5.6 Comparative analysis of oil and gold under conditions of economic policy uncertainty

A comparative analysis of Chapter 4's findings reveals significant distinctions between the ways in which gold and oil react to economic political uncertainty (EPU), demonstrating that the two commodities function through distinct financial and economic channels. The EPU has an impact on both markets, but the effects' magnitude, direction, and time horizon vary greatly, supporting the theoretical differentiation between cyclical and countercyclical assets.

The findings indicate that, over the medium and long term, oil and economic policy uncertainty are primarily negatively correlated. This behavior is closely related to oil's function as a vital component of production and a gauge of world economic activity. Expectations for future growth and energy consumption decline during times of high EPU, which puts pressure on oil yields. This result is consistent with research by Kilian (2008) and Hamilton (2009) as well as more recent studies like Albulescu et al. (2019), which highlight how political unpredictability has a detrimental impact on energy markets through investment choices and the demand channel.

A comparison of the wave analysis results also shows that the frequencies at which the EPU–oil and EPU–gold correlations occur differ. For gold, the link is more stable and less susceptible to short-term swings, whereas for oil, the biggest co-movements happen during certain times of extreme and protracted uncertainty. This result is consistent with research by Soni et al. (2023) and Xiao et al. (2022), who contend that the way commodities react to EPU varies according to their core attributes and their place in investors' portfolios.

Notwithstanding these variations, the direction of causality is a feature that both commodities share. Granger audits demonstrate that there is no evidence of a reverse causal relationship between changes in oil and gold yields and economic political uncertainty. This finding is consistent with the theoretical frameworks of Pastor and Veronesi (2013) and lends credence to the idea that the EPU operates as a common macroeconomic factor that influences markets in diverse ways based on the type of asset in question.

Overall, the comparative study indicates that gold and oil are reacting to political and economic unpredictability in different but complimentary ways. Gold represents the change in investing psychology and the desire for security, whereas oil mostly represents the impact of uncertainty on the actual economy. This distinction emphasizes the significance of multi-asset analysis in the context of economic uncertainty and improves our knowledge of the heterogeneity of commodity markets.

6. Conclusion

This chapter outlines the study's key findings, emphasizes its theoretical and practical contributions, identifies its primary shortcomings, and makes recommendations for future research areas. The thesis used a combined methodological approach that incorporates time-frequency analysis and econometric causality controls to examine the relationship between Economic Policy Uncertainty (EPU) and the yields of two major commodities, gold and oil.

6.1 Main findings

The study's primary finding is that there is no steady or linear relationship between economic policy uncertainty and commodity markets; rather, it varies greatly across time and across investment horizons. The co-movements between EPU and oil and gold yields are primarily reinforced in the medium and long range, according to the wave analysis's findings, whereas the correlations seem weaker and less stable at short-term scales. According to this research, markets are impacted by economic political uncertainty mostly when it becomes structural and persistent.

The findings indicate that, at low frequencies, the association between oil and economic political uncertainty is primarily negative. This inverse relationship implies that extended periods of increased uncertainty are linked to a drop in oil yields, which is indicative of lowered projections for future economic growth and energy use. This conduct supports the idea that oil is a cyclic good that is closely related to the actual economy.

The association between gold and economic political uncertainty, on the other hand, is constantly positive and gets stronger as the analytical time horizon grows. Given that investors typically raise their demand for gold during times of increased institutional and political risk, this result validates gold's status as a safe haven. Gold seems to react less to predictions for the actual economy and more to shifting risk perceptions than oil.

The findings of causative tests, which show that fluctuations in oil and gold yields are preceded by political and economic uncertainty, are particularly significant. The lack of reverse causality implies that commodity markets respond to political uncertainty rather than systematically influencing it, which strengthens the EPU's position as an exogenous macroeconomic actor.

6.2 Theoretical and practical contributions

The paper adds to the body of knowledge on economic uncertainty and asset pricing theoretically by demonstrating the multifaceted and time-dependent consequences of political uncertainty on commodities markets. The use of time-frequency techniques reveals dynamic interactions that conventional temporal models are unable to sufficiently capture, highlighting the need for more adaptable and multi-scaled methodologies.

Furthermore, the theoretical differentiation between cyclical and countercyclical (or safe) assets is strengthened by a comparison of gold and oil. The study demonstrates that, depending on the core attributes of the specific commodity and its use in investment strategies, the same source of uncertainty can have varying consequences.

Practically speaking, investors, risk managers, and those who formulate economic policy can all benefit from the findings. The findings emphasize how crucial it is for investors to diversify their holdings and choose appropriate assets based on the time horizon and degree of uncertainty. The EPU can serve as an early warning system for risk managers to modify their hedging tactics. The results show policymakers that increased uncertainty in policy choices can have significant but indirect consequences on markets.

6.3 Limitations of the study

Notwithstanding the methodical technique, the study has many drawbacks. First off, using monthly data may obscure short-term market responses to recent political developments, even if it is consistent with the EPU indicator's nature. Secondly, the research is predicated on a general measure of economic political uncertainty, which might not account for variations among nations or political uncertainty types.
Third, other macroeconomic variables that are known to affect commodity markets such as interest rates, currency rates, or inflation expectations are not explicitly included in the empirical framework, which mainly concentrates on bivariate interactions. Lastly, causality tests can only be interpreted in terms of pure causality because they only capture predictive relationships rather than deeper structural mechanisms.

6.4 Suggestions for future research

The current study could be expanded in a number of ways by future research. One viewpoint is to analyze more immediate market responses to political statements or events using higher-frequency data. Furthermore, adding more variables to multivariate time-frequency models would help to better understand the mechanisms of uncertainty transmission and adjust for potential confounding effects.

In order to determine whether the relationship between EPUs and commodities is systematically differentiated, another approach involves analyzing various eras or regimes, such as stages of economic crises or geopolitical tensions. Lastly, expanding the research to include additional commodities or uncertainty indicators unique to a certain nation may offer a more thorough understanding of how economic uncertainty affects global markets.

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