The Oil Market and Macroeconomic Stability: What is the Role of Policy Uncertainty?

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Abstract

We analyse the fluctuating connection between economic policy uncertainty (EPU) and oil prices (OP) in Croatia through sub-sample rolling-window Granger causality analyses. Statistical inference based on Granger causality tests suggests that OP acts as a leading indicator for EPU, with evidence of bidirectional feedback. The negative influence of OP on EPU indicates that OP will affect the government's economic policy stability and then affect EPU. Conversely, EPU exhibits both positive and detrimental effects on OP. These results align with general equilibrium models, highlighting the interdependence between OP and EPU. Given the increasing financial attributes of oil, gaining insight into the connection between OP and EPU is essential for enabling the government to formulate more effective economic policies to mitigate the impacts of fluctuations in OP.

Keywords: Oil price; Rolling-window test; Economic policy uncertainty; Variable with time

JEL: Q43; C32; E69; H3

Crude oil operates as a crucial foundation material for industrial production, significantly influencing the stable operation of the global economy (Mengqi Gong *et al.*, 2024). The interconnection between OP with EPU of an oil-importing country has fascinated the attention. For importers, the response of EPU to the fluctuations of OP should be more sensitive (Boqiang Lin and Rui Bai, 2021). Therefore, studying the dependence between EPU and OP in oil-importing economies holds significant academic and practical value. Based on the importance and necessity of the above discussion, this paper contributes several nuanced yet significant additions to the existing body of literature. Firstly, it delves into the intricate relationship between OP and EPU, systematically examining how external uncertainties influence OP and elucidating the specific transmission mechanisms through which these effects manifest in oil-importing countries. While the majority of scholarly work has predominantly focused on the interaction between EPU and OP in global or dominant economies, such as the United States and China, there has been a notable lack of attention given to Central and Eastern European countries. Our study addresses this gap by focusing on Croatia, offering a unique perspective on how OP influences economic activity through the lens of policy uncertainty in nations characterized by high energy dependence and smaller economic scales. This focus not only enriches the literature but also provides a more comprehensive understanding of the diverse economic contexts in which OP and EPU interact.

The rest of the study is as follows: Section 1 provides the background of Croatia. Section 2 presents the literature review. Section 3 provides the empirical method and data The empirical results are presented in section 4. Section 5 summarises the conclusions and makes policy recommendations.

1. Background of Croatia

Croatia, being one of the fastest growing economies in the Eastern Europe, can be largely characterized as having a strong dependency on energy prices, especially OP as stated by Djula Borozan and Marina Lolic Cipcic (2022). Oil is responsible for 38% of the total primary energy consumption in Croatia. For example, tourism is one of the main pillars of the Croatian economy, which is highly sensitive to the OP fluctuation since OP affects the transportation cost and in turn the tourism industry (Luka Vukić, Davor Mikulić and Damira Keček., 2021). On the other hand, the domestic oil production in Croatia is estimated to be only about 20% of the total demand, which means that the country is importing 80% of its oil (Dejan Živkov, Jasmina Đurašković and Slavica Manić., 2019). Therefore, OP fluctuation will have a large impact on the investment level and inflation rate, which are two major economic indicators in the country. The issue of OP is also closely related to political issues in the context of Croatia. In terms of revenue, taxes on oil are one of the largest components of the national budget. Therefore, the oil taxation policy is a highly significant policy tool (Marko Šarić, 2023). In general, high OP would suppress petroleum consumption and reduce government tax revenues, while low OP would be beneficial for consumers, but it might lead to fiscal instability and low policy certainty in the long run (Chunjuan Guo, Xiangwei Zhang and Sajid Iqbal., 2024). Therefore, the policymakers in Croatia must consider the dynamic changes of OP when designing economic policies. In addition to the national level, the economic policy in Croatia also follows the rules and regulations set by the European Union (EU). According to Philipp Genschel and Markus Jachenfuchs (2018), while the key national powers such as monetary policy and fiscal policy have been transferred to the supranational institutions for EU integrated countries, Croatia has still been able to maintain a relatively high level of independence in designing its economic policies. Unlike some other European Union countries, the Croatian economy has not been restricted in its economic policy direction since joining the European Union and the euro, which means that it can still find ways to deal with the OP issue (Josip Lučev and Dario Cvrtila, 2021). Finally, the relationship between OP and economic policy stability in Croatia is also affected by the geopolitical situation in the region. As the Balkans area has been a region with geopolitical instability, which means that geopolitical events would have a large impact on the economic policy stability in Croatia (Milovan Trbojević, Dejan Jovanović and Diona Đurđević., 2024; Chi Wei Su *et al*., 2025). In summary, there are four main distinctive characteristics of the relationship between OP and EPU in Croatia: high energy dependence, sensitive tourism industry to OP fluctuation, relatively high level of policy flexibility in the EU context, and high geopolitical sensitivity. These characteristics make the OP play a vital role in the Croatian economy.

2. Literature review

Previous studies have found that EPU enhances OP fluctuations (Ine Van Robays 2016). In other words, some studies suggest that EPU has a positive impact on OP. That is, EPU plays a key role in explaining oil prices. For example, EPU changes affect consumers' expectations and thus increment future demand for oil, which in turn raises OP. (Ron Alquist and Lutz Kilian 2010; Kai Wu *et al.* 2020). Riadh Aloui, Rangan Gupta and Stephen M. Miller. (2016) examined whether EPU affected oil suppliers' expectations during financial crises and the economic depression of the 1930s. They found that EPU induced oil suppliers to store oil, thus increasing demand and raising OP. This result is consistent with the result obtained by Ahmet Tunc, Mustafa Kocoglu and Alper Aslan. (2022) who found that EPU and OP positively correlate during oil shocks. Furthermore, Ifedolapo Olanipekun, Godwin Olasehinde-Williams and Seyi Saint Akadiri (2019) point out that escalating EPU increases uncertainty regarding prospective supplies of petroleum derivatives, leading consumers to boost current gasoline demand and elevating OP. Zheng Zheng Li *et al.* (2023) believe that an imperiling economic environment would induce policymakers to release policies more frequently. Hence an increase in EPU would prompt manufacturers and consumers to enhance their depletion of non-renewable fuel resources, which would further increase OP. By contrast, other researchers believe that EPU has a negative influence on OP. Oguzhan Ozcelebi (2021) believe that high EPU would disturb the steadiness of economic environment and capital market. With the financial characteristics of oil becoming more prominent, high EPU may have an adverse impact on OP and cause prices to decline. Furthermore, an increase in EPU would possibly suppress industrial economic growth and raise financing costs for investors. In addition, it would cause an economic slowdown, which greatly influences oil demand and causes a significant decrease in OP (Can-Zhong Yao and Bo-Yi Sun., 2018; Jingyu Chen *et al.*, 2019). Furthermore, EPU's influence on the economic environment would cause the investment expected return to change. That is to say, the willingness of investors to invest would be suppressed and OP would decrease when EPU rises (Nikolaos Antonakakis, Ioannis Chatziantoniou and George Filis, 2014; Xiuwen Chen, Xiaolei Sun and Jianping Li., 2020). Yanhong Feng *et al.* (2020) found that OP during the global financial crisis and European sovereign debt crisis was influenced by EPU. Furthermore, Feng Liu *et al.* (2023) found that OP was inversely related to EPU.

Fangying Liu *et al.* (2024) found that an increase in EPU over the short term reflected a worsening situation in the economy, and investment partners adopted a prudent strategy for investment in energy. For this reason, disinvestment of a large amount of capital in the oil market would cause a decrease in OP.

Another portion of studies indicates that OP is a determining factor of the EPU index (Wensheng Kang and Ronald A. Ratti, 2013; Lu Yang, 2019). Likewise, there are two distinct conclusions regarding how OP affects EPU. Su *et al.* (2021) note that in China, India, and Brazil, which are highly dependent on oil, OP positively influences EPU. Moreover, Kai-Hua Wang *et al.* (2022) demonstrate that due to varying degrees of oil dependence among different countries, the impact of OP volatility on EPU varies. In the long term, the volatility of OP in India has a significant positive effect on EPU. Nevertheless, the research by Lin and Bai. (2023) does not support the conclusion above. Their outcomes imply that OP has an adverse effect on EPU in Brazil, China, Europe, Japan, Korea, Mexico, Russia, Sweden, and America. Additionally, during the COVID-19 pandemic, the negative dynamics of OP led to an increase in EPU (Arshian Sharif, Chaker Aloui and Larisa Yarovaya., 2020). Some studies also suggest that a time-varying relationship exists between OP and EPU. Abebe Hailemariam, Russell Smyth and Xibin Zhang. (2019) point out that the increase in OP reduced EPU before the global financial crisis but increased EPU. Hasanul Banna *et al.* (2023) reveal that the influence of OP shocks on EPU during periods of significant global OP fluctuations may also vary depending on the country's oil consumption and import and export status. Furthermore, the sensitivity of developing and developed countries to global oil shocks may also differ (Leila Dagher and Fakhri J. Hasanov, 2023; Xin Li and Su, 2024).

Furthermore, there remains a lack of consensus regarding the impact of OP fluctuations on Croatian EPU. Different economic dynamics suggest both positive and negative effects, adding to the complexity of the relationship. On one hand, following the enactment of the Law on the Market of Oil and Petroleum Products, the Croatian government has significantly reduced its direct interventions in the petroleum sector. This change in policy leads to a decrease in OP. However, fuel taxes represent a large proportion of total Croatian tax revenue (Borozan and Cipcic 2022). Therefore, a decline in OP leads to a decrease in revenue from fuel taxation. Consequently, policymakers are forced to respond by changing fiscal policy, which may include altering the tax system (thus increasing EPU). Alternatively, an increase in OP leads to inflation in Croatia (Ondřej Bednář *et al*. 2022). In years when OP has been high, governments have often raised prices, resulting in increased inflation. In response, the government implements price controls on oil and its derivatives and decreases some taxes to alleviate the effects of higher consumer prices (Keček 2023). Although it may be desirable for the government to intervene and control prices in an attempt to reduce inflation, such intervention may contribute to greater policy uncertainty because it signals that policies are frequently changed and that the government is adopting a command-and-control approach to inflation. James E. Payne *et al*. (2023) also point out yet another important aspect of this relationship. They note that high EPU results in a low number of foreign tourist arrivals into Croatia. Because this country has a significant reliance on tourism as a source of income, an increase in uncertainty leads to a decrease in tourism activities, which in turn leads to a decrease in domestic oil demand and a decrease in OP. In contrast, using quantile and panel analysis, Vishal Dagar *et al*. (2024) find that high EPU leads to an increase in OP. That is, uncertainty in the economic policy environment weakens the government's decision-making process, leading it to engage in regulatory actions that affect the energy market. In turn, these regulatory changes undermine Croatian energy security in ways that are important to understand.

Prior investigations have widely examined the one-way relationship between OP and EPU. However, more analysis is necessary to delve deeper into this interrelationship. First, existing studies primarily focus on large economic entities such as China and the United States, while there is little knowledge about small open economies highly dependent on oil imports. As one of the oil imports in Eastern Europe, Croatia is particularly sensitive and vulnerable to OP shocks. Therefore, the study of Croatia holds not only regional significance but also serves as an essential comparative case in global economic research. It provides a valuable framework for analysing the similarities and differences in the interaction between EPU and OP across diverse economic contexts and evaluating the effectiveness of policy interventions. Secondly, previous research is primarily concerned with the unidirectional causal link between OP and EPU, with limited research addressing the bidirectional causal relationship between these two variables. Therefore, a deeper investigation into the correlation between EPU and OP in Croatia could yield significant insights for formulating government policies. Third, prior studies neglect the change of the arrangement of time series and fluctuating factors in the Granger causality testing approach, which hinders the analysis of the variable relationship and direction of influence between EPU and OP. To tackle the above gaps, this paper utilises the bootstrap sub-sample rolling-window causation test to ensure a robust empirical result to capture the evolving relationship between OP and EPU as time progresses (Ran Tao *et al.*, 2021; Xi Yuan *et al.*, 2022).

3. Empirical method and data

3.1 General equilibrium model

This research paper systematically looks into the complex interplay and dynamic relationship between EPU and OP by utilizing a sophisticated general equilibrium model that was originally developed and introduced by Ľuboš Pastor and Pietro Veronesi in their seminal 2012 work. The adoption of this robust analytical framework enables a comprehensive examination of the intricate connections and causal mechanisms that exist between government policy decisions and fluctuations in oil prices. By leveraging this well-established model, the study establishes a rigorous theoretical foundation and provides a structured analytical framework for exploring the multifaceted interactions and interdependencies among these critical economic variables. This approach not only enhances our understanding of the underlying economic dynamics but also offers valuable insights into how policy-related uncertainties and energy market fluctuations influence each other within the broader economic context.

First, we assume an economy characterised by a continuous number of oil investors η, operating within a defined time period. Assume all investors' returns at time 0 are $N_0^\eta = 1$. Thereafter, investors continue to allocate capital to the oil market, yet they can only expect to receive stochastic investment returns (OP_t^η). We can then derive the asset growth equation for oil investors, described as $dN_t^\eta = N_t^\eta dOP_t^\eta$. In addition, N_t^η represents the equity capital return for investors η at the t moment. Consequently, we can establish a general equilibrium model as follows.

$$dOP_t^\eta = (m + v_t)dt + \gamma dZ_t^\eta \quad t \in [0, T] \tag{1}$$

Where m represents additional factors that may play a role in volatility in the oil market. v_t indicates that the average profitability of investors is influenced by fluctuations in economic policies. $m=0$ means that means that fluctuations of the OP will not trigger the adjustments of economic policy. γ and γ_1 are coefficients of Brownian motion (Z_t). What's more, Z_t^η is the independent Brownian motion of investor i. Besides that, p^{old} signifies the present impact of OP. Generally, p^{old} is a constant value unless OP are adjusted at a point κ $(0<\kappa<T)$. If the price of oil fluctuates, p^{new} will replace p^{old}. Therefore, p_t could be described using the following.

$$p_t = \begin{cases} p^{old} \; for \; t \le \kappa \\ p^{old} \; for \; t > \kappa \; no \; price \; fluctuates \\ p^{new} \; for \; t > \kappa \; price \; fluctuates \end{cases} \tag{2}$$

If the OP changes at the point of κ,the price influence would become effective instantly. Through the temporal scope $t \in [0,T]$, the influence of price amendment on policy is indeterminate. This suggests the value of p_t is unclear. Furthermore, both p^{old} and p^{new} are zero-mean normal distributions with a known variance σ_p^2. On top of that, p_t represents the effect of OP. σ_p is the standard deviation of p_t. In the background of continuous fluctuations of OP, uncertainty (σ_p) could exacerbate the adjustment of economic policies. Although there is a big difference between p^{old} and p^{new}, their sizes cannot be compared. If $p^{old} > p^{new}$, OP and EPU have a mutually negative effect on each other. Consequently, we can deduce that OP affects EPU, although the direction of this effect is indeterminate.

3.2 data

To look into whether fluctuations in OP have impacted EPU in Croatia, we select monthly observations covering the time frame from 2013:M07 to 2024:M05. On July 1, 2013, Croatia was officially accepted as the 28th member state of the European Union. Furthermore, given that Croatia's accession coincided with a particularly challenging period for the EU economy, some citizens believe that domestic demand from the EU will have a limited effect on their economy (Paul Stubbs and Siniša Zrinšcak, 2017). Following its formal accession, it is expected to implement a series of new policies, and the rise in business costs in Central Europe post-accession would likely elevate Croatia's EPU. We utilise the index developed by Petar Sorić and Ivana

Lolić. (2017) to quantify the level of EPU in Croatia. This index is derived from a searchable methodology informed by essays from popular Croatian news portals, including the legal amendments library and various business and consumer surveys. To qualify for inclusion in their EPU index, a Croatian-language article must contain at least one term from each of three categories: economic terminology, policy-related vocabulary, and uncertainty indicators. Once we filtered out the articles meeting our specified conditions, we calculated monthly relative frequencies by dividing the number of relevant articles by the total article count. These figures were then standardized and compiled into monthly averages across each news platform. A higher EPU index indicates greater instability in economic policy, whereas a lower index reflects more stable conditions (Yang, 2025). Furthermore, according to Ivo Krznar and Kunovac (2010), a significant portion of fluctuations in Croatian economic activity can be attributed solely to market OP, which represents about 50% of the fluctuations in the country's Gross Domestic Product. There are compelling reasons to suggest that energy prices, particularly OP, serve as the primary determinants of economic activity (Croatian National Bank, 2015). The behaviour of Croatia's oil and energy market is heavily influenced by government regulation and the operations of the state oil corporation (Industrija nafte), which maintained a monopoly until the early 2000s. This indicates a strong correlation between OP and the country's economic policies. This is in line with the findings of Borozan and Cipcic. (2022), the OP is expressed in U.S. dollars per barrel, with data sourced from the Directorate-General for Energy of the European Commission. Additionally, as OP is subject to global uncertainties such as climate change and geopolitical factors, we incorporate the World Uncertainty Index (WUI) as a control variable (Wang *et al.*, 2022). Besides that, when the price of OP rises, firms may switch to coal or natural gas, pushing up the price of alternative energy sources. This linkage makes GP and CP proxies for the feedback loop between OP and EPU (Su *et al.*, 2024). These two variables are also included among our control variables. We also incorporate the production level of OPEC (OPEC) as a proxy variable for global oil supply shocks into our empirical study to ensure the robustness of our results (Zhe Ma and Yang, 2024). By incorporating these elements, we aim to elucidate the relationship between OP and EPU and further explore whether OP has influenced policy stability in Croatia. The trend variations of OP and EPU are illustrated in Figure 1.

< Figure 1 is inserted about here>

Since the influence of the global financial crisis on Europe has not entirely dissipated, Croatia initiated the Excessive Deficit Procedure (EDP) in 2014. It was abolished by the Council in 2017 as per the recommendation of the Commission. As shown in Figure 1, during this period, Croatia's EPU maintains relatively stable fluctuations in these three years, except for brief increases at the beginning and end of the EDP (Sorić and Lolić, 2017). Additionally, since the oil product market in Croatia was not fully liberalised until 2014, the cost of oil products was previously affected by government regulations. After the Oil and Petroleum Products Market Act (OG 19/14) was promulgated in 2014, the OP in Croatia started to decline (Borozan and Cipcic, 2022). However, fuel taxes account for a considerable proportion of Croatia's tax revenue. Although the government usually does not lower tariffs when OP rises, it does increase tariffs to maintain budget revenue as OP falls. In 2015, as international OP continued to decline, Croatia raised fuel taxes, and the cost increase led to a continuous rise in OP. In 2017, Croatia experienced a significant peak tourist season, recording 17,430,580 tourist visits and 86,200,261 overnight stays (Ender Demir *et al.*, 2022). This surge in tourism has a notable impact on domestic energy demand, which is exacerbated by the growth of the tourism sector, consequently contributing to an increase in OP. From the fourth quarter of 2018 to the beginning of 2021, the economy of Croatia was characterised by moderate and steady inflation and the shock of the pandemic in 2020, which had serious macroeconomic and fiscal consequences. The government initiated substantial discretionary fiscal policies (tax reliefs, deferred taxes, and compensatory payments to support households and firms affected by income and revenue losses from lockdowns), which sharply deteriorated public finances (Frane Banić, Milan Deskar-Škrbić and Hrvoje Šimović*.,* 2023). The fiscal policy is clearly not sustainable during this period, causing a substantial increase in EPU (Karsten Staehr, Oļegs Tkačevs and Katri Urke., 2024). At the same time, in early 2020, the global crude oil market experienced a significant downturn, driven by the combined effects of the oil price war between Russia and Saudi Arabia and the economic disruptions caused by the COVID-19 pandemic. As a result of these external shocks, global crude oil prices plummeted, leading to a corresponding decline in Croatia's oil prices (Meng Qin *et al.*, 2024). Moreover, from the end of 2021 to the end of 2023, as the economy is recovering from the COVID-19 pandemic and confronts the European energy crisis, Croatia re-enters a period of high inflation. The long-term persistent inflation inevitably leads to adjustments in expenditures such as government salaries, retirement benefits, household subsidies, and all other operational and capital spending categories (Banić *et al.*, 2023). The tight monetary policy affects economic activities, thereby influencing tax revenue. The fiscal situation is unstable during this period, leading to fiscal policy discontinuing (Pave Rebić and Vladimir Arčabić., 2023). As a result, EPU fluctuates significantly during this period. Meanwhile, the European energy crisis in 2022 caused energy prices across Europe to soar, and OP in Croatia increased (Maria Kola-Bezka, 2023).

Table A1 in the Appendix gives descriptive statistics of the data. The average values of OP, EPU, WUI, GP, CP and OPEC are concentrated at 74.112, 174.266, 24315.860, 3.307, 115.347 and 27.818 respectively. The skewness of the first five variables is positive, indicating a right-skewed distribution. The skewness of the OPEC is negative, indicating a left-skewed distribution. Additionally, the kurtosis for OP is below 3, suggesting a platykurtic distribution. In contrast, the kurtosis values for EPU, WUI, GP, CP and OPEC exceed 3, indicating a leptokurtic distribution. Furthermore, the Jarque-Bera test reveals that OP exhibits a significant non-normal distribution at the 5% level, while the other five variables demonstrate significant non-normal distributions at the 1% level. Consequently, traditional causality tests are deemed inappropriate for the analysis. Therefore, we employ the RB method to mitigate possible deviations from normality in OP, EPU, WUI, GP, CP and OPEC. Additionally, this study uses a guided sub-sample rolling-window Granger causality test to explore the time-varying relationship between OP and EPU.

3.3.1. Bootstrap full-sample causality test

The Granger causality test statistics using the conventional vector autoregression (VAR) framework may not conform to the typical asymptotic model, resulting in results bias (Hiro Y. Toda and Peter C. B. Phillips., 1994). Ghazi Shukur and Panagiotis Mantalos (2004) address this problem by introducing the critical threshold of the residual-based bootstrap (RB) technique to reduce bias and improve the accuracy of the Granger causality test. Moreover, Shukur and Mantalos (2000) introduce the Likelihood Ratio (LR) method, whose power and size characteristics can be modified. This paper uses the revised LR technique based on RB to explore the causal relationship between OP and EPU. The bivariate VAR (y) system is described as Equation (3):

$$X_t = \alpha_0 + \alpha_1 X_{t-1} + \cdots\ldots + \alpha_r X_{t-y} + \mu_t t = 1,2,\ldots\ldots,T \tag{3}$$

where y is selected according to the Akaike Information Criterion (AIC) for the purpose of choosing the optimal lag order. In addition, we can denote X as $X_t = (OP_t, EPU_t)'$. Then get Equation (4).

$$\begin{bmatrix} OP_t \\ EPU_t \end{bmatrix} = \begin{bmatrix} \alpha_{10} \\ \alpha_{20} \end{bmatrix} + \begin{bmatrix} \alpha_{11}(L) & \alpha_{12}(L) & \alpha_{13}(L) & \alpha_{14}(L) & \alpha_{15}(L) \\ \alpha_{21}(L) & \alpha_{22}(L) & \alpha_{23}(L) & \alpha_{24}(L) & \alpha_{25}(L) \end{bmatrix} \begin{bmatrix} OP_t \\ EPU_t \\ WUI_t \\ GP_t \\ CP_t \\ OPEC_t \end{bmatrix} + \begin{bmatrix} \mu_{1t} \\ \mu_{2t} \end{bmatrix} \tag{4}$$

From the above VAR (y) system it is possible to test the alternative hypothesis that OP Granger leads to EPU$\left(\alpha_{21,k} = 0\right)$. If OP has a significant effect on EPU, the hypothesis can be accepted. Similarly, the alternative inverse hypothesis EPU Granger leads to OP$\left(\alpha_{12,k} = 0\right)$ can be rejected thus EPU has no considerable effect on OP.

3.3.2 Parameter stability tests

The postulate for applying the abovementioned approach is that the coefficients of the VAR (y) system must be nonconstant. However, such a state is often hard to achieve in reality. Therefore, bootstrap full-sample techniques are not robust if the parameters exist structural mutations in the VAR (y) process. To secure the reliability of the findings, the *Sup*-F, *Ave*-F, and *Exp*-F techniques are used in this study (Donald W. K. Andrews, 1993; Andrews and Ploberger, 1994). In this case, the *Sup*-F technique serves to identify mutations in the VAR (y) system as well as in each time series, while the *Ave*-F, as well as *Exp*-F techniques, are designed to capture whether there are coefficients that change gradually over time. In addition, this study employs the L_c statistical technique suggested by Jukka Nyblom (1989) and Bruce E. Hansen (1992) to test whether the parameters are consistent with a random walk behavior. If the above method proves that there is structural variation in the parameters produced, it indicates that the Granger causality between OP and EPU is unstable. Therefore, this paper utilises the more progressive bootstrap subsample technique instead of the full sample technique to explore the fluctuating relationship between these two variables.

3.3.3 Sub-sample rolling-window causality test

The relationship between two sequences is often intricate and subject to variability. Mehme Balcilar *et al.* (2010) introduce the sub-sampling technique to capture this varying correlation. This technique divides the entire data into small parts based on the width of the rolling-window, allowing these small parts to scroll in a loop from beginning to end. The specific routine is as follows: at the beginning, assume the time series' duration be denoted as L and its width be represented as w. The choice of window width is based on experience, as small window width may result in misaligned results, while large window widths cannot guarantee frequency. As noted by M. Hashem Pesaran and Allan Timmermann (2005), we adopt a minimum rolling-window width of 24 for our analysis, given the lack of reliable parametric stability. Then, at the end of every segment, $w, w+1, \dots, L,$ We can get $L-w+1$ sub-samples. Second, based on the modified LR technique of RB, each sub-sample yields a Granger causality. Third, the *p*-value and LR statistics are computed in temporal sequence, thus obtaining the outcomes of the bootstrap sub-sampling technique. In addition, the average of most estimates ($N_b^{-1}\sum_{k=1}^{y}\hat{\alpha}_{21,k}^{*}$ and $N_b^{-1}\sum_{k=1}^{y}\hat{\alpha}_{12,k}^{*}$) points out the effect of OP on EPU and the effect of EPU on OP. Moreover, according to Balcilar *et al.* (2010), 90% confidence intervals with homoscedastic lower (5th quartile) and upper (95th quartile) confidence intervals are used in our study. It is critical to note that Granger causality tests identify statistical precedence in time series data (C. W. J. Granger, 1969), reflecting predictive significance rather than direct causal mechanisms. For instance, if lagged OP values Granger-cause EPU, this may imply that OP serves as a leading signal for EPU, but the underlying economic channels require further theoretical contextualization.

4. Empirical results

In this study, the optimal lag order is determined to be 2 based on the Akaike Information Criterion (AIC). Following this selection, we proceed to construct the VAR (y) process for the bootstrap full-sample test, as specified in Equation (4). The results derived from this methodology are presented in Table 1. From the findings, it is evident that OP serves as a Granger cause of EPU at the 5% significance level. However, the reverse relationship does not hold, as EPU is not identified as a Granger cause of OP at the 10% significance level. This result contradicts the conclusions drawn in previous studies (Tunc *et al.*, 2022; Li *et al.*, 2023). Moreover, these findings also deviate from the assumptions of the general equilibrium model, which posits that external uncertainty plays a distinct role in influencing OP.

< Table 1 is inserted about here>

However, the technique above assumes that the coefficients in the VAR (y) process remain constant and that Granger causality is present throughout the sequence. If the OP, EPU, and VAR (y) process experience structural changes, the findings shown in Table 1 are incorrect, highlighting that the relationship between OP and EPU is dynamic (Balcilar and Ozdemir, 2013). Consequently, this study utilises *Sup*-F, *Ave*-F, *Exp*-F, and *Lc* statistical methods to demonstrate parameter constancy. From Table 2, the *Sup*-F method shows OP and EPU reject the null hypothesis at a 1% significance, with the VAR (y) system's coefficients revealing significant structural changes at the 10% threshold. The *Ave*-F and *Exp*-F techniques further confirm that OP and EPU reject the null hypothesis at the 1% level, while the coefficients in the VAR (y) system show significant changes over time at a 1% and 5% level, respectively. Additionally, *Lc* statistical techniques demonstrate that VAR (y) processes can reject the null hypothesis of random walks at the 1% level. Hence, we can validate the existence of a time-varying relationship between OP and EPU. Therefore, this study utilises advanced sub-sample techniques to explore interactions between OP and EPU. Our results yield different results from the established literature due to the fact that Kang & Ratti (2013) based on large open economies (e.g., U.S., China) with low elasticity of demand for energy and a variety of policy instruments, where EPU-OP feedbacks can be easily absorbed by the domestic buffer mechanism, and Croatia, as a small energy-import-dependent economy, which is more sensitive to oil price fluctuations and exogenous shocks to policy.

< Table 2 is inserted about here>

Figures 2 and 3 display the p-values and coefficients of OP on EPU. OP significantly causes EPU at a 10% level during the periods 2015:M01-2016:M01 and 2020:M06-2021:M11.

< Figures 2 and 3 are inserted about here>

The adverse impact of OP on EPU suggests that variations in OP can introduce instability into Croatia's economic policy framework. Notably, the period from 2015:M01 to 2016:M01 experienced a significant downturn in the global crude oil market. This decline was primarily precipitated by the Organization of the Petroleum Exporting Countries (OPEC) decision during its 2014 annual meeting to maintain production levels rather than implement output cuts. Consequently, OP underwent a series of sustained declines starting in early 2015. The subsequent discussion provides an in-depth analysis of the mechanisms through which OP fluctuations exert adverse and disruptive effects on EPU, offering a deeper understanding of these dynamics.

While a decline in OP driven by demand-side factors may, to some extent, benefit the Croatian economy by increasing real incomes, this advantage may be insufficient to offset the broader negative consequences associated with weaker global demand, rising inflationary pressures, and reduced economic activity, as highlighted by Jovičić and Kunovac (2017). Furthermore, the sharp decline in global OP has imposed significant constraints on the European Central Bank's policy interest rates, pushing them toward the lower bound. This limitation has subsequently diminished the effectiveness of conventional monetary policy tools, as observed by Bobeica Elena and Jarociński Marek (2017). Finally, a comprehensive evaluation of OP's impact on the Croatian economy necessitates a clear distinction between supply-side and demand-side fluctuations. Failure to make this distinction could result in unnecessary and potentially misguided monetary policy interventions, ultimately exacerbating economic policy uncertainty, as noted by Martin Bodenstein, Luca Guerrieri and Lutz Kilian (2012).

In addition, the relationship between OP and EPU exhibits a negative correlation from 2020:M06 to 2021:M11. At the onset of 2020, OP hit record lows amid COVID-19's global economic fallout, which severely curtailed global demand for oil. However, beginning in the latter half of 2020 and continuing through 2021, international oil prices began to recover from their record lows. This rebound was driven by a gradual resurgence in global demand, tightening oil supply, and sustained declines in inventory levels. These factors collectively contributed to the upward trajectory of OP during this period. The transmission mechanism through which OP influences EPU can be explained by several key factors. First, as the global economy began to recover from the pandemic-induced downturn, the rise in OP was accompanied by increasing domestic demand and an upward trend in the prices of other goods and services. This economic recovery led to growth in both personal income and corporate operating profits (Banić *et al.*, 2022; Qin *et al.*, 2024). The resulting moderate inflation, coupled with robust increases in personal income and corporate earnings, bolstered government revenues through higher direct and indirect tax collections, as well as increased social security contributions (Mustafa Gömleksiz and Kıvanç Altıntaş, 2023; Staehr *et al.*, 2024). These improvements in fiscal revenue helped mitigate the substantial debt accumulation that had resulted from the economic shock and the sharp decline in nominal GDP during the early stages of the pandemic. As a consequence, the public debt-to-GDP ratio improved during this period, signaling enhanced fiscal sustainability and greater stability in economic policy (Sek Kun Siok, 2019; Banić *et al.*, 2023; Liu *et al.*, 2024). This overall economic improvement, characterized by rising incomes, stronger corporate performance, and healthier public finances, contributed to a reduction in EPU. The stabilization of economic conditions and the positive outlook for fiscal policy during this phase played a crucial role in alleviating uncertainty, thereby reinforcing the negative relationship between OP and EPU from mid-2020 to late 2021. This dynamic highlights the interplay between energy markets, economic recovery, and policy stability in shaping EPU during periods of significant global upheaval.

Figures 4 and 5 provide a detailed depiction of the directional influence of EPU on OP, alongside their respective correlation coefficients. The analysis indicates that between 2015:M02 and 2015:M09, EPU exerts a statistically significant positive influence on OP at the 10% significance level. However, this relationship shifts in the period from 2017:M09 to 2018:M02, during which EPU has a negative impact on OP.

Firstly, consider the bidirectional causality relationship between OP and EPU in the period 2015:M02-2015:M09. In 2014, there was a significant political event in Croatia, in May, Slavko Linić was dismissed and then the government made a series of policy changes in June due to these political events, these policies affected OP greatly. After Slavko Linić was removed from his position, the Croatian government made some changes to their tax laws, including value-added tax (VAT) laws, income tax laws, lottery tax laws, real estate transfer tax laws and consumption tax laws. The purpose of these policy changes was to enhance fiscal policy effectiveness, encourage FDI, and enhance economic predictability to lower EPU. With an absence of political risk, Croatia received more FDI, thus the domestic economy increased and energy demand increased (Li *et al.* 2023; Su *et al.* 2024). Although in the short term this would cause an increase in demand and place a pressure to increase OP, in the long term the economy would be more efficient and costs would be lowered, which would allow OP to stay constant or lower (Yanfeng Wei 2019; Liu *et al.* 2024). Even though Croatia made improvements in their economic policies, crude oil supply in the rest of the world was still a factor. During this period, OPEC also adjusted its production strategies by increasing output in response to persistently low OP levels. The additional supply injected into the market helped counteract some of the upward pressure stemming from rising domestic demand in Croatia, thereby tempering potential price increases (Dominic Quint and Fabrizio Venditti, 2023).

< Figures 4 and 5 are inserted about here>

On the contrary, the period from 2017:M09 to 2018:M02 presents a contrasting dynamic, where EPU exerts a negative influence on OP. During this time, Croatia achieved a significant fiscal milestone by recording its first fiscal surplus in nearly two decades, marking a notable shift from a deficit to a surplus of 0.6% of GDP. This fiscal turnaround was underpinned by steady growth in government revenue, which played a crucial role in stabilizing Croatia's economic policy landscape (Deskar-Škrbić and Milutinović, 2021). The improved fiscal position not only enhanced the government's capacity to implement strategic reforms but also contributed to a reduction in EPU, fostering a more predictable and favorable economic environment. To further stimulate the development of domestic enterprises, the Croatian government introduced a series of tax reforms aimed at reducing the corporate tax burden and incentivizing investment. These reforms were complemented by efforts to enhance the domestic business environment, including the simplification of administrative procedures and the reduction of unnecessary regulations. Such measures were designed to increase Croatia's attractiveness to both domestic and foreign investors, thereby promoting economic efficiency and reducing EPU. The combination of fiscal stability and business-friendly policies created a conducive environment for economic growth, which was reflected in various sectors of the economy. One of the most notable outcomes of this period of economic stability was the unprecedented success of Croatia's tourism industry. In the second half of 2017, Croatia experienced its best tourist season in history, driven by the country's improved economic conditions and enhanced global appeal (Demir *et al.*, 2022). According to data from the Croatian Bureau of Statistics (Državni zavod za statistiku), the total export value of Croatia's tourism industry reached an impressive 9.5 billion euros in 2017. The surge in both domestic and international demand for Croatian tourism services had a ripple effect on the broader economy, including the energy sector. The increased economic activity associated with the tourism boom led to higher energy consumption, which in turn exerted upward pressure on oil prices (llhan Ozturk, 2022; Božović Miloš, 2022). In summary, the period from 2017:M09 to 2018:M02 illustrates a scenario where reduced EPU, driven by fiscal stability and pro-business reforms, negatively impacted OP. The fiscal surplus achieved in 2017, coupled with strategic tax reforms and regulatory simplifications, created a stable and attractive economic environment that reduced uncertainty and fostered growth. The resulting boom in the tourism sector, evidenced by record-breaking revenues, significantly increased energy demand, thereby boosting oil prices. This interplay between fiscal policy, economic stability, and sectoral performance highlights the complex and dynamic relationship between EPU and OP in the context of Croatia's evolving economy.

In summary, the application of Granger causality analysis using rolling-window method successfully overcomes the problem of parameter instability and offers a more granular insight into the relatedness and causality of OP and EPU. The empirical results show that OP exerts a strong negative impact on EPU, mainly through its effect on governmental policy assessments and policy stability in Croatia. That is, the changes in OP generate uncertainties for policymakers who find it increasingly difficult to make and implement effective economic policies, which in turn aggravate EPU. While the influence of EPU on OP is mixed with both positive and negative effects. On the one hand, the positive effect implies that an effective economic policy, brought about by reduced EPU, enables firms to optimize their supply chains in the long run and establish effective cost control mechanisms, which in turn may stabilize or even reduce OP over time. On the other hand, the negative effect implies that an effective and short-term policy stability, accompanied by improved fiscal continuity, may stimulate energy demand in Croatia, which in turn exerts upward pressure on OP. The above results are also consistent with the predictions of general equilibrium models, if parameter values imply that OP increase effectively strengthen government finances (for instance, increases fiscal revenues or signals higher future output), the model predicts that OP will decrease EPU. That is, a higher OP leads to lower EPU. Intuitively, high oil prices shield the economy against budget shortfall, thereby reducing the likelihood of large policy changes and lowering uncertainty. On the other hand, if parameter values imply that OP decrease exacerbate imbalances, for instance, increases inflationary pressure or signals fiscal vulnerability, the model predicts that OP will increase EPU. That is, a lower OP leads to higher EPU. Here, low OP force more aggressive (and uncertain) policy responses, that is, government exerts more policy pressure to change its previous policies, which in turn increases the volatility of its actions and raises uncertainty. The findings indicate that analyzing energy markets and economic policies requires differentiating short-term from long-term impacts. The results may be useful for policymakers who are seeking to balance energy price stability with economic policy certainty.

5. Conclusions and policy implications

This paper examines the cross-sectional interaction between OP and EPU using a detailed analytical framework of bootstrap analysis on both full-sample and sub-sample data. The empirical results show that there exists a significantly negative relationship between OP and EPU, which means that the global oil market exerts a large degree of influence on the decision-making of the government. That is, when the oil price is volatile, the policymaker may misjudge the cause of oil price shock and thus take inappropriate or even opposite policy actions. Such a misjudgment will increase economic policy uncertainty because the policymaker cannot identify and implement appropriate policies to solve the problem of oil price fluctuation; that is, an environment of economic instability and uncertainty will be generated in the process of economic policy making and implementation. Furthermore, the study shows that EPU and OP have a dualistic relationship. The positive impact of EPU on OP means that a long-term stable policy environment can stabilize the oil market and reduce oil price fluctuation. Stabilization of the oil market means that the oil price will be stabilized because the stable and consistent economic policy makes participants confident and then the stable and consistent investment and consumption behavior will be formed in the energy market. Therefore, the stable economic policy will stabilize the energy market. However, the study also finds that EPU has a counteracting negative impact on OP. When the economic policy is stable in the short term, the economy will be stimulated and the demand for energy will be increased. Then, the price of oil will be raised due to the increased demand, which means that the stability of economic policy increases the volatility of the oil price. The above results are also supported by general equilibrium models. General equilibrium models indicate that OP and EPU have bidirectional causality and are interconnected; that is, long-term policy stability can reduce the volatility of oil prices, but policy stability in the short term will reduce the volatility of economic policies, which will further stabilize the energy market, and then policy stability in the short term will increase the volatility of oil prices.

An in-depth understanding of the interaction mechanism between OP and EPU during critical sub-periods can offer valuable guidance for both investors and policymakers. First, given the dynamic and complex causal correlation between these two variables, investors should exercise increased vigilance regarding fluctuations in EPU, as such variations have the potential to disrupt market stability and influence their participation in the oil sector. Monitoring policy changes and macroeconomic conditions will be essential for making informed investment decisions and mitigating potential risks associated with uncertainty in the oil market. Second, for policymakers, ensuring the continuity, stability, and transparency of macroeconomic policies is of paramount importance. When responding to external shocks in OP, it is crucial to accurately identify the underlying sources of these disturbances to implement well-targeted and effective economic policies. By doing so, policymakers can minimize the volatility of OP, absorb unexpected fluctuations, and create a more predictable economic environment. This approach will not only support sustained national economic growth but also help mitigate the adverse effects of oil price fluctuations on EPU. Finally, maintaining a relatively stable level of EPU is particularly significant for Croatia, especially in the context of its ongoing energy transition. To facilitate this process, key stakeholders should actively increase investments in the exploration and utilization of renewable energy sources. At the same time, the government should introduce and reinforce supportive policies aimed at fostering the development of sustainable energy infrastructure. By promoting a balanced and diversified energy mix, Croatia can reduce its reliance on oil, enhance energy security, and create a more resilient economic environment in the long run.

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Appendix

Table A1. Descriptive statistics

	OP	EPU	WUI	GP	CP	OPEC
Mean	74.112	174.266	24315.860	3.307	115.347	27.818
Median	71.580	164.270	21842.740	2.924	87.450	27.890
Maximum	123.560	495.980	57517.980	9.189	433.700	30.710
Minimum	22.740	70.540	9050.270	1.648	48.800	21.130
Std. Dev.	24.587	59.258	9414.367	1.298	84.815	1.904
Skewness	0.151	1.852	1.164	2.034	2.439	-1.072
Kurtosis	2.001	8.870	4.376	8.060	8.482	4.285
Jarque-Bera	6.576	291.114	44.202	254.666	325.345	37.747
Probability	0.037**	0.000***	0.000***	0.000***	0.000***	0.000***

Notes: **and*** denote the significance at 5% and 1% levels.

Table 1. Bootstrap full-sample method.

Tests	H0: OP does not Granger cause EPU		H0: EPU does not Granger cause OP	
	Statistics	p-value	Statistics	p-value
Bootstrap	9.074	0.014	0.619	0.751

Table 2. The outcomes of parameter stability techniques.

Tests	OP		EPU		VAR (y) process	
	Statistics	p-values	Statistics	p-values	Statistics	p-values
Sup-F	75.982***	0.000	33.906***	0.000	26.717*	0.055
Ave-F	13.016***	0.003	17.991***	0.000	18.813***	0.009
Exp-F	33.584***	0.000	13.304***	0.000	11.653**	0.018
Lc					3.822***	0.005

Notes: *, ** and *** denote the significance at 10%, 5% and 1% levels.

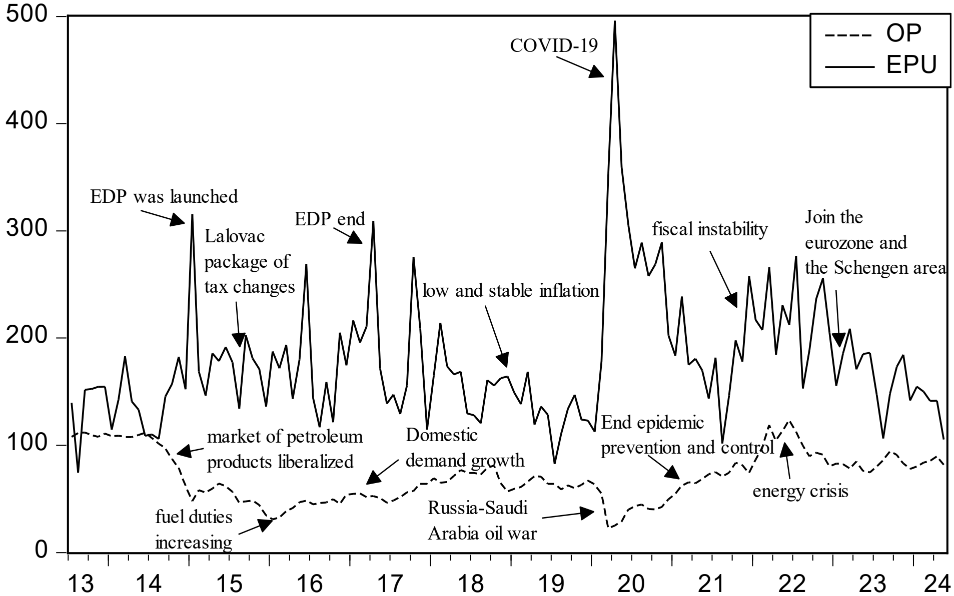

Figure. 1. The trends of OP and EPU.

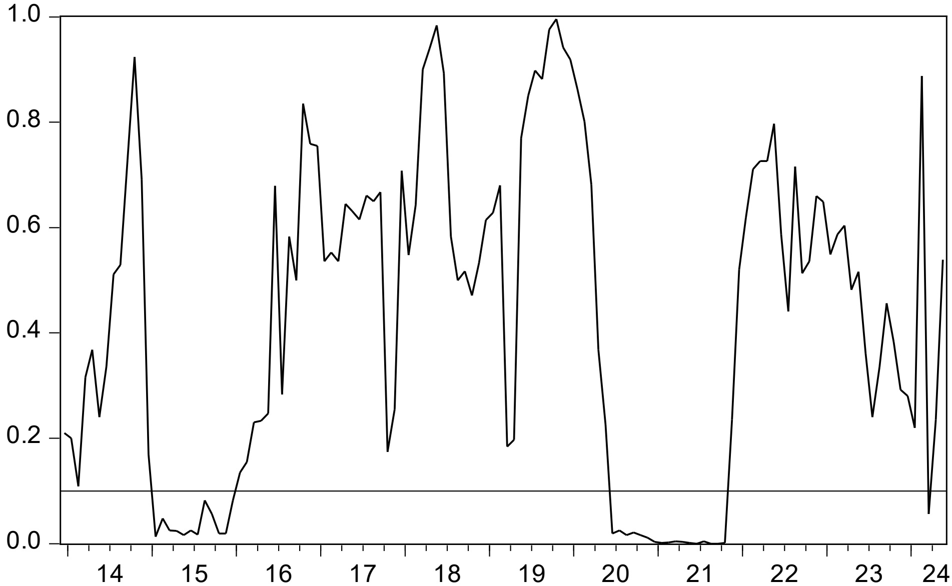

Figure 2. Bootstrap p-values of rolling test statistic testing the null hypothesis

that EPU is not subject to Granger causality from OP.

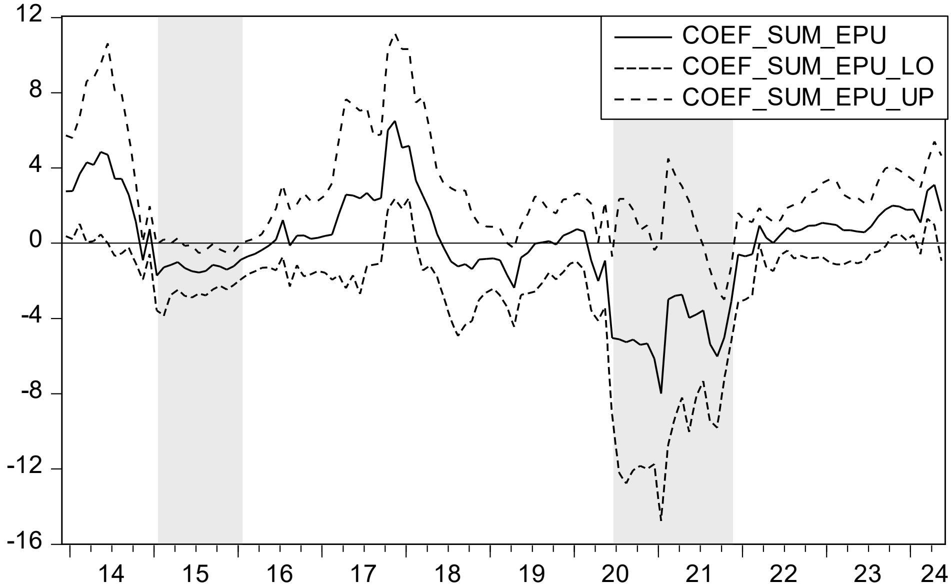

Figure 3. Bootstrap estimates of the sum of the rolling-window coefficients for the influence of OP on EPU.

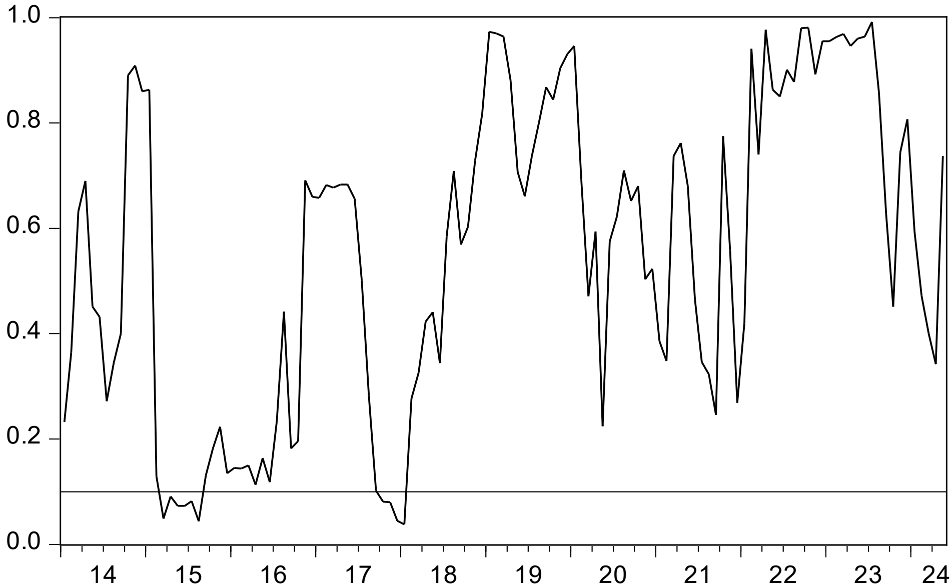

Figure 4. Bootstrap p-values of rolling test statistic testing the null hypothesis that OP is not subject to Granger causality from EPU.

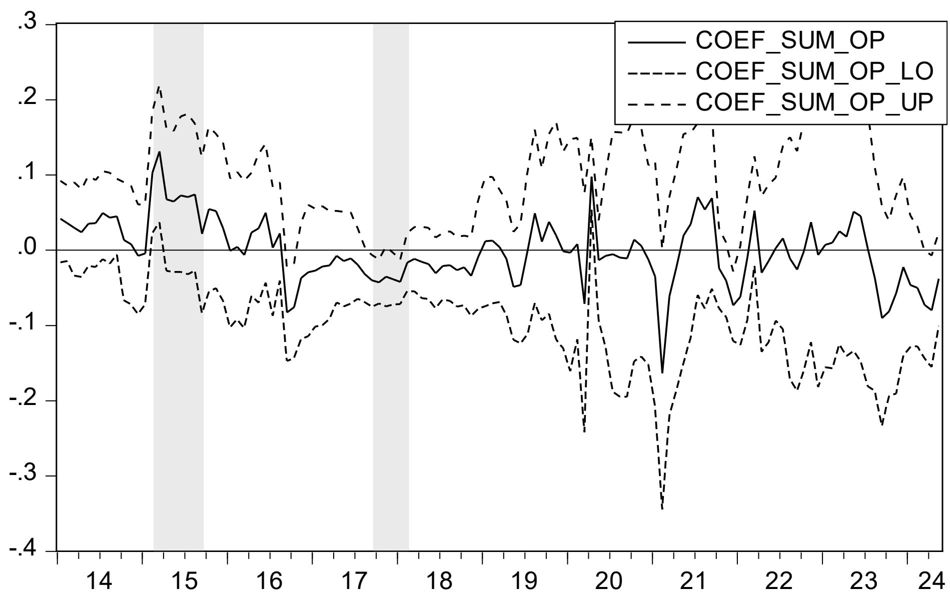

Figure 5. Bootstrap estimates of the sum of the rolling-window coefficients for the influence of EPU on OP.