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Oil Supply Shock, Foreign Exchange Rate Misalignments and Industrial GDP: Copula-GARCH Estimation of Effects

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Abstract: This study examines the impact of oil price shock (OSS), and foreign exchange rate misalignments on industrial output in four oil-exporting economies of OECD: Denmark, Finland, Germany, and Ireland. The U.S. economic policy uncertainty (EPOU) serves as a moderating/control variable in the analysis. Using quarterly data from 2008 to 2024, the Copula-GARCH procedure was used in the study to explore the nexus between these key economic variables. The findings reveal that OSS and EPOU are significant drivers of industrial output in Denmark and Finland, being more vulnerable to external shocks. Foreign exchange rate misalignments do significantly influence industrial production some countries. Denmark's economy exhibits strong correlations between OSS and EPOU, with substantial tail dependence coefficients indicating that extreme negative shocks, such as oil supply downturns, significantly correlates with adverse policy changes. Finland's industrial production is similarly influenced by these factors, though the relationship with FXM is weaker, reflecting the less direct impact of foreign exchange market misalignments on industrial output. The interaction of oil supply shocks and forex market misalignments reveal substantial association with industrial production, given significant Kendall values with robust tail dependence in Ireland and Germany respectively. There is a considerable industrial output effect of joint influence from oil supply shocks and the uncertainty arising

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from economic policy. The joint effect of policy uncertainty and foreign exchange rate misalignments was also robust for all countries. While both Germany and U.K. are also affected by oil supply shocks, the detrimental influence becomes stronger in Denmark and Finland as policy uncertainties that characterized the monetary and fiscal policies of the U.S. rises. The study underlines the importance of economic diversification, and improved policy frameworks. In addition, it highlights the necessity for funding green power to strengthen manufacturing to enhance industrial productivity. This research contributes to the empirics of dynamic interdependencies amongst oil supply shock, forex market misalignments and industrial growth.

Keywords: OECD, industrial output, Copula-GARCH model, oil-producing economies

JEL Classification: A20, B30, C34

1. Introduction

Over the years, oil producing countries have become highly susceptible to the volatility of global oil prices, which directly impact their economies, particularly government revenue and economic output. These countries often face a delicate balancing act, as they must adapt to shifting oil prices while also managing the risks posed by external economic shocks and policy changes in major economies such as the U.S. (Jiang *et al*., 2020). When oil prices rise, these countries often experience increased revenues, which can be channeled into industrial production and investment in infrastructure. On the contrary, a steep drop in oil prices can lead to reduced economic activity, cutting back on industrial production due to lower income from oil exports (Baumeister & Kilian, 2016). Shocks in oil supply can induce both direct and indirect effects on industrial activities, influencing production costs, investment decisions, and long-term planning. Oil supply shock refers to the unpredictability and volatility in crude oil supply, driven by factors such as geopolitical events, economic policies, natural disasters, and market speculation. Oil supply shocks affect fiscal revenues, exchange rates, and investment decisions, making it a pivotal economic indicator, especially in oil-dependent economies (Kilian & Zhou, 2018). Hence, the volatility of global oil markets remains a critical concern for oil-exporting countries, as fluctuations in oil supply and/or production significantly influence macroeconomic stability and industrial production. A drop in oil prices reduces national income of oil-exporting nations and this leads to budgetary constraints and cuts in public spending (Pindyck, 2021). In reverse, an increase in oil production can result in a revenue surge that may overheat the economy and cause inflation (Arezki & Bruckner, 2019). These fluctuations also affect industrial output (GDP), as industries reliant on oil production face higher costs whenever there are drops in output supply or reduced demand during price hikes.

While prior studies have explored the individual impacts of oil price uncertainty, U.S. EPOU, and FX market shocks on macroeconomic indicators, research focusing on their combined effects remains scarce. Most literature tends to isolate these variables, overlooking potential interdependencies that could offer deeper insights into their cumulative impact on industrial production (Chadwick, 2020; Huang *et al*., 2022). This gap is particularly pronounced in oil-exporting countries, where differing economic structures and policy frameworks may yield divergent outcomes (Fang & You, 2017; Rizvi *et al*., 2023). Existing global studies often provide broad assessments without region-specific considerations, thereby limiting their applicability to targeted policy interventions (Wang & Zhou, 2020; Lee *et al*., 2024).

The industrial sectors in OECD are particularly vulnerable due to their limited diversification and reliance on energy-intensive industries, which makes them sensitive to fluctuations in global oil supply/production variations. Prolonged periods of oil price volatility can dampen industrial growth by creating a lack of confidence among businesses, especially in capital-intensive sectors like manufacturing and construction (Liu *et al*., 2021). The spillover effects of oil supply shock are particularly pronounced in the context of global interconnectedness. The objectives include estimating and analyzing oil-exporting OECD countries; the effects of oil supply shock and forex misalignments, on industrial GDP. The ambiguity surrounding U.S. economic policy served as a control predictor in the model. The research accentuates the prominence of mitigating the adverse effects of oil supply shocks and economic policy uncertainty on exchange rate stability. For oil-exporting nations, especially those in oil-exporting OECD, these relationships are crucial for economic planning and ensuring long-term stability. In oil-exporting OECD, where economic performance is heavily reliant on oil revenues, addressing exchange rate volatility and reducing policy uncertainty is essential for attracting foreign investments and promoting sustainable growth. Similarly, understanding these dynamics helps maintain economic equilibrium in the face of external shocks, strengthening their role in global economic governance. This study is organized into six parts. The next reviews the existing literature on the topic. In Part 3, the study's methodology is covered in full, along with the econometric models that were used. The Copula-GARCH method, variable description, and data sources are all covered. The data analysis and findings are presented in Part 4, which provide a thorough assessment of the empirical findings. Part 5 was devoted to a thorough analysis of the findings and a comparison with similar findings that had already been acquired. Part 6 wraps up the study by summarizing the main conclusions and offering suggestions for policy.

2. Earlier Research Findings

Empirical studies have extensively analyzed the effects of exchange rate misalignments and oil price shock, on industrial production within OECD countries. Research from 2020 to 2024 reveals as follows: With respect to exchange rate shocks, the results obtained by Mason & Carter (2022) who evaluated empirically the influence of exchange rate misalignment on industrial output in the United States and Canada, using a panel data approach. The findings showed that exchange rate depreciation positively affected industrial production in export-intensive industries, particularly in Canada's oil and gas sector. However, in both countries, exchange rate volatility increased production costs for energy-intensive and import-dependent industries. The authors suggested that governments adopt hedging strategies and enhance policy frameworks to reduce the adverse effects of exchange rate shocks on industrial output. Müller & Schmidt (2021) studied the effects of exchange rate misalignment on industrial production in Germany using a VAR model. The study analyzed the joint effect of exchange rate changes, and export competitiveness on industrial output. The findings revealed that exchange rate appreciation negatively impacted industrial production, particularly in export-driven industries such as automobiles and machinery. Conversely, depreciation enhanced industrial competitiveness, albeit with a lag effect due to adjustment costs. The authors suggested that Germany adopt a more flexible exchange rate policy to maintain competitiveness and stabilize industrial growth in the face of global currency fluctuations.

On previous evidence regarding oil supply shocks, the quantile AR model results of Ozcelebi *et al.* (2025) uphold that under both typical and severe conditions, oil shocks are the greatest net sender of shocks to the US sectors. This suggests that oil shocks are responsible for substantial fluctuations in US sectors. Furthermore, the research findings highlight the part that asymmetry plays in the US sector's reaction to oil shocks in stocks, implying that asymmetric features should be accounted for by those who seek to lessen the negative effects of oil shocks on the stock market and advance financial stability. The impact of shocks to oil supply, the total demand,

and oil-specific demand on Alaska's oil industrial output is the subject of in-depth research by Baek (2024). The study discovered that while oil-specific demand shocks have little effect, oil supply and total demand shocks have a major effect on oil production across both short and long time periods. The study finds asymmetric long-term impacts, especially when it comes to how aggregate demand and demand shocks related to oil affect Alaska's oil output. In the medium run, however, no asymmetric consequences were noted for the three oil shocks.

Ahmed & Sener (2024) demonstrated that oil price shocks disproportionately affected energy intensive industries, with stronger impacts observed in oil-importing nations. Their recommendations include reducing fossil fuel dependence and enhancing energy efficiency to mitigate volatility-induced disruptions. The aggregate demand-side effects of oil price shocks are similarly significant across SEE and G7 economies. Liu and Wang (2024) using a GARCH-in-mean model, found that while Japan's diversified energy mix provided some protection, oil price increases still led to higher input costs, which negatively impacted industrial production. The study argued that Japan's reliance on oil imports made it vulnerable to global price fluctuations, and recommended stronger policy measures to increase domestic energy production.

Duong (2024) using monthly series, a two-block structural vector autoregressive model subjected short-term effect matrix to the lower triangular Cholesky decomposition. Using variation decomposition techniques, the researchers found that while positive shocks in aggregate demands considerably and persistently raise these domestic indicators, oil supply shocks have a negligible impact on nationwide industrial output. Supply-side oil shocks have very little explanatory power for changes in domestic variables, according to analysis of variance decompositions. The research reported possible threats to Vietnam's economic future in the event that the effects of fluctuations in oil prices are not adequately addressed. Barbosa and Silva (2023) focused on the effect of oil price shocks on the economies of Italy and Spain, two key economies in the Southeast European region. They applied the input-output model and discovered that both countries experienced substantial declines in industrial production due to higher oil prices, particularly in the manufacturing and transportation sectors. The authors also reported that shocks exacerbate inflationary pressures, which in turn impacted the purchasing power of households.

In West African oil-exporting nations, Umoru *et al*. (2023) evaluated the extent to which news shocks about the oil supply affected exchange rate variations as well as the influence of exchange rate variations on news shocks about the oil supply. Estimates were made using the panel NARDL model. According to the study's findings, exchange rate depreciation is considerably induced by increased variations in news about disruptions in the oil supply. Unmistakably, a spike in news shocks of 1% about the oil supply sparked an appreciation of 1.59432 percent, while a corresponding drop in oil supply news resulted in a devaluation of 0.86397 percent. These confirm the existence of asymmetrical exchange rate behaviour with respect to the oil market. WA's oil-producing nations ought to use the foreign cash (FX) received from oil exports to fund capital-intensive projects. The study recommends that WA's oil-producing nations use the FX from oil exports to fund costly projects.

Adi, Samuel, and Amadi (2022) used daily data to study the transmission of shock and volatility between the exchange rate and oil price markets. In order to capture the spillover effect of shock and volatility, the study used the VAR-AGARCH model. The study found that present exchange rate and oil price market volatility is largely influenced by prior shocks and volatility. The USD/Naira and Brent oil price experienced bidirectional shocks and volatility spillovers, while the Brent oil price experienced unidirectional shocks and volatility spillovers to the efficient market for exchange rates. While a symmetric shock was identified in the price of Brent oil, the researchers also reported asymmetric shocks affecting exchange rates and the price of WTI oil. When establishing foreign exchange strategy and simulating shocks to currencies and instability, it is imperative to take oil price innovation into account. This was advised by the authors.

Graham and Reijnders (2021) conducted a study on the impact of oil price shocks on industrial output in Canada, employing the IS-LM model to assess supply-side effects from 2016 to 2021. According to the IS-LM framework, increases in oil prices raise the cost of production, leading to a leftward shift in the aggregate supply curve, which reduces output and increases inflation. The study found that Canada's dependence on oil production provided some insulation against oil price shocks, but other energy-intensive industries experienced significant downturns. The authors suggested that while oil price shocks can act as a stabilizing factor for oil-exporting economies like Canada, the broader economy still suffers due to increased costs in the manufacturing and transportation sectors. Based on these findings, they recommended diversifying the energy mix and improving energy efficiency across all sectors of the economy.

With regards to studies on the aggregate demand-side effect of oil price shocks on the economy; Bovens *et al*. (2024) focused on the aggregate demand-side consequences of oil price shocks in Italy, a key member of the G7. Using a nonlinear time-series model, results showed that oil price increases significantly contracted household consumption, especially in low-income households that faced higher energy and transportation costs. The authors recommended fiscal policies focusing on income redistribution and energy transition incentives to buffer the negative consequences of rising oil prices on domestic consumption.

Petrovic and Mirovic (2024) analyzed the effects of oil price shocks on economic stability in the G7 countries, with a focus on Japan and Germany. The study applied the monetary policy transmitting mechanism as a channel that influences aggregate demand and economic activity through various channels, including oil prices. Utilizing a GARCH-based econometric model, they examined data from 2015 to 2024 to explore the volatility transmission between oil prices and indicators such as GDP, unemployment, and inflation. The study found that variations in the cost of oil had a negative impact aggregate demand side of the economy, leading to reduced disposable income and weaker consumption. Policymakers were urged to develop strategies to decouple economic growth from oil price volatility, particularly by promoting green technologies and improving energy efficiency.

Kostadinov (2023) investigated the impact of oil price fluctuations on the industrial output of South East European oil-importing economies, focusing on Romania and Greece. The study applied the supply-side economics theory, which highlights the role of production costs, including oil prices, in influencing industrial output. Using a co-integration approach, the study analyzed time-series data from 2010 to 2023. The results showed that a rise in the pricing of oil had a significant negative effect on industrial production, especially in the manufacturing sector. The study noted that oil price volatility exacerbated inflationary pressures, reducing consumer purchasing power and weakening domestic demand.

Zhang and Zhao (2022) examined the aggregate demand-side effects of oil price fluctuations on the economies of G7 nations, particularly the U.S. and Canada. Results shown oil price shocks significantly affected domestic consumption and investment, with the U.S. exhibiting higher sensitivity due to its greater oil consumption. The study found that rising oil prices led to reduced consumer spending and private investment, mainly through increased production and transportation costs.

Vukovic *et al.* (2021) examined the impact of shocks to oil pricing on economic growth of Southeast European economies of Serbia, Croatia, and Bulgaria. The study utilized the Keynesian aggregate demand model, which emphasizes the relationship between national output and aggregate demand, especially under the influence of external shocks such as oil prices. Using a panel data approach and the ARDL model, the study examined both short-run and long-run dynamics. The results showed short-term effects included a significant adverse impact on industrial production and consumption, while long-term effects were less pronounced. The authors suggested diversifying energy sources to reduce the detrimental consequences of oil price shifts and enhance economic resilience.

The reviewed studies provide consistent recommendations to reduce the negative implications of changes external shocks for industrial production. These include developing alternative energy sources to reduce dependence on oil imports, implementing clear and consistent economic policies to enhance investor confidence and reduce misalignments of exchange rate through the mitigation of the impacts of currency fluctuations to promote domestic production, and enhance industrial productivity and efficiency. In conclusion, the literature underscores the interconnectedness of oil supply shock, foreign exchange market misalignments, policy uncertainty with industrial production, highlighting the need for tailored and proactive policy interventions to foster economic resilience in all countries.

3. Methodology

Econometric methods such as the GARCH-Copula approach was utilized to capture the dynamic volatility of oil prices, illustrating how fluctuations impact industrial production through both cost-push and demand-side effects. The Copula-GARCH regression model integrates copula theory with GARCH models to capture the complex dependencies and volatility dynamics among multiple economic and financial variables. This methodological approach is particularly useful when examining non-linear and time-varying relationships, such as the impact of oil supply shock (OSS), uncertainty about US economic policy (EPOU), and foreign exchange market misalignments (FXM) on industrial production (IGDP) (Bollerslev, 1986; Patton, 2006).

GARCH models approach captures heteroskedasticity, which manifests as fluctuations in variance over time in response to new economic information. By applying GARCH models, this study seeks to understand how volatility in OSS, EPU, and FXM affects IGDP (Engle, 2001). However, traditional GARCH models assume linear relationships, which may be inadequate when analyzing financial and economic data exhibiting non-linearity or tail dependence. To address this limitation, Copulas are incorporated to model marginal variations and the dependence structure independently. This approach enhances flexibility in capturing non-linear interdependencies and tail dependence which are essential for financial analysis, particularly during periods of market stress and policy uncertainty (Joe, 1997; Patton, 2006). In this study, the Copula-GARCH model is employed to examine the dependencies between OSS, EPU, FXM, and IP. The analysis follows a two-phase procedure. First, the marginal distributions of each variable are estimated using appropriate patterns of probabilities, such as the normal, t-distribution, or skewed distributions, depending on the empirical characteristics of each dataset. Next, the GARCH model is applied to each variable to track volatility that changes over time. The conditional variance equation for IGDP is given as:

$$\sigma^2_{IGDPit} = \vartheta_i + \theta_i \mu^2_{i,IGDPt-1} + \beta_i \sigma^2_{i,IGDPt-1} \tag{1}$$

where $\mu^2_{i,IGDPt-1}$ represents the lagged residual term, and $\sigma^2_{i,IGDPt-1}$ denotes the conditional variance of industrial production, σ^2_{it} is conditional variance of each series, ϑ_i is constant term, θ_i is coefficient for the past shocks $\mu^2_{i,t-1}$, β_i is coefficient for the past variance $\sigma^2_{i,t-1}$, The log-likelihood (LL) value for our sample is as given in equation (2) if q is the column of all coefficients to be estimated:

$$\ell(q) = \sum_{t=1}^{T} \ell t(q), \tag{2}$$

where:

$$\ell t(q) = \ln c(F_1(z_{1t}; q_1), F_2(z_{2t}; q_2), Q(z_{1,t-1}, z_{2,t-1}; q_c)) + \sum_{i=1}^{2} \ln f_i(z_{it}; q_i)$$

The first term captures the copula density, modeling dependence between variables. The second term represents the sum of log-marginal densities, describing individual distributions. Following the estimation of copula-GARCH components, each residual takes on an independent univariate GARCH process as earlier specified in equation (1). For i = IGDP, EPOU, FXM, OSS. Each residual is transformed into uniform margins using the probability integral transform:

$$U_{i,t} = F_i(\epsilon_{i,t}) \tag{3}$$

Accordingly, F_i represents the sum of the distribution function (CDF) of $\mu_{i,t}$. The dependence structure of the residuals was captured as shown in equation (4).

$$C(\mu IGDP, t, \mu EPOU, t, \mu FXMt, \mu OSSt; \theta) \tag{4}$$

Where $C(.)$ = copula function, $U_{i,t} = F_i(\mu_{i,t})$ are uniform margins, θ is the copula parameter measuring dependency. Accordingly, θ is used to simulate the reciprocal distribution of the residuals from the GARCH models. This enables capturing both linear and non-linear dependencies. A t-copula may be employed to model tail dependence, effectively capturing extreme co-movements among the variables during financial distress or oil price shocks (Patton, 2006). The choice of copula be it Gaussian, t-copula, or Archimedean, determines how the dependencies among OSS, EPOU, FXM, and IGDP are structured. The general specification of the Copula-GARCH regression model is expressed as:

$$\text{Copula-GARCH}= \begin{matrix} IGDPt - OSSt & IGDPt - EPOUt & IGDPt - FXMt \\ IGDPt - OSSEPOUt & IGDPt - OSSFXMt & IGDPt - EPOUFXMt \\ OSSt - EPOUt & OSSt - FXMt & EPOUt - FXMt \end{matrix}$$

where: IGDPt represents industrial production at time t, OSS_t is oil price uncertainty, EPOUt is U.S. economic policy uncertainty, FXM_t denotes shocks in the foreign exchange market, $OSSEPOU_t$ represents the interaction between oil price uncertainty and uncertainty associated with U.S. economic policies, $OSSFXM_t$ denotes the interaction between oil price uncertainty and foreign exchange shocks, $EPUFXM_t$ captures the interaction between U.S. economic policy uncertainty and foreign exchange shocks, ϵt is the residual term modeled using the GARCH framework.

The choice of copula be it Gaussian, t-copula, or Archimedean copulas, determines how the dependencies among OSS, EPU, FXM, and IGDP are structured. For example, a t-copula might be used to model tail dependence, which captures extreme co-movements between variables during periods of market stress or oil price shocks (Patton, 2006). The Copula-GARCH regression model has several key advantages. It allows for the modeling of non-linear dependencies between variables, which is crucial when relationships are not purely linear, as is often the case with oil price fluctuations and foreign exchange volatility (Patton, 2006). The model also provides flexibility in specifying marginal distributions for each variable, which is useful when dealing with data exhibiting skewness or heavy tails. Moreover, it can capture tail dependence, which is particularly important for understanding extreme events in economic data, such as financial crises or significant shifts in U.S. economic policies. Additionally, the GARCH component enables the modeling of time-varying volatility, allowing for a better understanding of how shocks in the oil market, U.S. economic policy uncertainty, and exchange rate movements affect industrial production over time.

This study uses daily series from February 1 to March 30, 2025 to examine the nexus between industrial production, oil supply shock, U.S. economic policy uncertainty, and misalignments in the foreign exchange market. Among the OECD nations that export oil are Denmark, Finland, Germany, and Ireland. Given their substantial oil exporting roles and differing levels of oil dependency, these nations were chosen to provide a range of viewpoints on the relationship between macroeconomic policy, foreign exchange volatility, and oil dependence. The dependent variable is industrial production, which includes all of a nation's industrial output from industries including mining, manufacturing, and utilities. Table 1 provides a detailed description of variables, and measurement of data and their sources.

Table 1: Description of Variables, Data Measurement, and Sources

Variables	*Description*	*Measurements*	*Data Sources*
Industrial Production (Dependent Variable)	Total industrial output of a country, covering manufacturing, mining, and utilities.	National industrial production indices.	IMF, World Bank.
Oil supply shocks	Measures the variations in oil supply/production	Historical production variations derived from WTI crude oil production benchmark.	OPEC data and U.S. (EIA)
Uncertainty that surrounds economic policies in the U. S.	Captures uncertainty in U.S. fiscal and monetary policies.	Baker, Bloom, and Davis (2016) EPOU index.	U.S.policy uncertainty website.
Foreign exchange rate misalignments.	Measures sudden fluctuations in exchange rates.	Difference between actual and expected exchange rate movements.	IMF, World Bank.
Interaction: oil supply shocks & U.S. economic policy uncertainty	Examines the combined effect of oil supply fluctuations and U.S. economic policy uncertainty.	Interaction term between oil supply variations and index of uncertainty that surrounds economic policies in the U. S. index.	Derived from existing datasets on oil supply variations and EPOU index.
Interaction: oil supply shock & exchange rate misalignments	Analyzes how oil supply variations impacts foreign exchange rate misalignments.	Interaction term between oil supply variations and foreign exchange rate misalignments.	Derived from EIA and World Bank
Interaction: Uncertainty that surrounds economic policies in the U. S. & foreign exchange rate misalignments.	Assesses the effect of Uncertainty that surrounds economic policies in the U. S. on foreign exchange market misalignments.	Interaction term between the EPOU index and foreign exchange rate misalignments.	Derived from EPOU index and exchange rate data.

Sources: Authors' estimation (2025) using Eviews 13

4. Results

The descriptive statistics are well behaved for each variable as contained in Appendices 1 to 4. The results of unit root test for all countries show that all variables are stationary. These are reported in Appendices 5 to 8. Appendix 9 shows only one co-integrating equation for Azerbaijan. Finland had also had one co-integrating relation as reported in Appendix 10. In Germany, and Ireland, two co-integrating relation were reported as seen in appendices 11 and Table 12 respectively. Table 1 presents the Copula-GARCH results for Denmark, showing the univariate GARCH model estimates for industrial GDP, and oil supply shock, economic policy uncertainty, and foreign exchange rate misalignments. Each variable is associated with key parameters (ω, α, β, γ) and the LL value, which together illustrate the dynamics of volatility. The parameter ω (constant) reflects the baseline variance, with industrial GDP having the highest value (0.0025), indicating the most inherent uncertainty among the variables. In contrast, Oil supply shock shows a relatively lower baseline variance (0.0016), suggesting minimal inherent volatility. Oil supply shock (0.1734) exhibits the strongest sensitivity to past shocks, followed by economic policy uncertainty (0.1521). Foreign exchange rate misalignments (0.1247) and industrial production (0.1126) demonstrate relatively lower sensitivity to previous shocks.

Economic policy uncertainty (0.8134) and foreign exchange market misalignments (0.8120) exhibit the highest persistence, suggesting that shocks in these variables have long-term effects on volatility. Industrial GDP has a slightly lower persistence (0.7864), while oil price uncertainty also shows strong volatility persistence (0.7542). The leverage term (γ) accounts for the asymmetry in volatility. Economic policy uncertainty (0.0418) displays the strongest leverage effect, indicating that negative policy-related shocks amplify shocks more significantly. Industrial GDP (0.0347) and oil supply shock (0.0283) also show moderate leverage effects, while foreign exchange rate misalignments (0.0125) exhibit minimal asymmetry. The LL values assess the goodness-of-fit for each variable. Oil supply shock had the highest log-likelihood (401.57), indicating the best model fit, followed by economic policy uncertainty (392.83). Foreign exchange rate misalignment (387.12) and industrial GDP (372.89) show slightly lower model fit quality. The analysis reveals that volatility persistence is consistently high across variables, emphasizing the lasting impact of shocks. Oil supply shock exhibits strong model fit and significant sensitivity to past shocks, while industrial GDP shows the highest inherent uncertainty. These results underscore the interconnected nature of these variables in an oil-exporting economy like Denmark, suggesting the need for further analysis to understand their joint behavior.

Table 1: Copula-GARCH Results for Denmark (Univariate GARCH Model Estimates)

Variable	*ω (Constant)*	*α (ARCH)*	*β (GARCH)*	*γ (Leverage)*	*Log-Likelihood*
OSS	0.0016	0.1734	0.7542	0.0283	401.57
EPOU	0.0023	0.1521	0.8134	0.0418	392.83
FXM	0.0018	0.1247	0.8120	0.0125	387.12
IGDP	0.0025	0.1126	0.7864	0.0347	372.89
IOSSEPOU	0.0021	0.1345	0.8012	0.0294	389.43
IOSSFXM	0.0019	0.1278	0.7956	0.0267	384.61
IEPOUFXM	0.0022	0.1439	0.8073	0.0315	391.78

Sources: Authors' estimation (2025) using Eviews 13

Table 2 provides an evaluation of different copula types Gaussian Copula (GAC), Clayton Copula (CC), Gumbel Copula (GC), and Student's t (S t-C) based on their ability to model the dependent pattern across variables. Three metrics log-likelihood (LL), AIC, and BIC are used to assess the performance of each copula. The LL values indicate the fit of each copula, with higher values representing better fits. The S t-C achieves the highest LL (470.4), followed by the GC (456.6), CC (452.8), and GAC (440.2). This suggests that the S t-C best captures the joint behavior of the variables.

AIC, which balances goodness-of-fit with model simplicity, also identifies the S t-C as the best-performing model, with the lowest value (-924.7). The Gumbel Copula (-897.3), CC (-891.6), and GAC (-872.4) rank lower, consistent with the log-likelihood results. The BIC, which applies a stricter penalty for model complexity, further confirms the S t-C as the most appropriate, with the lowest BIC value (-909.8). The GC (-883.9), CC (-878.2), and GAC (-861.7) follow in descending order. These results indicate that the S t-C provides the most accurate representation of the dependence structure, outperforming the other copula types in all criteria. Its ability to model tail dependence makes it particularly suitable for financial and economic data, where extreme co-movements are significant. In comparison, the Gumbel and Clayton copulas perform moderately well but are less comprehensive, likely due to their focus on specific aspects of dependence, such as upper or lower tails. The GAC shows the weakest performance, highlighting its limitations in capturing complex dependencies. Largely, the analysis underscores the importance of selecting a copula that accurately reflects the characteristics of the data.

Table 2: Copula-GARCH Selection and Goodness-of-Fit Results for Denmark

Copula Type	*AIC*	*BIC*	*Log-Likelihood*
Gaussian Copula	-872.4	-861.7	440.2
Clayton Copula	-891.6	-878.2	452.8
Gumbel Copula	-897.3	-883.9	456.6
Student's t-Copula	-924.7	-909.8	470.4

Sources: Authors' estimation (2025) using Eviews 13

Kendall's τ and tail dependence coefficients (λU and λL) are used to analyze the dependence structure among the study's crucial financial variables in Table 3. The results show that OSS and EPOU have the largest reliance among the variable pairs (τ = 0.53), indicating a substantial positive interaction between macroeconomic policy instability and oil supply shock. This suggests that oil supply shock closely align with changes in policy uncertainty. The next strongest relationship is between IGDP and OSS (τ = 0.49), highlighting the significant impact of oil supply shock on industrial GDP. Moderately strong dependencies are observed between OSS and FXM (τ = 0.48) and between EPOU and FXM (τ = 0.45), demonstrating notable interconnections among these variables.

For OSS and EPU, the coefficients (λU = 0.39, λL = 0.42) suggest a slightly higher probability of extreme negative shocks occurring jointly compared to extreme positive shocks. This asymmetry highlights the sensitivity of macroeconomic policy instability to significant negative changes in oil prices. A similar pattern is evident for IGDP and OSS (λU = 0.36, λL = 0.38) and for OSS and FXM (λU = 0.37, λL = 0.35), where extreme negative events are slightly more likely than positive ones. Across EPU and FXM, the tail dependence is the least (λU = 0.34, λL = 0.31), suggesting that there are fewer extreme co-movements between foreign exchange shocks and policy uncertainty. The findings highlight the crucial connections between industrial GDP, foreign exchange misalignments, policy uncertainty, and oil supply shock. The close correlation between OSS and EPOU highlights how important the oil supply shock is in causing uncertainty in economic policy. In the meantime, their interrelated dynamics are reflected in the mild dependencies involving OSS, FXM, and IGDP. Risky negative shocks are more likely to cascade across these variables, according to tail dependence research, underscoring possible threats to economic stability, especially for economies that export oil.

Table 3: Results of Dependence Parameters Copula-GARCH Model for Denmark

Variable Pair	*Kendall's τ*	*Tail Dependence (λU, λL)*
OSS - EPOU	0.53	(0.39, 0.42)
OSS – FXM	0.48	(0.37, 0.35)
EPOU – FXM	0.45	(0.34, 0.31)
IGDP – OSS	0.49	(0.36, 0.38)
OSSEPOU - IGDP	0.50	(0.38, 0.40)
OSSFXM - IGDP	0.47	(0.35, 0.37)
EPOUFXM IGDP	0.51	(0.39, 0.41)

Sources: Authors' estimation (2025) using Eviews 13

Table 4 shows that EPOU exhibits the highest baseline variance (0.0024), indicating greater inherent uncertainty compared to the other variables. IGDP follows closely with a baseline variance of 0.0021, suggesting relatively high variability in industrial GDP. In contrast, OSS has the lowest constant term (0.0012), reflecting lower inherent volatility in oil supply shock. Oil supply shock demonstrates the highest sensitivity to past shocks (α = 0.1527), indicating that oil price volatility in Finland is highly responsive to recent market events. The IGDP (α = 0.1349), EPU (α = 0.1283), and FXM (α = 0.1178) exhibit progressively lower sensitivities, reflecting diminished immediate responsiveness to shocks. IGDP displays the highest persistence (β = 0.8117), suggesting that past volatility has a significant influence on future volatility in industrial GDP. FXM (β = 0.7925) and EPOU (β = 0.7843) also demonstrate high persistence, while OSS (β = 0.7684) exhibits slightly lower, though still substantial, volatility persistence.

Also, IGDP shows the strongest leverage effect (γ = 0.0453), indicating that negative shocks substantially amplify industrial production volatility. EPOU (γ = 0.0367) and OSS (γ = 0.0321) display moderate leverage effects, while FXM exhibits the weakest leverage effect (γ = 0.0256), suggesting minimal asymmetry. Oil supply shock achieves the highest log-likelihood (416.42), reflecting the strongest model fit. EPOU (398.14) and FXS (391.87) follow, while IP has the lowest log-likelihood (380.13), indicating a comparatively weaker fit. In summary, the analysis reveals distinct volatility dynamics among the variables. Oil supply shock demonstrates strong sensitivity to recent shocks and robust model performance, reflecting its immediate responsiveness to market conditions. Industrial output exhibits high volatility persistence and significant asymmetry, with negative shocks amplifying its variability. Macroeconomic policy instability cum uncertainty and foreign exchange rate misalignments display considerable persistence and moderate asymmetry, emphasizing their long-lasting effects on uncertainty. These findings underscore the interconnections between these variables in Finland and their potential implications for the nation's economic stability.

Table 4: Copula-GARCH Results for Finland (Univariate GARCH Model Estimates)

Variable	*ω (Constant)*	*α (ARCH)*	*β (GARCH)*	*γ (Leverage)*	*Log-Likelihood*
OSS	0.0012	0.1527	0.7684	0.0321	416.42
EPOU	0.0024	0.1283	0.7843	0.0367	398.14
FXM	0.0016	0.1178	0.7925	0.0256	391.87
IGDP	0.0021	0.1349	0.8117	0.0453	380.13
OSSEPOU	0.0019	0.1392	0.7965	0.0342	395.28
OSSFXM	0.0017	0.1245	0.7814	0.0289	388.72
EPOUFXM	0.0020	0.1321	0.8056	0.0401	392.34

Sources: Authors' estimation (2025) using Eviews 13

Table 5 evaluates different copula models based on their ability to capture the dependence structure among the study variables, using three metrics: log-likelihood, AIC, and BIC. The S t-C achieves the uppermost LL value (491.4), followed by the GC (477.9), CC (473.5), and GAC (459.3). This indicates that the S t-C provides the best fit for modeling the dependence structure. The S t-C has the lowest AIC value (-982.7), making it the most suitable model for the data. The GC (-950.3) and CC (-942.1) are also effective, but the Gaussian Copula (-910.6) is the least favorable, reflecting its limitations in capturing complex dependencies.

BIC, which imposes a stricter penalty for model complexity, follows a similar trend. The S t-C again has the lowest BIC value (-966.3), confirming its superior fit. The GC (-934.2) and CC (-926.8) rank next, while the GAC (-898.4) again performs the weakest. The S t-C outperforms all other models across all metrics, highlighting its ability to capture both tail dependence and complex relationships in the data. This makes it the most reliable option for the analysis, while the GAC struggles to model the essential features of the data, particularly tail dependence.

Table 5: Copula-GARCH Selection and Goodness-of-Fit Results for Finland

Copula Type	*AIC*	*BIC*	*Log-Likelihood*
Gaussian Copula	-910.6	-898.4	459.3
Clayton Copula	-942.1	-926.8	473.5
Gumbel Copula	-950.3	-934.2	477.9
Student's t-Copula	-982.7	-966.3	491.4

Sources: Authors' estimation (2025) using Eviews 13

Table 6 shows that all Kendall's τ pairs exhibit moderate positive dependence, with values between 0.42 and 0.50. The strongest nexus was observed between OSS and EPOU, with $\tau = 0.50$, signifying a moderate correlation between fluctuations in oil supply shock and economic policy uncertainty. The second strongest dependence is between OSS and FXM ($\tau = 0.47$), followed by EPOU and FXM ($\tau = 0.44$), suggesting that shocks in the foreign exchange market misalignments are also moderately correlated with both oil supply shock and economic policy uncertainty. The weakest dependence is between IGDP and FXM ($\tau = 0.42$), indicating a relatively weaker, though still notable, relationship between these two variables.

Higher values coefficients of tail dependence suggest a greater probability of extreme co-movements. For the relationship between OSS and EPOU, the coefficients of tail dependence given by $\lambda U = 0.37$ and $\lambda L = 0.39$ indicate that extreme negative movements (in the lower tail) are slightly more likely than extreme positive movements (in the upper tail), suggesting a tendency for negative shocks in both variables to occur together. A similar pattern is observed for the pairs OSS and FXM ($\lambda U = 0.33$, $\lambda L = 0.34$) and EPOU and FXM ($\lambda U = 0.31$, $\lambda L = 0.32$), where lower tail co-movements are more probable, indicating that negative severe incidents are more probable to happen simultaneously than positive ones. Between IGDP and FXM ($\lambda U = 0.29$, $\lambda L = 0.31$), the tail dependence coefficients are weaker, suggesting that extreme co-movements in either direction (upper or lower tail) are less likely. Thus, the table reveals moderate positive dependencies between the variables, with the strongest correlation between OSS and EPOU. Negative tail dependence predominates in most pairs, indicating a higher likelihood of simultaneous extreme negative events compared to positive ones. The weaker tail dependence between IGDP and FXM suggests that extreme co-movements are less significant in this pair.

Table 6: Results of Dependence Parameters Copula-GARCH Model for Finland

Variable Pair	*Kendall's τ*	*Tail Dependence (λU, λL)*
OSS - EPOU	0.50	(0.37, 0.39)
OSS – FXM	0.47	(0.33, 0.34)
EPOU – FXM	0.44	(0.31, 0.32)
IGDP – OSS	0.42	(0.29, 0.31)
OSSEPOU - IGDP	0.48	(0.36, 0.37)
OSSFXM - IGDP	0.45	(0.33, 0.35)
EPOUFXM IGDP	0.49	(0.38, 0.39)

Sources: Authors' estimation (2025) using Eviews 13

In Table 7, the univariate GARCH model estimates for four variables in Germany: oil supply shock, macroeconomic policy instability in the U.S., foreign exchange rate misalignments, and industrial production. The GARCH model parameters (ω, α, β, γ) and log-likelihood values offer insights into the volatility dynamics of each variable and the model's performance. The constant term, ω reflects the baseline variance of each variable. For Germany, the baseline variance is lowest for OSS (ω = 0.0009), followed by IGDP (ω = 0.0015), FXM (ω = 0.0012), and EPOU (ω = 0.0028). This indicates that economic policy uncertainty has the highest inherent volatility, suggesting greater baseline uncertainty in policy-related matters, while oil supply shock shows the lowest baseline variance, indicating comparatively lower inherent volatility in the framework of oil prices.

In Germany, EPOU (α = 0.1453) shows the highest sensitivity, meaning that changes in economic policy uncertainty respond strongly to recent shocks. The OSS (α = 0.1382) also exhibits a relatively high sensitivity, followed by FXM (α = 0.1346) and IGDP (α = 0.1182), which have lower sensitivities. This suggests that economic policy uncertainty and oil supply shock are more reactive to past disturbances compared to industrial production and foreign exchange rate misalignments. IGDP demonstrates the highest persistence (β = 0.8726), meaning that past volatility has a significant impact on future volatility in industrial production. The EPOU (β = 0.8406) and FXM (β = 0.8032) also exhibit high persistence, while OSS has a slightly lower persistence (β = 0.8127). This indicates that industrial GDP is more stable over time compared to the other variables, with past volatility having a larger influence on future changes.

IGDP shows the maximum leverage effect (γ = 0.0425), indicating that negative shocks significantly amplify volatility in industrial production. The OSS (γ = 0.0357), FXM (γ = 0.0342), and EPOU (γ = 0.0292) also show leverage effects, though they are slightly weaker. This implies that negative shocks in these variables tend to have a more pronounced impact than positive shocks. The OSS has the highest LL (382.71), indicating the best model fit among the variables. EPOU follows with a LL of 364.38, then FXM with 359.74 and IGDP with 348.91. The higher LL for OSS suggests that the GARCH model fits the volatility dynamics of oil supply shock better than the other variables.

In Germany, oil supply shock demonstrates strong sensitivity to past shocks and a relatively good model fit, indicating its immediate responsiveness to market conditions. Economic policy uncertainty shows the highest sensitivity to shocks and a significant persistence in volatility, but with a slightly weaker leverage effect compared to industrial GDP. Industrial production exhibits the highest persistence and leverage effect, implying that past volatility plays a substantial role in shaping future changes in industrial production, with negative shocks having a strong amplifying effect. Foreign exchange rate misalignments show moderate sensitivity and persistence, with a relatively low leverage effect. These findings suggest that oil supply shock, economic policy uncertainty, foreign exchange shocks, and industrial production in Germany are interconnected through varying degrees of volatility persistence, sensitivity to past shocks, and leverage effects, with different dynamics influencing each variable's behavior.

Table 7: Copula-GARCH Results for Germany (Univariate GARCH Model Estimates)

Variable	*ω (Constant)*	*α (ARCH)*	*β (GARCH)*	*γ (Leverage)*	*Log-Likelihood*
OSS	0.0009	0.1382	0.8127	0.0357	382.71
EPOU	0.0028	0.1453	0.8406	0.0292	364.38
FXM	0.0012	0.1346	0.8032	0.0342	359.74
IGDP	0.0015	0.1182	0.8726	0.0425	348.91
OSSEPOU	0.0014	0.1297	0.8251	0.0386	355.82
OSSFXM	0.0013	0.1265	0.8143	0.0328	352.47
EPOUFXM	0.0017	0.1332	0.8472	0.0411	358.26

Sources: Authors' estimation (2025) using Eviews 13

Table 8 shows that the GAC with AIC of -812.6 and BIC of -800.4, is the least preferred among the models, as it does not capture the dependence structure as effectively as the other copulas. Despite its higher simplicity in terms of model parameters, its LL value (410.3) is the lowest, suggesting it provides a weaker fit to the data. The CC performs better than the GAC with a more favorable AIC of -845.2 and BIC of -830.6. Its LL (427.6) also reflects a better fit, particularly in modeling lower tail dependence. The GC, though slightly better than the Gaussian, has AIC of -858.4 and BIC of -842.7, with a LL of 436.2, showing it is a stronger candidate but still not the best. The S t-C outperforms all others with the best LL value of 456.1, and the most favorable AIC (-902.1) and BIC (-885.9). This indicates that it captures the dependence structure most effectively, particularly in modeling tail dependencies, and is the most suitable model for this analysis. Thus, the S t-C is the most appropriate model for this analysis, providing the best balance of fit, while the GAC is the least suitable for accurately modeling the dependence between the variables.

Table 8: Copula-GARCH Selection and Goodness-of-Fit Results for Germany

Copula Type	*AIC*	*BIC*	*Log-Likelihood*
Gaussian Copula	-812.6	-800.4	410.3
Clayton Copula	-845.2	-830.6	427.6
Gumbel Copula	-858.4	-842.7	436.2
Student's t-Copula	-902.1	-885.9	456.1

Sources: Authors' estimation (2025) using Eviews 13

Using Kendall's τ and tail dependence coefficients, Table 9's results demonstrate the dependence parameters between several economic variables, highlighting the type and strength of those interactions. These values help in understanding the correlation and extreme co-movements between the variables, which in this case include oil supply shock, economic policy uncertainty, foreign exchange market misalignments, and industrial GDP. The Kendall's τ pairs exhibit moderate positive dependence, with Kendall's τ values ranging from 0.36 to 0.42. The strongest relationship is between oil supply shock and macroeconomic policy uncertainty of the U.S., with τ = 0.42, indicating a moderately strong positive correlation between these two variables. This suggests that changes in oil supply shock are moderately associated with changes in macroeconomic policy instability. The nexus between macroeconomic policy instability and foreign exchange rate misalignments follows closely with τ = 0.40, indicating a moderate dependence between these two variables as well. The pair with the weakest correlation is industrial GDP and economic policy uncertainty, with τ = 0.36, suggesting a relatively weaker, but still noticeable, positive relationship between these variables.

The tail dependence coefficients (λU, λL) range from 0.25 to 0.31, suggesting that the probability of extremely unfavorable circumstances (lower tail) occurring together is slightly higher than extreme positive events (upper tail), but the difference is relatively small for most pairs. For example, the pair between oil supply shock and economic policy uncertainty has tail dependence coefficients of (λU = 0.29, λL = 0.30), indicating a slightly higher probability of joint extreme negative movements compared to extreme positive movements. Likewise, the other pairs show similar patterns, with a slightly higher likelihood of extreme negative co-movements compared to extremely positive ones, such as for OSS and FXM (λU = 0.26, λL = 0.28) and EPU and FXM (λU = 0.30, λL = 0.31). Thus, Table 9 reveals moderate positive correlations between the economic variables, with the strongest dependence between oil supply shock and macroeconomic policy uncertainty. Tail dependence suggests that extreme negative shocks are more likely to occur jointly than extreme positive shocks across most pairs. This indicates that these variables are more susceptible to synchronized negative events than to positive ones, which could have important implications for understanding the dynamics of economic instability.

Table 9: Results of Dependence Parameters Copula-GARCH Model for Germany

Variable Pair	*Kendall's τ*	*Tail Dependence (λU, λL)*
OSS - EPOU	0.42	(0.29, 0.30)
OSS – FXM	0.38	(0.26, 0.28)
EPOU – FXM	0.40	(0.30, 0.31)
IGDP – OSS	0.36	(0.25, 0.26)
OSSEPOU - IGDP	0.41	(0.28, 0.29)
OSSFXM - IGDP	0.39	(0.27, 0.28)
EPOUFXM IGDP	0.43	(0.31, 0.32)

Sources: Authors' estimation (2025) using Eviews 13

Table 10 report the highest constant for OSS at 0.0032, indicating the greatest inherent volatility. EPOU follows closely with a value of 0.0017, while FXM and IGDP have slightly lower constants of 0.0021 and 0.0019, respectively. This suggests that oil supply variations or shocks has the most significant baseline variance, implying that oil supply is the most volatile among the variables in this study. The OSS shows the highest sensitivity to past shocks with an α value of 0.1904, indicating that oil price volatility in the United States responds strongly to recent market disturbances. EPOU (α = 0.1786) and FXM (α = 0.1105) also exhibit sensitivity, but to a lesser degree, showing that Macroeconomic policy instability and foreign exchange market shocks have a relatively weaker immediate impact on their respective volatilities. IGDP (α = 0.0932) demonstrates the least sensitivity to past shocks, suggesting that industrial production is the least responsive to immediate volatility from past events. Industrial production has the highest persistence with a β value of 0.8923, showing that historical volatility had a substantial influence on future fluctuations in industrial production. The FXM (β = 0.8541) and EPOU (β = 0.7982) also show substantial persistence, meaning that past volatility has a lasting effect on future instability. Oil supply shock (OSS) with a coefficient given by β = 0.7467 exhibits somewhat lower persistence, although still notable, suggesting that oil price uncertainty's volatility is less persistent over time than the other variables.

Industrial output growth had the highest leverage effect with γ = 0.0463, indicating that negative shocks to industrial GDP significantly amplify its volatility. Oil supply shock (γ = 0.0439) and EPU (γ = 0.0328) also show moderate leverage effects, meaning that negative shocks influence these fluctuation of variables greater than that of positive shocks. FXM has the smallest leverage effect (γ = 0.0234), indicating that negative shocks have a relatively smaller impact on its volatility. OSS has the highest LL value of 521.34, suggesting the best model fit among the variables. EPU follows with a LL of 498.92, while FXM (487.53) and IGDP (471.22) have lesser values, reflecting relatively weaker fits for these models. Inclusively, the analysis of the Copula-GARCH results for the Ireland highlights that oil supply shock has the highest inherent volatility, immediate response to past shocks, and strongest model fit. Industrial GDP exhibits the highest persistence and leverage effect, suggesting that past volatility plays a significant role in shaping future volatility, particularly following negative shocks. Macroeconomic policy instability and foreign exchange rate misalignments demonstrate moderate sensitivity, persistence, and leverage effects, with each having a significant, though less pronounced, influence on volatility dynamics. These results underscore the intricate relationship between these variables and their potential implications for the broader economic landscape in the Ireland.

Table 10: Copula-GARCH Results for Ireland (Univariate GARCH Model Estimates)

Variable	*ω (Constant)*	*α (ARCH)*	*β (GARCH)*	*γ (Leverage)*	*Log-Likelihood*
OSS	0.0032	0.1904	0.7467	0.0439	521.34
EPOU	0.0017	0.1786	0.7982	0.0328	498.92
FXM	0.0021	0.1105	0.8541	0.0234	487.53
IGDP	0.0019	0.0932	0.8923	0.0463	471.22
OSSEPOU	0.0025	0.1623	0.8257	0.0412	479.81
OSSFXM	0.0018	0.1435	0.8148	0.0356	473.27
EPUOFXM	0.0020	0.1568	0.8412	0.0441	481.94

Sources: Authors' estimation (2025) using Eviews 13

Table 11 presents very clearly that the Gaussian Copula has the lowest AIC (-1245.6) and BIC (-1231.8), with a LL of 627.8. Although this copula performs well based on AIC and BIC, its LL is relatively lower compared to the other copulas, implying that it does not fit the data as well as some of the others. The CC has an AIC of -1298.7 and BIC of -1280.3, with a LL of 654.4. This model has a slightly better log-likelihood than the GAC, suggesting a better fit to the data, despite having higher AIC and BIC values, which reflect its complexity compared to the GAC.

The GC shows an AIC of -1302.4, BIC of -1284.2, and a LL of 661.2. This copula provides a better LL than both the Gaussian and Clayton copulas but has higher AIC and BIC values, indicating greater model complexity. The S t-C has the lowest AIC (-1350.3) and BIC (-1334.5), as well as the highest LL of 680.2. This suggests that the Student's t-Copula provides the best overall fit to the data, balancing both performance and complexity, with the highest LL and the lowest AIC and BIC. In summary, the S t-C achieves the best fit to the data, while the Gumbel and Clayton copulas also perform well based on log-likelihood, making them viable alternatives depending on the modeling needs. The GAC, though simple, is outperformed by the other copulas in terms of log-likelihood, indicating a weaker fit.

Table 11: Copula-GARCH Selection and Goodness-of-Fit Results for Ireland

Copula Type	*AIC*	*BIC*	*Log-Likelihood*
Gaussian Copula	-1245.6	-1231.8	627.8
Clayton Copula	-1298.7	-1280.3	654.4
Gumbel Copula	-1302.4	-1284.2	661.2
Student's t-Copula	-1350.3	-1334.5	680.2

Sources: Authors' estimation (2025) using Eviews 13

Kendall's τ and tail dependence coefficients (λU, λL) are used to measure the dependence parameters for different pairings of economic variables in Table 12. For the pair between oil supply shock (OSS) and economic policy uncertainty (EPOU), Kendall's τ is 0.60, which reflects a strong positive correlation between these two variables. The tail dependence coefficients (λU = 0.44, λL = 0.46) suggest that there is a slightly higher likelihood of extreme negative movements (lower tail) occurring simultaneously than extreme positive movements (upper tail). This indicates that negative shocks in both oil supply shock and economic policy uncertainty are more likely to happen together than positive shocks.

Also, the pair between oil supply shock and foreign exchange rate misalignments has a Kendall's τ of 0.55, indicating a moderately strong positive nexus. The tail dependence coefficients (λU = 0.40, λL = 0.42) also suggest a higher probability of joint extreme negative movements compared to extreme positive movements, pointing to the likelihood that negative shocks in both oil supply shock and foreign exchange market misalignments are more likely to occur together. For the pair between macroeconomic policy instability and foreign exchange market misalignments, Kendall's τ is 0.50, indicating a moderate positive relationship. The coefficients (λU = 0.35, λL = 0.38) again show a slightly higher probability of extreme negative movements occurring together than extreme positive movements, suggesting that misalignments in the foreign exchange rate are more likely to coincide with negative macroeconomic policy instability than with positive policy uncertainty.

The weakest dependence is observed between industrial production and foreign exchange rate misalignment, with Kendall's τ of 0.47, indicating a relatively weaker, but still moderate, positive nexus. The tail dependence coefficients (λU = 0.33, λL = 0.34) suggest that extreme co-movements in both the upper and lower tails are less likely compared to the other variable pairs, but still significant. The results so show that oil supply shock, macroeconomic policy instability, and foreign exchange rate misalignment exhibit moderate to strong positive nexus with each other, with a tendency for extreme negative events to occur jointly more frequently than extreme positive ones. The dependence between industrial GDP and FXM is weaker but still notable. These results imply significant interdependencies between these variables, which can have important implications for economic stability in the studied context.

Table 12: Results of Dependence Parameters Copula-GARCH Model for Ireland

Variable Pair	*Kendall's τ*	*Tail Dependence (λU, λL)*
OSS - EPOU	0.60	(0.44, 0.46)
OSS – FXM	0.55	(0.40, 0.42)
EPOU – FXM	0.50	(0.35, 0.38)
IGDP – OSS	0.47	(0.33, 0.34)
OSSEPOU - IGDP	0.52	(0.37, 0.39)
OSSFXM - IGDP	0.48	(0.34, 0.35)
EPOUFXM IGDP	0.54	(0.38, 0.40)

Sources: Authors' estimation (2025) using Eviews 13

5. Discussion

In Denmark, the Copula-GARCH results show a strong dependence (Kendall's τ = 0.49) between oil supply shock and industrial production, with tail dependence values (λU = 0.36, λL = 0.38), signifying that extreme downturns in oil supply variations or shocks have a more pronounced impact on industrial production than extreme increases. The asymmetric impact of oil supply variations is more pronounced in Denmark, where extreme downturns in oil production result in severe industrial contractions. The findings obtained for Denmark reveal significant dependencies among key economic variables, including oil supply shock, economic policy uncertainty, foreign exchange rate misalignments, and industrial GDP, as assessed through Kendall's τ and tail dependence coefficients (λU and λL). Kendall's τ indicates a moderate to strong positive correlation between the variables, with the strongest nexus observed between OSS and EPOU (τ = 0.53), suggesting that oil supply fluctuations are closely linked with shifts in policy uncertainty. The nexus between IGDP and OSS (τ = 0.49) underscores the substantial impact of shocks calculated as the variations in oil supply on industrial production. Additionally, OSS and FXM (τ = 0.48) and EPOU and FXM (τ = 0.45) exhibit notable interdependencies, illustrating the interconnected nature of these economic indicators.

The tail dependence coefficients further emphasize the likelihood of joint extreme movements between the variables. For OSS and EPOU, the higher lower tail dependence (λL = 0.42) compared to the upper tail (λU = 0.39) suggests a greater likelihood of concurrent negative shocks, indicating that policy uncertainty is more sensitive to oil supply downturns than to upward movements. A similar asymmetry is observed for IGDP and OSS (λU = 0.36, λL = 0.38), as well as OPU and FXS (λU = 0.37, λL = 0.35), where negative shocks are more likely to co-occur. The weakest tail dependence is noted between EPOU and FXM (λU = 0.34, λL = 0.31), implying less pronounced co-movements during extreme events. These findings highlight the complex relationships and sensitivities among the economic variables, with a notable emphasis on the impact of negative shocks.

Comparable trends emerge from the Finland data. The Copula-GARCH model reveals a significant relationship (Kendall's τ = 0.47) between oil supply shock and industrial production, while the tail dependence values (λU = 0.33, λL = 0.35) indicate that extreme oil supply shock substantially influences industrial production in Denmark and Finland. The Copula-GARCH results indicate that foreign exchange rate misalignment have a higher impact on industrial production in Denmark (τ = 0.50) with tail dependence coefficients (λU = 0.38, λL = 0.40), than in Finland (τ = 0.48) with tail dependence coefficients (λU = 0.36, λL = 0.37). Hence, we conclude that foreign exchange market misalignments do significantly influence industrial production in Denmark, and Finland. Finland findings highlight the moderate positive relations between the key economic variables, indicating significant interdependencies. The strongest correlation is between OSS and EPOU, suggesting that fluctuations in oil prices are closely tied to policy instability. This is followed by moderate correlations between OSS and foreign exchange rate misalignment (FXM) and EPOU and FXM, reflecting the interconnectedness of global markets. The weakest correlation is between industrial production (IGDP) and FXM, pointing to a less pronounced relationship between foreign exchange rate misalignment and industrial output.

The tail dependence coefficients offer further insight into the likelihood of extreme co-movements. Notably, both OSS and EPOU, and OSS and FXM, exhibit stronger joint extreme negative movements (in the lower tail), signaling that negative shocks in these variables tend to occur together. This suggests that crises or downturns in oil supplies, policy uncertainty, and foreign exchange rate misalignments are more likely to coincide. The link between IGDP and FXM displays weaker tail dependence, implying that extreme movements in industrial production and foreign exchange rate misalignments are less likely to align. These results highlight how crucial monitoring both moderate and extreme co-movements in these variables for a comprehensive understanding of the economic dynamics at play.

The results for Denmark and Finland reveal complex dynamics among oil supply variations, foreign exchange rate misalignments, and industrial growth. These findings align with and expand upon prior research, particularly recent studies exploring the interconnectedness of economic uncertainties in oil-exporting nations and developing economies. The significant correlations observed between oil supply shock and economic policy uncertainty ($\tau = 0.53$ in Denmark; moderate in Finland) corroborate the findings of Tsalavoutas & Konstantinou (2022) where the structural vector autoregressive (SVAR) model was estimated and found that surge in oil supply triggered higher production costs, leading to a reduction in industrial output and GDP in the short run. However, they also observed that Germany's diverse energy sources and its advanced technological base cushioned the long-term effects. The authors established that Germany's economic structure provided a degree of insulation from oil production volatility, but advised the country invest more heavily in renewable energy technologies to further stabilize its economy. The current findings also aligns results reported by Kotsakis & Papadopoulos (2021) who econometrically examined the supply-side impact of oil supply shocks on Germany's industrial output, employing a co-integration approach to analyze data spanning from 2010 to 2020. The study utilized the classical supply-side economic theory, which posits that fluctuations in production costs (such as oil prices) affect the aggregate supply curve, shifting it leftward when prices rise. The study revealed evidence of a delayed effect, suggesting that the economy's adjustment to oil price shocks took several quarters. Based on their findings, Kotsakis and Papadopoulos recommended that Greece diversify its energy sources and pursue energy efficiency measures to enhance resilience to future oil price shocks. Further, the substantial tail dependence coefficients obtained for Denmark (e.g., $\lambda L = 0.42$ for OSS and EPOU) echoes the deductions of Hernandez and Zeynalov (2020) who explored the supply-side effects of oil price variation in the U.K. Accordingly, the study found that oil price increases contributed to higher production costs, which resulted in reduced industrial output and higher inflationary pressures in the short run. The Phillips curve theory suggests that the UK had to choose between joblessness and rising prices, with oil price shocks exacerbating this trade-off.

The Copula-GARCH results show a Kendall's τ of 0.42 for the relationship between oil supply shock and industrial production in Germany and a Kendall's τ of 0.60 in the United Kingdom, indicating a strong dependency in both countries. Likewise, the Copula-GARCH results show that foreign exchange rate misalignment and industrial production are strongly linked with a Kendall's τ of 0.47 in Germany and 0.40 for the United Kingdom. Accordingly, we conclude that foreign exchange market misalignments do significantly influence industrial production in Germany and U.K. The Copula-GARCH results show that EPOUFXM moderately correlated with industrial production, with Kendall's τ of 0.47 in Germany and 0.40 in Ireland suggesting that economic policy uncertainty and forex market misalignment jointly influenced industrial production. Relatively, the interaction of oil supply shocks and forex rate misalignments (OSSFXM) reveal substantial association with industrial production, with Kendall's τ of 0.47 and 0.56 in Ireland and Germany respectively. This implies a considerable industrial production effect due to joint influence from oil supply shocks and forex rate misalignments. The joint effect of policy uncertainty and market misalignments (EPUFXM) is also significant for all countries.

In Germany, the findings from the table reveal the dependence parameters between key economic variables oil price uncertainty, macroeconomic policy uncertainty, foreign exchange rate misalignment and industrial output growth (IGDP) as analyzed through Kendall's τ and tail dependence coefficients. Kendall's τ values reflect the strength and direction of the rank correlation between the variables, with all pairs showing moderate positive correlations. The strongest positive association is between OSS and EPOU, with a τ value of 0.42, indicating a moderately strong association. This suggests that oil supply shock is moderately linked to changes in policy uncertainty, highlighting the potential economic risks when oil prices become volatile. The second strongest nexus is between EPOU and FXM (τ = 0.40), signifying a moderate dependence between economic policy shifts and foreign exchange rate misalignments, which underscores the role of policy in influencing currency stability. The weakest correlation is between IGDP and EPOU (τ = 0.36), implying a less pronounced but still significant connection between industrial production and policy uncertainty.

Also, tail dependence coefficients (λU and λL) assess the likelihood of extreme co-movements between the variables. The coefficients range from 0.25 to 0.31, indicating a slightly higher probability of extreme negative shocks (lower tail) occurring jointly than extreme positive shocks (upper tail). This pattern is consistent across most variable pairs, suggesting that negative shocks, such as sudden drops in oil production or economic policy shifts, are more likely to co-occur than positive ones. For instance, the pair OSS and EPOU shows λU = 0.29 and λL = 0.30, with the lower tail showing a slightly higher probability of joint extreme movements. Similar trends are observed in other pairs, such as OSS and FXM (λU = 0.26, λL = 0.28) and EPU and FXM (λU = 0.30, λL = 0.31), where the likelihood of extreme negative co-movements is slightly greater. In conclusion, the findings reveal moderate positive correlations among the economic variables, with the strongest dependence between oil supply shock and EPOU. Additionally, tail dependence indicates that extreme negative shocks are more likely to occur together, suggesting that the economy is more susceptible to synchronized downturns than to positive booms. This insight is critical for understanding economic instability and the potential risks of negative co-movements in key economic factors.

The findings on the Ireland illustrate the dependence parameters between pairs of economic variables, evaluated through Kendall's τ and tail dependence coefficients (λU and λL). Kendall's τ reflects the strength and direction of rank correlation, while λU and λL measure the likelihood of severe joint movements in the upper and lower distribution tails, respectively. Higher values indicate stronger relationships and a greater likelihood of extreme co-movements. The nexus between oil supply shock and economic policy uncertainty is strong, with Kendall's τ of 0.60. This indicates a robust positive correlation, suggesting these variables often move in the same direction. Tail dependence coefficients (λU = 0.44, λL = 0.46) reveal that severe negative co-movements are slightly more likely than extreme positive ones, implying a higher chance of concurrent negative shocks in OSS and EPOU. Between oil supply shock and foreign exchange rate misalignments, Kendall's τ is 0.55, indicating a moderately strong positive nexus. The tail dependence coefficients ($\lambda U = 0.40$, $\lambda L = 0.42$) further suggest that extreme joint negative movements are more likely than those that are positive, emphasizing the interconnectedness of negative shocks in these variables.

Macroeconomic policy uncertainty and foreign exchange rate misalignments display a moderate positive relationship, with Kendall's τ of 0.50. The tail dependence coefficients ($\lambda U = 0.35$, $\lambda L = 0.38$) show a higher likelihood of extreme negative co-movements, indicating that adverse movements in FXM and EPOU tend to align. The weakest interdependence is observed between industrial production and foreign exchange shocks, with Kendall's τ of 0.47. This moderate positive correlation suggests a less pronounced relationship compared to other pairs. Tail dependence coefficients ($\lambda U = 0.33$, $\lambda L = 0.34$) imply a lower probability of extreme co-movements in this pair, although such events remain statistically significant. The analysis demonstrates that OSS, EPOU, and FXM share moderate to strong positive correlations, with a pronounced tendency for joint extreme negative movements. Conversely, the nexus between IGDP and FXM is relatively weaker but still meaningful. These findings underscore critical interdependencies among these variables, suggesting that joint negative shocks could amplify economic instability. Understanding these relationships is vital for governments and market players aiming to mitigate risks in volatile economic environments.

The aggregate demand-side consequences of oil supply variations are similarly significant and corroborate the results of Vukovic *et al*. (2021) who identified negative GDP growth impacts in Denmark, and Finland and due to reliance on oil imports, exacerbated by reduced consumption and industrial output. Zhang & Zhao (2022) and Petrovic & Mirovic (2024) extended this analysis to Germany, and Ireland nations, revealing significant reductions in domestic consumption and investment, particularly in the Germany, and Ireland. These findings suggest that fiscal and monetary policies, along with investments in alternative energy, can alleviate the negative effects of oil supply shocks on aggregate demand.

On the supply side, oil price shocks increase production costs, thereby reducing industrial output and exacerbating inflation. Changes in oil supply significantly affect industrial production and supply chains. Production costs rise in response to rising oil costs particularly for energy-intensive industries. These higher costs can reduce output and affect profit margins, leading to a slowdown in industrial activity. Additionally, rising energy costs can disrupt supply chains by increasing transportation expenses and causing delays (Rosen, 2023). Studies such as Kotsakis & Papadopoulos (2021) for Greece and Liu and Wang (2024) for Japan highlight how energy dependency amplifies these effects. Japan's experience, as documented by Liu and Wang, underscores the importance of domestic energy production and diversification to shield industrial sectors from global price fluctuations. Hernandez and Zeynalov (2020) provide similar insights for the UK, emphasizing the trade-offs between inflation and unemployment caused by oil price volatility.

Specifically, the uncertainty channel theory posits that increased economic policy uncertainty leads to reduced investment and economic activity. In the context of oil-exporting economies, heightened uncertainty can cause businesses to delay or scale back investment projects due to concerns about future policy directions. This reduction in investment can lead to lower industrial output (Gabler, 2025). Lower economic policy uncertainty is often linked to higher investment growth, while increased uncertainty can hinder overall economic activity (Baker *et al*., 2016).

Our findings also support those of Wei & Guo (2022) where it was detected that an exogenous oil supply shock to real economic activity using proxy SAVRs, and then investigate how this shock affects real economic productivity in the United States. According to the authors, after the mid-1980s, shocks to the external oil supply had a significant and long-lasting effect on actual economic activity in the United States. Their findings additionally identified new pathways of transmission via which shocks to the exogenous oil supply affect the real GDP of the United States. In particular, adverse exogenous oil supply shocks reduce real total exports through the terms of trade effect, lower the consumer sentiment index, lower real government consumption expenditures and investment, all of which contribute to a decline in real output growth.

Higher oil prices generally raise production costs for industries dependent on oil, which can reduce industrial output (Bjørnland & Leitemo, 2020). On the other hand, lower oil prices can stimulate economic activity by reducing production costs and increasing disposable income for consumers, thereby promoting industrial production (Baumeister & Kilian, 2019). Uncertainty in U.S. macroeconomic policies spreading to industrial production, particularly in oil-exporting nations, occurs through several channels. First, policy uncertainty can lead to fluctuations in oil prices, which directly impact the revenues of oil-exporting countries. Increased uncertainty may cause oil prices to become more volatile, affecting the economic stability of these nations (Feldstein, 2017). Second, global investors may adjust their portfolios in response to U.S. policy changes, influencing capital flows and investment decisions in oil-exporting countries (Dube, 2019). Third, trade policies and tariffs imposed by the U.S. can alter demand for exports from oil-exporting nations, thereby affecting their industrial production.

Additionally, the theory suggests that uncertainty can lead to increased risk premiums, making financing more expensive and further dampening investment and industrial production. Various types of economic policy uncertainty include fiscal uncertainty, which concerns government spending and taxation policies (IMF, 2024), monetary uncertainty, which revolves around central bank actions such as interest rate changes (European Commission, 2024), trade uncertainty, which pertains to ambiguity in trade policies like tariffs and trade agreements (Reuters, 2024), and regulatory uncertainty, which focuses on potential future regulations affecting businesses and industries (Bloom, 2023). These uncertainties can lead to cautious behavior among businesses and consumers, with companies delaying investment decisions and consumers reducing spending, both of which can dampen economic growth (European Commission, 2024).

The results of this study support the findings of studies that reported energy costs, measured in form of oil prices, are significant determinants of industrial production. As oil prices rise, production costs escalate because businesses face higher energy and raw material expenses. To compensate, companies often adjust their pricing strategies, which can lead to higher consumer prices (Blanchard, 2021). Such shocks raise production costs, causing inflation while simultaneously slowing economic growth due to reduced consumer spending and investment (Mankiw, 2022). Industries that are highly reliant on oil, such as manufacturing and transportation, are particularly vulnerable to these shocks. Rising oil prices can increase operational costs, reduce profit margins, and potentially lead to cutbacks in production or employment (Baffes, 2021). Rising energy costs often lead to higher production expenses, reducing overall output and profitability, while falling energy prices can lower production costs, boosting output (Baker & Adams, 2024). Energy-intensive industries, such as chemicals and steel production, are more vulnerable to fluctuations in oil prices compared to non-energy-intensive sectors. These industries bear the brunt of rising energy costs, which can lead to reduced competitiveness and profitability.

Non-energy-intensive industries, while less directly affected, may experience indirect impacts through increased costs in their supply chains (Baker & Adams, 2024). Industries that diversify their energy sources, invest in technological innovations, and maintain flexible production processes tend to be more resilient. Such resilience is crucial for navigating economic uncertainties and mitigating the adverse effects of price volatility (Gabler, 2025). The study estimates aligns with the theory regarding the role of oil prices in shaping consumer behavior, business investment decisions, and the broader economic environment (Herrera *et al.*, 2023). Changes in oil prices can alter consumer spending patterns. This reduction in spending can dampen economic activity, as lower demand leads to decreased production and potential job losses (Bjørnland & Thorsrud, 2023). The findings of Mimiko & Adebayo (2023) on Ghana's economy revealed that favorable shocks to the price of oil have a more significant and immediate negative effect on aggregate demand compared to negative shocks. Relatively, it was also reported that positive oil-specific demand shocks significantly reduce spending while increasing spending on foreign autos (Herrera *et al.*, 2023). Managing industrial production during periods of economic instability, particularly those caused by external shocks like oil price fluctuations, is vital for maintaining economic stability. Strategic investments in technology, energy diversification, and flexible production processes can help buffer industrial sectors from such shocks, ensuring long-term economic resilience (Rosen, 2023; Baker & Adams, 2024).

The research findings support those of studies that collectively underscore the precarious role of macroeconomic policy uncertainty as a central variable that hosts and present risk into production affecting output levels. This finding indeed upholds the theory of policy uncertainty with emphasis on the effects of unpredictable government policies on production activities. This result indeed lends credence to Baker, Bloom & Davis (2016) who contends that heightened EPU increases risk premiums, reduces investment, and disrupts long-term decision-making by firms. Also, the finding lend credence to the results of Hofmann & Müller (2022) where uncertainty had been shown to adversely affect industrial production by undermining investor and consumer confidence. According to the authors, heightened EPU reduced Germany's industrial output, driven by global trade tensions and domestic policy changes. Similarly, Papadakis & Dimitriou (2023) documented more pronounced negative effects of EPU in Italy and Greece. Our finding upholds as well the results of Matsumoto & Tanaka (2024) where it was demonstrated that Japan's export-oriented industries were particularly vulnerable to both domestic and global EPU, underscoring the importance of fostering policy clarity and consistency to stabilize industrial performance. Our research results for Denmark, and Finland support those of Popov & Milosevic (2021) and Kovačić & Lukić (2023) where the dual impact of oil price shock with delayed but persistent negative effects due to high reliance on oil imports was strongly draw attention to. These findings highlight the need for energy diversification and financial hedging strategies.

6. Conclusion

This study investigates the nexus between oil supply shock, U.S. economic policy uncertainty, foreign exchange rate misalignments and industrial output in the oil-producing OECD economies. These economies are Denmark, Finland, Germany, and Ireland. The methodology of the Copula-GARCH was implemented. This research makes significant contributions to the body of knowledge concerning the interaction between oil supply shock, economic policy uncertainty, and industrial output in OECD oil-exporting countries, particularly in Denmark, Finland, Germany, and Ireland. By applying the Copula-GARCH model, the study offers novel findings into the complex dynamics of these economies in the face of external shocks. The application of the Copula-GARCH models, for instance, allows for a more nuanced understanding of the co-dependence and spillover effects between oil supply variations, foreign exchange rate misalignment, and industrial output. Furthermore, this research contributes to policy-oriented knowledge as regards mitigating the adverse effects of oil price and policy uncertainty. To mitigate the effects of oil supply cum production fluctuations, the establishment of stabilization funds and contingency reserves is essential. These funds can help smooth out the economic shocks caused by sudden drops in oil supply, providing governments with the financial flexibility to maintain critical investments in industrial invention and other sectors. The strategic accumulation of reserves during periods of high oil supply can help buffer the economy during downturns. It emphasizes the need for economic diversification, stable policy frameworks, and regional cooperation, providing a useful reference for policymakers in oil producing OECD countries namely Denmark, Finland, Germany, and Ireland. The study's findings also underscore the importance of improving the resilience of industrial sectors to external shocks, contributing to the broader discourse on economic stability and growth. The research deepens our understanding of the vulnerabilities faced by oil producing OECD countries namely Denmark, Finland, Germany, and Ireland and offers new perspectives on how countries can better manage uncertainty. It acts as a vital resource for impending studies on macroeconomic policy, industrial production, while also informing the development of more resilient economic strategies. Essentially, governments should execute policies aim to reduce the exposure of oil-exporting nations to exogenous shocks and foster a more diversified, stable, and resilient industrial base. A coordinated regional approach can also enable countries to share best practices, harmonize policy responses, and pool resources to address collective challenges. Policymakers should prioritize economic diversification to reduce dependence on oil revenues.

The study's emphasis on oil-exporting countries excludes the potential impacts of oil supply variations and macroeconomic policy uncertainty on oil-importing nations, which may experience different economic dynamics. This restraint narrows the applicability of the findings to a specific subset of economies and does not account for the broader global economic implications of oil supply shocks and exchange rate misalignments. Future research could broaden the scope of economies. This research primarily focused on oil supply shock and economic policy uncertainty of the United States, but other external factors could also play a significant role in influencing industrial output growth. Perhaps, global trade tensions, technological disruptions, or climate change-related events could also contribute to economic instability in oil-exporting countries. Future research could broaden its scope by incorporating additional external factors, allowing for a more holistic assessment of the factors influencing industrial sectors in these economies. The study did not control for the role of institutional quality and governance in mitigating the effects of oil supply and policy uncertainty. Future research could explore how different institutional structures and governance frameworks influence the output of oil-exporting countries amidst external shocks. Finally, further studies could incorporate elements of behavioral economics to better understand the role of market sentiment and expectations in the context of oil supply and policy uncertainty. Investors' and consumers' expectations often drive economic behavior and so influence output growth; and incorporating these factors could offer additional predictions of industrial productivity.

References

Abhyankar, A., Xu, B., & Zhao, J. (2022). Oil price uncertainty and economic activity: Insights from emerging markets. *Energy Economics, 115*, 106337.

Ahmadi, M., & Manera, M. (2021). Oil price shocks and economic growth in oil-exporting

countries. FEEM Working Papers 311052, Fondazione Eni Enrico Mattei (FEEM).DOI: 10.22004/ag.econ.311052

Arezki, R., & Bruckner, M. (2019). Oil rents, corruption, and state stability: Evidence from panel data. International Monetary Fund Working Papers.

Baffes, J., Ayhan, K., & Stocker, M. (2024). Oil price dynamics and economic impacts: A global perspective. The World Bank Group.

Baker, S. R., Bloom, N., & Davis, S. J. (2016).Measuring economic policy uncertainty. *The Quarterly Journal of Economics*, 131(4), 1593-1636.

Baker, W., & Adams, J. (2024). Energy costs and industrial production: Challenges and resilience. Oxford Economic Studies.

Balcilar, M., Gupta, R., & Wohar, M. E. (2021).Tail dependencies between oil prices and economic uncertainty. *Journal of Commodity Markets, 23*, 100153.

Bamaiyi, G. (2024). Impact of Oil Price Shocks and Economic Growth in Nigeria: Evidenec

from 1990- 2021, *International Journal of Developing and Emerging Economies*, *12*(1), 1-18. doi: https://doi.org/10.37745/ijdee.13/vol12n1118.

Baumeister, C., & Kilian, L. (2016). Understanding the implications of the recent oil price slump. *Energy Journal, 37*(1), 1-32.

Baumeister, C., &Kilian, L. (2019).Measuring the effects of oil price shocks on the global economy. *Annual Review of Economics, 11*(1), 427-452.

Bjørnland, H. C., &Leitemo, K. (2020).Identifying the interdependence between US monetary policy and the stock market. *Journal of Monetary Economics, 5*6(2), 275-282.

Bjørnland, H. C., &Thorsrud, L. A. (2023). Macroeconomic effects of oil price volatility: A demand-side approach. *Journal of Economic Perspectives, 37*(1), 89-110.

Blanchard, O. J. (2021). Historical oil crises and economic disruptions: Lessons for the future. MIT Press.

Bloom, N. (2023).The impact of policy uncertainty on global economic activity. Princeton University Press.

Bollerslev, T. (1986).Generalized autoregressive conditional heteroskedasticity. *Journal of Econometrics, 31*(3), 307-327.

Chadwick, M. (2020). Oil price uncertainty and its impact on industrial production in oil-exporting countries. *Energy Economics, 85*, 104564.

Dohyoung, K. (2024). Changes in the effects of oil price shocks on US industrial production. *International Journal of Finance & Economics*, 29(2), 2515-2526. DOI: 10.1002/ijfe.2802

Dube, A. (2019). The global spillover effects of U.S. economic policy uncertainty. *IMF Economic Review, 67*(3), 387-418.

Eid, A.G., Mrabet, Z. & Alsamara, M. (2024). Assessing the impact of energy R&D on green growth in OECD countries: a CS-ARDL analysis. *Environ Econ Policy Stud*. https://doi.org/10.1007/s10018-024-00413-4

Engle, R. F. (2001). GARCH 101: The use of volatility models. The Journal of Economic Perspectives, 15(4), 157-168.

European Commission (2024). Monetary policy and uncertainty in the global economy. Brussels: European Union Publications.

Feldstein, M. (2017).Oil price volatility and economic performance in oil-exporting countries. National Bureau of Economic Research Working Paper No. 12345.

Gabler, P. (2025). Resilience in industrial sectors: Adapting to energy shocks. *International Energy Policy Journal, 12*(3), 241-259.

Georgiou, K., &Anastasiou, D. (2021).The impact of economic policy uncertainty on industrial production in Southeast European countries. *Journal of Economic Policy Analysis, 34*(2), 45-61.

Ghosh, S., &Kanjilal, K. (2021). Oil prices, exchange rate, and industrial production: A nexus in transition economies. *Resources Policy, 74*, 102361.

Gulen, H., & Ion, M. (2016).Policy uncertainty and corporate investment. *Review of Financial Studies, 29*(3), 523-564.

Hamilton, J. D. (2009). Causes and consequences of the oil shock of 2007-08. *Brookings Papers on Economic Activity, 40*(1), 215-283.

Hernandez, R., &Zeynalov, S. (2020). Supply-side effects of oil price volatility on the UK economy. *Energy Economics Review, 28*(4), 125-140.

Herrera, A. M., Karpoff, A., & Sun, X. (2023). Aggregate demand shocks and oil price fluctuations: A case study of consumer spending. *Journal of Applied Economics, 45*(3), 411-432.

Hofmann, T., & Müller, R. (2022). Economic policy uncertainty and industrial output in Germany: Evidence from an SVAR model. *German Economic Studies, 40*(3), 289-304.

International Monetary Fund. (2024). Economic policy uncertainty and its global effects. Washington, DC: IMF Publications.

Ji, Q., Bouri, E., &Roubaud, D. (2020). Economic policy uncertainty and oil price movements: A global perspective. *Energy Economics, 91*, 104838.

Jiang, Z., Miao, B., &Xie, X. (2020). The effects of U.S. economic policy uncertainty on the oil market: An empirical analysis. *Energy Economics*, 86, 104664.

Joe, H. (1997). Multivariate models and copulas. CRC Press.

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

Kostadinov, A. (2023). Oil price fluctuations and industrial output in South East European economies: Evidence from a co-integration approach. *Journal of Applied Economics and Energy Studies, 47*(2), 118-134.

Kovačić, N., &Lukić, Z. (2023).The dual effect of oil price volatility on industrial production in South East European oil-exporting countries. *Energy Economics Research Journal, 35*(1), 77-93.

Liu, H., & Wang, Y. (2024). Oil price volatility and industrial production in Japan: Insights from the cost-push inflation theory. *Asia-Pacific Energy Studies, 62*(3), 215-230.

Liu, D., Meng, L., & Wang, Y. (2020). Oil price shocks and Chinese economy revisited: New evidence from SVAR model with sign restrictions. *International Review of Economics & Finance*, 69(C), 20-32. DOI: 10.1016/j.iref.2020.04.011

Liu, Y., Zhou, Z., & Wang, J. (2021). Industrial production and oil price volatility in oil-exporting economies. *Energy Policy*, 146, 111791.

Miamo, C. W., & Achuo, E. D. (2021). Crude oil price and real GDP growth: an application of ARDL bounds co-integration and toda-yamamoto causality tests. Economics Bulletin, 41(3), 1615-1626. Handle: RePEc:ebl:ecbull:eb-21-00041

Mankiw, N. G. (2022). Macroeconomics (10th ed.). Worth Publishers.

Mason, J., & Carter, P. (2020).Economic policy uncertainty and its effects on industrial production in the US and UK. *Industrial Economics Review, 45*(4), 341-358.

Matsumoto, K., & Tanaka, S. (2024). The impact of domestic and global economic policy uncertainty on Japan's industrial production. *International Journal of Economic Policy, 51*(1), 15–34.

Matsumoto, K., & Tanaka, S. (2024). The impact of domestic and global economic policy uncertainty on Japan's industrial production. *International Journal of Economic Policy, 51*(1), 15-34.

Mimiko, N., & Adebayo, T. (2023). The asymmetric effects of oil price shocks: Evidence from emerging markets. *African Journal of Economics, 12*(2), 145-162.

Narayan, P. K., & Sharma, S. S. (2022). Exchange rate volatility and industrial production: Evidence from oil-exporting nations. *Energy Economics, 105*, 105758.

Papadakis, S., &Dimitriou, E. (2023). Economic policy uncertainty and industrial production in Italy and Greece: Evidence from a dynamic panel data approach. *Mediterranean Economic Review, 39*(2), 89-105.

Papadopoulos, N., & Giannopoulos, P. (2023). Exchange rate volatility and industrial production in Greece and Italy: A structural VAR approach. *European Economic Review, 67*(2), 195–210.

Patton, A. J. (2006). Modeling asymmetric exchange rate dependence. *International Economic Review, 47*(2), 527-556.

Pan, C., Huang, Y., & Lee, C.-C. (2024). The dynamic effects of oil supply shock on China: Evidence from the TVP-Proxy-VAR approach. *Socio-Economic Planning Sciences*, 95(C). DOI: 10.1016/j.seps.2024.102026 Petrou, A., &Kotsakis, I. (2020).The effects of exchange rate shocks on industrial production in Southeast European countries. *Economic Dynamics and Policy Research, 22*(1), 45-60.

Pindyck, R. S. (2021). The dynamics of commodity price volatility and its implications for the economy. *Energy Economics*, 93, 105025.

Popov, V., & Milosevic, D. (2021). Oil price uncertainty and industrial production in South East European countries: A DCC-GARCH analysis. *Energy Policy and Economic Studies, 50*(3), 178-196.

Reuters. (2024). Trade uncertainty and global market impacts. London: Reuters Economics Research.

Rosen, J. (2023). Industrial production and its role in economic resilience. New York: McGraw Hill.

Stiglitz, J. E. (2020). Inflation and supply-side shocks: The interplay of oil prices and economic growth. W.W. Norton & Company.

Tan, R., & Dai, W. (2024). Oil price shocks and the canadian stock market. *Journal of Risk and*

Financial Management, 17(11), 518. https://doi.org/10.3390/jrfm17110518

Tanaka, H., & Saito, M. (2024). Exchange rate shocks and Japan's industrial production: Insights from the J-curve theory. Asian Economic Journal, 36(1), 105–120.

Vukovic, M., Radic, L., &Petrovic, S. (2021). The effects of oil price shocks on economic growth in Southeast Europe: Evidence from the Keynesian Aggregate Demand Model. Balkan Energy Economics Journal, 29(3), 143–159.

Zhang, Y., & Zhao, W. (2022). Aggregate demand-side effects of oil price fluctuations in G7 economies. Journal of Global Economic Analysis, 57(2), 75–92.

Appendix 1: Summary Statistics for Denmark

Table 1: Descriptive Statistics

Statistics	IGDP	OSS	EPOU	FXM	IOSSUEPOU	IOSSFXM	IEPOUFXM
Mean	2.829940	54.57406	179.8747	0.050743	9483.992	1.473819	8.501776
Median	2.332620	52.66178	165.7441	-0.000105	9406.290	-0.007082	-0.012450
Std. Dev.	3.890764	16.66681	64.85926	0.151755	3790.956	4.867894	25.84981
Skewness	0.230571	0.005076	0.733762	2.649285	0.972952	2.306631	2.957591
Kurtosis	2.764559	1.647333	2.370579	9.112478	4.019347	7.475190	10.79240
Jarque-Bera	0.714893	4.879499	6.799466	174.4993	12.86830	110.1587	255.2290
Probability	0.699460	0.087183	0.033382	0.000000	0.001606	0.000000	0.000000

Appendix 2: Summary Statistics for Finland

Statistics	*IGDP*	*OSS*	*EPOU*	*FXM*	*IOSSEPOU*	*IOSSFXM*	*IEPOUFXM*
Mean	2.694074	54.57406	184.2415	0.120813	9723.554	6.224362	21.85743
Median	3.506834	52.66178	167.6850	0.037388	9574.854	1.544073	5.888544
Std. Dev.	4.074360	16.66681	68.42768	0.244624	4015.280	14.15386	48.87287
Skewness	-0.549065	0.005076	0.712345	0.829802	0.989775	0.887582	1.297693
Kurtosis	2.616448	1.647333	2.223864	2.474518	3.944496	2.738670	4.004773
Jarque-Bera	3.608007	4.879499	7.019018	8.081110	12.82852	8.585339	20.65493
Probability	0.164638	0.087183	0.029912	0.017588	0.001638	0.013668	0.000033

Appendix 3: Summary Statistics for Germany

Statistics	*IGDP*	*OSS*	*EPOU*	*FXM*	*IOSSEPOU*	*IOSSFXM*	*IEPOUFXM*
Mean	1.610725	54.57406	240.2366	0.016777	12569.74	0.721815	3.506614
Median	2.117123	52.66178	232.5706	0.022566	13551.02	1.088533	6.117687
Std. Dev.	2.456683	16.66681	84.56946	0.065409	4264.865	3.227648	13.15661
Skewness	-1.355716	0.005076	0.976850	0.176080	-0.079830	-0.418532	-0.131891
Kurtosis	4.604707	1.647333	3.795385	3.646132	1.752416	2.753810	3.324256
Jarque-Bera	26.47186	4.879499	11.86554	1.444008	4.218555	2.030098	0.465927
Probability	0.000002	0.087183	0.002651	0.485778	0.121326	0.362385	0.792183

Appendix 4: Summary Statistics for Ireland

Statistics	IGDP	OSS	EPOU	FXM	IOSSEPOU	IOSSFXM	IEPOUFXM
Mean	1.840534	54.57406	158.4210	0.017545	8382.164	0.768174	2.578964
Median	2.373368	52.66178	147.7109	0.007760	8502.004	0.599855	1.159691
Std. Dev.	1.950545	16.66681	49.76908	0.041384	2702.318	2.197631	6.386221
Skewness	-0.786722	0.005076	2.254572	0.177174	0.067093	0.442685	0.268992
Kurtosis	4.054532	1.647333	8.629021	2.010909	2.035399	2.862172	2.519929
Jarque-Bera	9.567377	4.879499	138.7154	2.943637	2.529227	2.141001	1.386386
Probability	0.008365	0.087183	0.000000	0.229508	0.282348	0.342837	0.499977

Appendix 5: Unit Root Results for Denmark

Variables	*Critical Values 5%*	*ADF T-Statistic*	*Order Of Stationary*	*Remark*
IGDP	-2.909206	-7.790314	I(1)	Stationary
OSS	-2.909206	-7.749418	I(1)	Stationary
EPOU	-2.909206	-7.804964	I(1)	Stationary
FXM	-2.909206	-7.746393	I(1)	Stationary
IOSSEPOU	-2.909206	-7.766783	I(1)	Stationary
IOSSFXM	-2.909206	-7.748219	I(1)	Stationary
IEPOUFXM	-2.909206	-7.746156	I(1)	Stationary

Appendix 6: Unit Root Results for Finland

Variables	*Critical Values 5%*	*ADF T-Statistic*	*Order Of Stationary*	*Remark*
IGDP	-2.909206	-6.166338	I(1)	Stationary
OSS	-2.909206	-7.749418	I(1)	Stationary
EPOU	-2.909206	-7.815308	I(1)	Stationary
FXM	-2.909206	-7.078412	I(1)	Stationary
IOSSEPOU	-2.909206	-7.770166	I(1)	Stationary
IOSSFXM	-2.909206	-7.883252	I(1)	Stationary
IEPOUFXM	-2.909206	-8.591558	I(1)	Stationary

Appendix 7: Unit Root Results for Germany

Variables	*Critical Values 5%*	*ADF T-Statistic*	*Order Of Stationary*	*Remark*
IGDP	-2.909206	-7.745969	I(1)	Stationary
OSS	-2.909206	-7.749418	I(1)	Stationary
EPOU	-2.909206	-7.767903	I(1)	Stationary
FXM	-2.909206	-7.745969	I(1)	Stationary
IOSSEPOU	-2.909206	-7.757081	I(1)	Stationary
IOSSFXM	-2.909206	-7.751441	I(1)	Stationary
IEPOUFXM	-2.909206	-7.751200	I(1)	Stationary

Appendix 8: Unit Root Results for Ireland

Variables	*Critical Values 5%*	*ADF T-Statistic*	*Order Of Stationary*	*Remark*
IGDP	-2.909206	-8.333280	I(1)	Stationary
OSS	-2.909206	-7.749418	I(1)	Stationary
EPOU	-2.909206	-7.746145	I(1)	Stationary
FXM	-2.909206	-5.916196	I(1)	Stationary
IOSSEPOU	-2.909206	-7.7409	I(1)	Stationary
IOSSFXM	-2.909206	-6.011976	I(1)	Stationary
IEPOUFXM	-2.909206	-6.846956	I(1)	Stationary

Appendix 9: Co-integration Results for Denmark

Hypothesized	*Eigenvalue*	*Trace statistics*	*0.05 Critical value*	*p-Value*
None	0.206583	49.89977	47.85613	0.0041
At most 1	0.134504	15.78398	29.79707	0.7274
At most 2	0.083958	6.972405	15.49471	0.5809
At most 3	0.026258	1.623153	3.841466	0.2027

Appendix 10: Co-integration Results for Finland

Hypothesized	*Eigenvalue*	*Trace statistics*	*0.05 Critical value*	*p-Value*
None	0.352227	51.66295	47.85613	0.0210
At most 1	0.265077	25.17584	29.79707	0.1552
At most 2	0.074184	6.388474	15.49471	0.6496
At most 3	0.027271	1.686618	3.841466	0.1940

Appendix 11: Co-integration Results for Germany

Hypothesized	*Eigenvalue*	*Trace statistics*	*0.05 Critical value*	*p-Value*
None	0.465372	71.27502	47.85613	0.0001
At most 1	0.244250	33.07783	29.79707	0.0202
At most 2	0.191870	15.99511	15.49471	0.0420
At most 3	0.047993	3.000145	3.841466	0.0833

Appendix 12: Co-integration Results for Ireland

Hypothesized	Eigenvalue	Trace statistics	0.05 Critical value	p-Value
None	0.313105	55.36440	47.85613	0.0084
At most 1	0.275161	32.45440	29.79707	0.0242
At most 2	0.106619	12.82424	15.49471	0.1214
At most 3	0.092890	5.946958	3.841466	0.0147