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Does policy uncertainty stifle the green transition? A multiscale analysis of the energy–growth nexus in the United Kingdom

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ABSTRACT

This paper examines the impact of economic policy uncertainty (EPU) on the United Kingdom's economic growth via energy consumption channels, using monthly observations from 1998M1 to 2024M12. The analysis employs a Multivariate Wavelet Quantile Regression (MWQR) framework to capture nonlinear relationships, scale-dependent associations, and regime-dependent interactions among real GDP per capita (GDPPC), share of renewable energy (REN), and energy use per capita (ENUE). The contributions of this paper are threefold: first, it provides a multiscale assessment of the impact of EPU on both REN and ENUE by decomposing dynamics into short-, medium-, and long-run horizons; second, it highlights asymmetric responses across the growth distribution with respect to EPU, wherein uncertainty shocks become more contractionary in low-growth states of the economy while being weaker or sometimes statistically insignificant in high-growth regimes; third, treating energy consumption as a transmission mechanism indicates that disruptions due to uncertainty in energy mix along with changes in demand patterns partially account for negative spillover from uncertainty onto macro performance in the UK. Empirical results show that EPU has a predominantly negative impact on GDP, significantly constrains renewable deployment over longer horizons, and affects total energy use depending on the state of the economy. Further robustness tests undertaken via univariate wavelet quantile regression yield similar results. These findings underscore the need for credible, stable policy frameworks and targeted support for clean energy investments as prerequisites for resilience to uncertainty shocks and for sustained low-carbon growth pathways in the UK economy.

Contribution/Originality: This paper uses a new Multivariate Wavelet Quantile Regression technique to identify the energy channels through which policy uncertainty affects UK growth. It finds that uncertainty shocks reduce output more at low growth rates and continue to impact renewable deployment in the long run. At the same time, it also shows how delayed efficiency investments can sever the relationship between energy use and growth outcomes.

1. INTRODUCTION

Recently, economic policy uncertainty has emerged as a crucial macroeconomic factor affecting investment decisions, energy consumption patterns, and overall economic dynamics. A substantial body of literature establishes the negative relationship between high uncertainty and capital expenditures, output, and financial stability (Baker, Bloom, & Davis, 2016; Bloom, 2009). However, the specific role of EPU in shaping the energy–growth nexus remains underexplored and therefore poorly understood. It is particularly salient in light of current global transitions towards renewable energy sources and increasing policy attention to sustainable economic development.

Energy is a vital input in modern economies and a principal driver of long-run growth. At the same time, the energy sector is heavily insulated from market forces by government interventions, environmental regulations, and geopolitical considerations. Hence, fluctuations in policy certainty can influence the energy system through different channels. First, higher uncertainty can deter both public and private investments in renewable energy development due to the long payback period and the high upfront costs of green technologies (Popp, Vona, Marin, & Chen, 2020). Second, firms may respond to this risk by using energy more efficiently, reducing everyday use, or slowing down the transition from fossil fuels toward renewables. Finally, households and firms can adjust their consumption decisions, which then impacts aggregate activity; it is through this indirect channel that energy outcomes are linked with broader growth outcomes.

The United Kingdom is an interesting country to study. In recent decades, the UK has experienced significant ups and downs in policies related to Brexit, fiscal changes, energy-price shocks, and changing environmental commitments. At the same time, there have been significant changes in the country's energy sector, with renewable energy growing rapidly while coal and oil are becoming less important in many areas. Determining if and how EPU influences these energy changes is, therefore, essential for designing effective policy frameworks that safeguard both longer-term economic objectives and environmental goals.

Even though this connection is very important, there are not many real-world examples because it is hard to measure true nonlinear, time-scale-dependent interactions among uncertainty, energy use, and economic growth. Traditional time-series tools assume linearity and stationarity, which may quietly mask uneven or misaligned effects across different moments in the business cycle. Recent developments in wavelet-based econometrics offer a better solution, as they enable the decomposition of time-series links across multiple scales while capturing evolving, complex dynamic relationships (Aguiar-Conraria & Soares, 2014). On top of that, this paper uses the Multivariate Wavelet Quantile Regression (MWQR) framework proposed by Adebayo, Abbas, Olanrewaju, and Uzun (2025), which merges wavelet decomposition with quantile regression. The goal is to uncover scale-specific, distributional impacts of EPU on growth, specifically via energy consumption channels.

To grasp these complexities more realistically, this study relies on a relatively new approach, MWQR, which is easier to conceptualize as a means of examining links across different time horizons and under varying economic circumstances simultaneously. Instead of assuming that the policy uncertainty effect remains constant across periods, MWQR allows us to separate short-run motion from long-run dynamics and low-growth moments (fragile) from high-growth episodes (robust). On top of that, because it brings multiple variables into one integrated setup, it can help untangle how energy consumption pathways, both renewable energy usage and total energy demand, transmit uncertainty into actual economic performance. That sort of adaptability makes MWQR especially well-suited to tracing the nonlinear, state-contingent nature of the uncertainty-energy-growth nexus.

So, by taking this approach, the current study contributes to the literature in three main directions. First, it presents a multiscale review of the channel through which policy uncertainty affects renewable energy consumption and per capita energy consumption. Second, it brings out the uneven or asymmetric EPU responses across the distribution of economic growth by separating low-, middle-, median-, and high-growth regions. Third, it tests whether energy consumption is a channel through which uncertainty ultimately affects macroeconomic performance in the United Kingdom.

This study is thus important for any policymaker who would want to stabilise the investment climate, protect energy security, and promote sustainable growth by looking at specific energy channels through which policy uncertainty may be affecting growth, and then providing evidence toward developing more predictable and resilient policy frameworks that can sustain high levels of uncertainty when things are not so stable and easy.

2. THEORETICAL FRAMEWORK AND LITERATURE REVIEW

2.1. Theoretical Framework

The interaction among EPU, energy consumption patterns, and economic development can be conceptualised through several theoretically related pathways that link investment behaviour, energy use, technological change, and macroeconomic outcomes, albeit not in a perfectly defined manner. This concept provides the theoretical backbone for assessing whether the dynamism of growth in the United Kingdom is responsive to changes in policy uncertainty, as reflected in the level and composition of aggregate energy use.

2.1.1. Policy Uncertainty and Macroeconomic Activity

A large body of literature has emphasised the direct channel through which greater uncertainty alters firm and household behaviour by increasing the option value of waiting before making irreversible decisions. In Real Options Theory, uncertainty increases the value of deferring investment decisions, particularly when investment projects entail high sunk costs and long-term horizons (Bernanke, 1983; Bloom, 2009; Dixit & Pindyck, 1994). Thus, when policy signals are mixed and opaque, economic agents may delay capital expenditures, deter hiring decisions, and avoid long-term commitments. Consequently, aggregate output may fall or grow more slowly due to declines in investment and delays in productivity-enhancing activities (Aastveit, Natvik, & Sola, 2013). Collectively, these mechanisms provide a clear theoretical link between EPU and economic outcomes.

2.1.2. Energy Use, Production, and Economic Growth

Energy is a fundamental input into production, affecting both the level and the efficiency of real economic activity. Most standard energy-growth narratives assume that changes in energy intensity, supply availability, and technological efficiency will affect output (Sadorsky, 2010; Stern, 2004). An increase in per capita energy use, ENUE, is generally associated with an increase in industrial output and, by extension, an increase in production capacity. Conversely, a decrease in energy use is usually associated with a decrease in output or a switch to more energy-efficient but capital-intensive methods (Apergis & Payne, 2009). In general, policy shocks that cause energy use to vary will also affect economic growth.

2.1.3. Energy Transition Dynamics and Policy Credibility

The transition to renewables is especially sensitive to the clarity and credibility of policy implementation. Renewable energy investments typically involve high sunk costs and long gestation periods, and depend on state support regimes such as feed-in tariffs, carbon pricing instruments, or broader infrastructure regulation. Research on directed technical change shows that under stable, predictable policies, firms receive clearer signals for innovation and renewable scale-up, whereas under unstable policy regimes, green investment stalls and technology diffusion slows (Acemoglu, Aghion, Bursztyn, & Hemous, 2012; Johnstone, Haščič, & Popp, 2010). When EPU increases, renewable projects may be delayed or cancelled due to tighter financing constraints, regulatory uncertainty, and higher risk premia (Popp, Newell, & Jaffe, 2010). Lower penetration of renewables feeds back into long-run productivity, energy security, and vulnerability to fossil-fuel price shocks.

2.1.4. Integrating Uncertainty, Energy, and Growth

Once again, we see this relationship in the theoretical framework as a multi-channel transmission pathway from EPU to economic growth, mediated by both energy use (ENUE) and the energy supply mix (REN). First, high EPU may reduce economic activity, which reduces overall energy demand (ENUE). This reduction in ENUE will pass through to output via the energy-to-output channel. Second, EPU may delay the adoption of renewable energy technologies, thereby lowering their share (REN) and further reducing spillovers from investment in clean energy, progress in green technology, and long-run productivity improvements (Aghion, Dechezleprêtre, Hemous, Martin,

& Van Reenen, 2016). Third, ENUE and REN may be mutually reinforcing; changes in the energy mix may affect total energy consumption through efficiency improvements or by altering the structure of economic activity. These interactions can be succinctly captured in the following functional relationships.

$$GDPPC_t = f(EPU_t, ENUE_t, REN_t), ENUE_t = g(EPU_t, GDPPC_t, REN_t), REN_t = h(EPU_t, GDPPC_t, ENUE_t) \quad (1)$$

This system allows for nonlinear, state-dependent, and feedback-driven linkages among the variables. Such relationships may vary by economic state, for example, recessionary versus expansionary episodes, as well as across time scales from short-run adjustments to long-term investment cycles. Classic linear models may be inadequate to capture the complexity within the uncertainty-energy-growth nexus. Wavelet-based and quantile-based econometric approaches have recently provided a more nuanced description of heterogeneous multiscale connections (Aguiar-Conraria & Soares, 2014; Reboredo & Rivera-Castro, 2014). These observations then guide the empirical approach taken here.

2.1.5. Theoretical Expectations

Based on this framework, several testable expectations emerge.

1. EPU is expected to exert a negative effect on economic growth, with stronger impacts during low-growth episodes due to amplified uncertainty effects (Baker et al., 2016; Bloom, 2009).
2. EPU is likely to influence total energy use, either by contracting economic activity or by altering investment and efficiency decisions (Sadorsky, 2012).
3. EPU is expected to hinder renewable energy expansion, slowing clean-energy transitions and potentially dampening long-term productivity gains (Johnstone et al., 2010; Popp et al., 2020).
4. Energy consumption and the renewable share are expected to serve as transmission mechanisms through which EPU affects macroeconomic performance.

These expectations form the conceptual basis for examining the role of energy channels in shaping the EPU–growth relationship within the MWQR framework.

2.2. Literature Review

Studies investigating the relationship between economic policy uncertainty, energy dynamics, and economic growth have increased significantly. However, empirical evidence from advanced economies such as the United Kingdom is limited.

Three strands of literature seem particularly relevant to this study. First, considerable work has documented the macroeconomic effects of EPU. It is rather straightforward. Using the EPU index for large economies, Baker et al. (2016) argue that uncertainty shocks are associated with lower investment, output, and employment. The findings of Bloom (2009) are similar; he finds that uncertainty shocks lead to sharp falls in activity because firms delay irreversible investment and hiring - this is evident in the pattern. Subsequent studies support this finding that EPU reduces industrial production, trade, and credit supply, predominantly in advanced economies (Jurado, Ludvigson, & Ng, 2015; Nguyen, 2022). Evidence from the UK indicates that episodes of uncertainty, such as Brexit-related uncertainty, have severely harmed business investment and reduced productivity growth (Bloom et al., 2019; Redl, 2017). These results generally support the proposition that EPU is an important determinant of both cyclical fluctuations and structural changes in GDP.

Numerous studies have examined the relationship between energy and economic growth. During its initial phase, researchers highlighted energy as an input to production and examined the causal relationship between energy consumption and output (Hamilton, 1983; Stern, 2004). Later studies use modern econometric methods along with more disaggregated measures of energy; they frequently come across results indicating bi-directional short-run causality between energy consumption and growth, although country-specific results differ as well as over time spans considered (Akadiri & Ozkan, 2025; Akadiri, Ozkan, Ogbekene, & Hamza, 2025; Apergis & Payne, 2009; Ozturk, 2010). When it comes to renewable energy, the argument is that higher consumption may support long-run growth by strengthening energy resilience, reducing exposure to fossil-fuel price shocks, and encouraging environmental investment and innovation (Ali, Anwar, & Nasreen, 2017; Apergis & Payne, 2012; Menegaki, 2011). For European economies, including the UK, empirical evidence indicates that renewable energy supports growth, particularly over longer horizons (Bölük & Mert, 2014; Stern, 2019).

Third, a growing body of work explicitly bridges EPU and energy markets, as well as the energy transition. In several studies, policy and macroeconomic uncertainty shape energy prices, energy demand, and investment choices in energy infrastructure (Caldara, Fuentes-Albero, Gilchrist, & Zakrajšek, 2016; Elder & Serletis, 2010). More recently, authors have reported that EPU can also reduce renewable energy investment, slow the pace of new capacity, and raise borrowing costs for clean energy projects (Anton & Nucu, 2020; Lu, Zhu, Lau, Isah, & Zhu, 2021). For OECD countries, evidence indicates that EPU weakens green innovation and can even stall the rollout of low-carbon technologies (Chu, Doğan, Abakah, Ghosh, & Albeni, 2023; Popp et al., 2020). Looking at the UK and Europe, there has been growing concern that policy instability on climate goals, carbon pricing, and support mechanisms for renewables has become a real obstacle. This is reflected by less consistent deployment of renewables and postponed grid decarbonization (Bayer & Aklin, 2020; International Energy Agency, 2022).

Methodologically, there is also an increasing use of nonlinear and time-frequency methods to examine uncertainty and macroeconomic linkages with energy. Wavelet-based tools have been applied to identify scale-dependent co-movement between oil price volatility and macro aggregates, similar to Aguiar-Conraria and Soares (2014) and Reboredo and Rivera-Castro (2014). Quantile regressions, together with quantile-oriented causality tests, have been used to assess the asymmetric impacts of EPU and energy shocks on the distributions of growth and financial variables (Balcilar, Gupta, & Pierdzioch, 2016; Troster, Shahbaz, & Uddin, 2018). There are very few papers that merge a multivariate wavelet design with quantile regression to address nonlinearity, unevenness across economic regimes, and scale dependence simultaneously while explicitly representing energy channels.

In this light, the present study makes three distinct yet interconnected contributions to the existing literature. To begin with, it provides fresh evidence on the EPU- growth relationship for the United Kingdom over a long monthly stretch, one marked by major events such as the global financial crisis, Brexit, and, more recently, energy price surges. Second, it does not merely mention energy factors in passing; instead, it explicitly introduces both the renewable energy share and total energy use per capita as potential transmission routes, thereby linking the EPU–macro side to the energy- growth side. Third, using the MWQR framework from Adebayo et al. (2025), the study offers an unusual view of how policy uncertainty interacts with energy conditions across the distribution and multiple time scales, influencing economic outcomes.

3. DATA AND METHODOLOGY

3.1. Data Description and Sources

This study uses monthly time-series data for the United Kingdom, spanning 1998M1 to 2024M12. The variables are as follows: (i) Economic Policy Uncertainty (EPU), which is taken from the index proposed by Baker et al. (2016); (ii) GDP per capita (GDPPC), expressed in constant 2021 international dollars (PPP) and obtained from the World Development Indicators (WDI); (iii) Renewable Energy Share (REN) related to electricity generation, collected via Our World in Data (OWID) together with REN21; and (iv) Energy Use per capita (ENUE), sourced from the WDI. To stabilise variance and improve interpretability, each series is transformed into natural logarithms before any analysis is conducted.

Because real GDPPC, REN, and ENUE are conventionally published annually, monthly observations were generated via temporal disaggregation using the quadratic sum (quadratic match-sum) interpolation method. In practice, the procedure spreads the lower-frequency aggregate levels across higher-frequency months by fitting a quadratic polynomial and ensuring that the sum of the interpolated monthly numbers equals the original annual aggregate. This keeps the baseline movement and rhythmic swings of the series while minimizing distortions that would come from straight-line or even jumpwise interpolation. After the changes already integrated into the interpolation process, no seasonal adjustment was applied to any of the series; all variables were then log-transformed to stabilize variance before estimation.

3.2. Methodology

This study adopts the MWQR approach of Adebayo et al. (2025) to capture the complex, nonlinear, and scale-dependent relationships among policy uncertainty, energy consumption, and economic growth. The MWQR setup is considered stronger than many standard time-domain models because it accounts for several key features of the data simultaneously. In particular, it tackles: (i) nonlinearity, through quantile estimation; (ii) time-frequency localisation, via wavelet decomposition; and (iii) confounding bias by embedding auxiliary control variables inside a multivariate structure that helps reduce unwanted spillovers from omitted drivers.

The method is implemented in two stages. First, the original time series is broken down into multiple frequency components using the Maximal Overlap Discrete Wavelet Transform (MODWT). Compared with the Discrete Wavelet Transform (DWT), the MODWT is non-orthogonal, so it can handle sample sizes without requiring the "power of two" condition, which makes it well-suited for economic time series (Aguiar-Conraria & Soares, 2014). The variables Y (dependent), X (independent), and Z (vector of controls) are decomposed into j scales, representing short-term (D1–D2), medium-term (D3–D4), and long-term (D5–D6) dynamics.

In the second stage, the wavelet coefficients are integrated into a quantile regression framework. The MWQR model is specified as follows.

$$Q_\tau(d_j[Y] \mid d_j[X], d_j[Z]) = \beta_{0,j}(\tau) + \beta_{1,j}(\tau) d_j[X] + \beta_{2,j}(\tau) d_j[Z] + \varepsilon_{j,t} \quad (2)$$

Where:

- $Q_\tau(\cdot)$ denotes the conditional τ-th quantile function of the dependent variable's wavelet coefficients at scale j.
- $d_j[Y]$, $d_j[X]$, and $d_j[Z]$ represent the MODWT coefficients for the dependent variable, the primary regressor (EPU), and the vector of control variables (REN and ENUE), respectively.
- $\beta_{1,j}(\tau)$ is the parameter of interest, capturing the quantile-specific effect of X on Y at scale j, while holding the influence of the control vector Z constant.
- $\tau \in (0,1)$ represents the quantile level, allowing us to observe how EPU affects growth during periods of low growth ($\tau = 0.1$) versus high growth ($\tau = 0.9$).

The inclusion of the control vector $d_j[Z]$ is a critical refinement over the baseline bivariate wavelet quantile structure. In the context of the UK energy–growth nexus, omitting energy consumption trends (REN and ENUE) from estimates of EPU's impact on GDPPC may introduce omitted-variable bias. By estimating the "conditional" effect, MWQR provides a richer multivariate representation that separates the direct effect of policy uncertainty from its joint effect with energy transition and total energy demand. This helps clarify the "energy channels" through which uncertainty affects the macroeconomy.

Before any MWQR estimation can take place, several diagnostic checks must first be performed to validate model choice as justified rather than assumed. The Jarque and Bera (1980) test will be used to assess whether the series is normally distributed; stationarity will be assessed using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. Most importantly, though, the BDS test by Broock, Scheinkman, Dechert, and LeBaron (1996) should be applied to the residuals of a linear model to detect unobserved nonlinear dependencies. If significant, BDS statistics would support moving from linear OLS to nonlinear MWQR, as they indicate a data-generating process driven by complex nonlinear dynamics that simple linear models fail to capture.

The preliminary analysis of the data properties, as shown in Table 1, provides a strong case for using a nonlinear, multiscale econometric model. Panel A describes the statistics for four variables: real GDP per capita (GDPPC), economic policy uncertainty (EPU), share of renewable energy (REN), and energy use per person (ENUE). This covers the period from January 1998 to December 2024. Results here show that GDPPC and EPU have fairly stable average values of 3.6011 and 2.0513, respectively. In contrast, the energy series, particularly REN, exhibits high dispersion, with a standard deviation of 0.4729. The Jarque-Bera test indicated strong evidence against normality for GDPPC (16.3853), REN (33.0817), and ENUE (24.3526), thus rejecting normality with high confidence; only EPU appears approximately normally distributed, with a p-value of 0.3995. These non-Gaussian features, characterized by varying degrees of skewness and platykurtosis, suggest that mean-based estimators may provide an incomplete picture of the underlying dynamics, thereby necessitating quantile-based regression.

Panel B provides further diagnostic insights by reporting results from the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests, indicating a mixed order of integration among the variables. Specifically, EPU is found stationary at levels I(0) with ADF and PP statistics equal to -4.3069 and -7.2813, respectively. In contrast, GDPPC, REN, and ENUE fail to reject the null hypothesis of a unit root at levels but become strongly stationary after first differencing with $p < 0.01$, identifying them as I(1) processes. This combination of I(0) and I(1) series, further supported by significant nonlinearity confirmed by the BDS test results in Table 2, reinforces the suitability of the MWQR approach, wherein decomposition into wavelet coefficients can effectively handle mixed integration orders while capturing scale-dependent distributional nuances often obscured in standard time-domain analyses.

Table 1. Preliminary Tests.

Panel A: Descriptive statistics				
	REN	**GDPPC**	**EPU**	**ENUE**
Mean	-0.0616	3.6011	2.0513	2.4003
Median	-0.0967	3.6009	2.0749	2.4024
Maximum	0.6406	3.6481	2.7468	2.5003
Minimum	-0.7333	3.5236	1.3809	2.2342
Std. Dev.	0.4729	0.0313	0.2258	0.0846
Skewness	0.0572	-0.5407	-0.1819	-0.3721
Kurtosis	1.4388	2.7896	3.0594	1.8819
Jarque-Bera	33.0817	16.3853	1.8353	24.3526
Probability	0.0000	0.0003	0.3995	0.0000
Panel B: Unit root test				
	ADF		PP	
	Level	First difference	Level	First difference
GDPPC	-2.9517	-5.1379*	-2.8525	-14.1625*
EPU	-4.3069*	-18.0273*	-7.2813*	-30.1608*
REN	-2.0830	-3.4713**	-1.7325	-14.1816*
ENUE	-2.3365	-6.3269*	-2.5901	-14.5390*

Note: "* and **" indicate significance at the 0.01 and 0.05 levels.

Following the distributional and stationarity properties established in the preliminary analysis, the study proceeds to assess the empirical dependence structure among the series, utilising the BDS test (Broock et al., 1996). Although unit root tests aid in determining the order of integration of variables, they are insufficient to capture the nonlinear dependencies commonly observed in macroeconomic and energy time series. In this context, the BDS test is particularly valuable as it serves as a diagnostic tool for testing the null hypothesis of independent and identically distributed (i.i.d.) series against any unspecified nonlinear dependence structure.

Table 2. BDS Test Results.

Output	**GDPPC**	**EPU**	**REN**	**ENUE**
DIM2	0.2075*	0.0961*	0.2075*	0.2042*
DIM3	0.3518*	0.1625*	0.3518*	0.3457*
DIM4	0.4523*	0.2068*	0.4523*	0.4441*
DIM5	0.5225*	0.2316*	0.5225*	0.5126*
DIM6	0.5715*	0.2426*	0.5715*	0.5604*

Note: *P<0.01.

Table 2 results show strong evidence of nonlinear dependency for all variables and embedding dimensions (DIM 2 through DIM 6). The test statistics for GDPPC, REN, and ENUE are identical or very close, with values of approximately 0.2075 at DIM 2 and 0.5715 at DIM 6; all are statistically significant at the 1% level (p<0.01). EPU also shows statistically significant nonlinearity, with the statistics increasing from 0.0961 to 0.2426 across dimensions. These results mean that policy uncertainty, energy consumption, and economic growth are related by complex nonlinear processes that cannot be captured adequately by standard linear models, thus providing strong BDS results as an empirical basis for moving from a linear framework to the MWQR model that takes account of such nonlinearities across quantiles and time scales.

4. EMPIRICAL OUTCOMES

4.1. Multivariate Wavelet Quantile Regression Results

After identifying the nonlinearity and mixed integration orders in the series, as established by the unit root results and the BDS tests, attention is turned to the MWQR results presented in Figure 1. The analysis of how the effect of EPU on major macro energy variables varies across the conditional growth distribution and across different time scales is shown in Figure 1a-c. In this manner, the conditioning states and varying horizons are somewhat combined, albeit rather imperfectly.

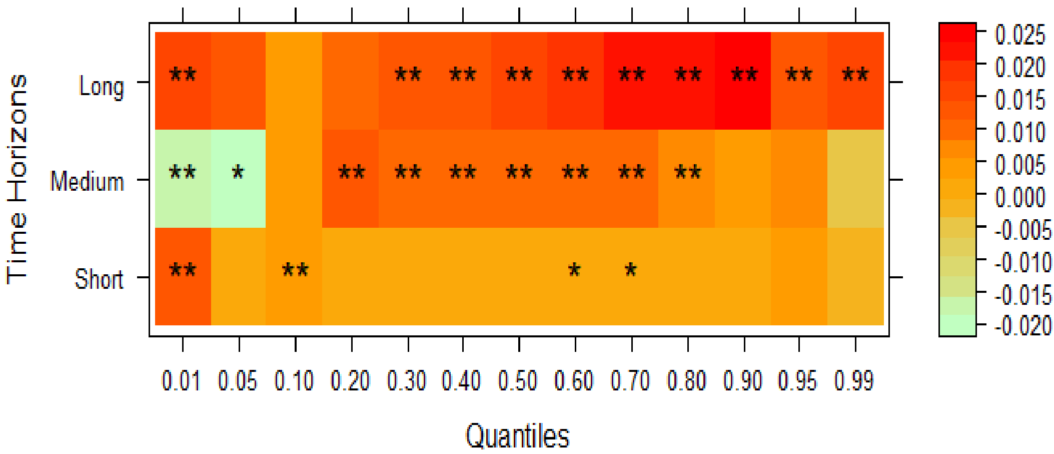

Figure 1a. $(GDPPC \sim EPU \mid \overline{REN}, \overline{ENUE})$.

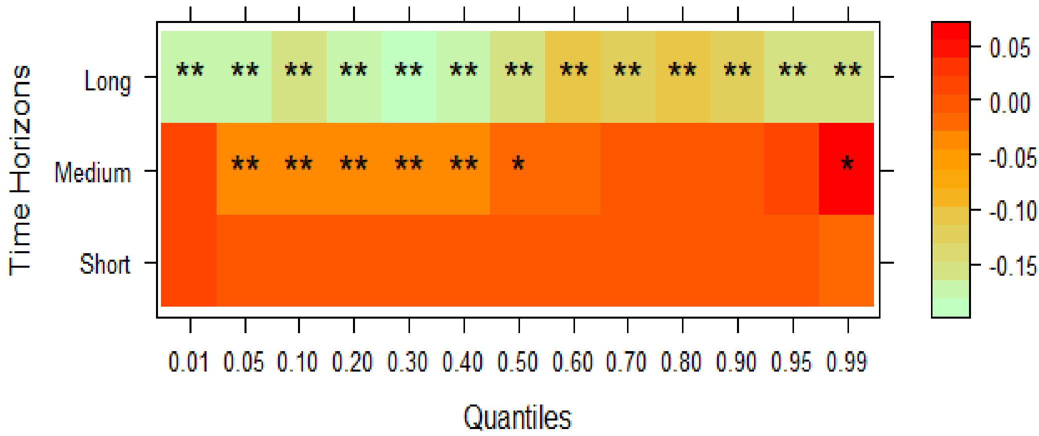

Figure 1b. $(REN \sim EPU \mid \overline{GDPPC}, \overline{ENUE})$.

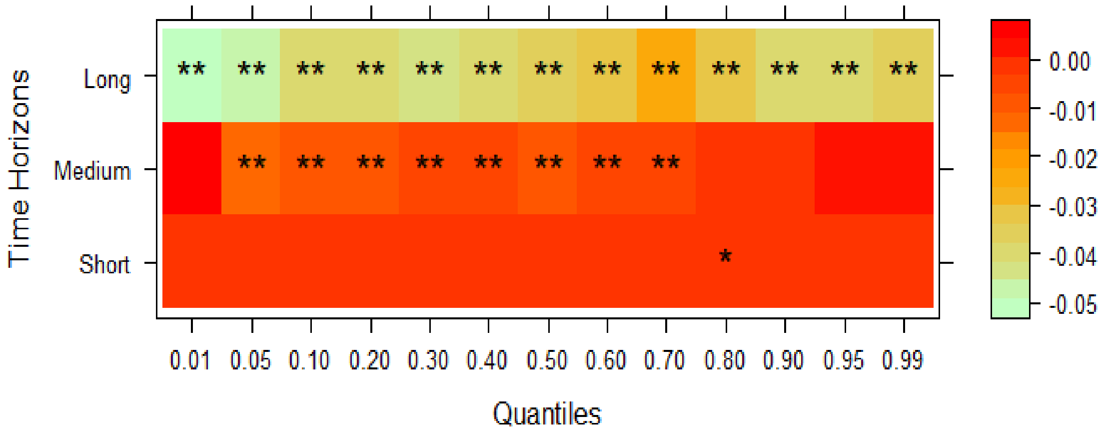

Figure 1c. $(ENUE \sim EPU \mid \overline{GDPPC, REN})$.

Figure 1a-c: Multivariate wavelet quantile regression results.

Note: * and ** indicate the 10% and 5% significance levels, respectively.

In Figure 1a (GDPPC–EPU | REN, ENUE), the MWQR estimates indicate that EPU's effect on GDPPC is predominantly negative, particularly at lower quantiles and at medium-to-long wavelet scales. Specifically, in episodes of weak economic performance, such as in the lower tail of the GDPPC distribution, an increase in policy uncertainty appears to have a more pronounced contractionary effect on output. This type of asymmetry and dependence on the state of the economy are consistent with the real-options and uncertainty-shock strand of literature, which asserts that uncertainty shocks have a greater burden on investment and activity in recessive or fragile macro states. This is also pointed out by Aastveit et al. (2013); Bloom (2009), and Baker et al. (2016). The attenuation, or even possible insignificance, of the EPU effect at higher quantiles and shorter horizons is consistent with better-performing economies or with the idea that uncertainties that do not persist for too long are more immune to policy risk.

Moving to Figure 1b (REN–EPU | GDPPC, ENUE), results indicate that EPU has a generally dampening impact on the renewable energy share, with more robust and longer-lasting negative coefficients observed at higher scales (long-run horizon) and in the middle- to upper-quantiles of REN. Such a pattern would imply that policy uncertainty disrupts renewable deployment not only in low-renewable states but also in high-renewable ones, where large-scale investment and technological upgrading are needed, becoming more visible as the horizon stretches. These findings are consistent with studies showing that policy volatility and regulatory uncertainty increase the cost of financing, delaying irreversible investments in renewable energy projects (Johnstone et al., 2010). They further support the notion that credible long-term policy frameworks are necessary to sustain momentum toward the energy transition.

In Figure 1c (ENUE–EPU | GDPPC, REN), MWQR results indicate a somewhat nuanced and uneven association between EPU and total energy use per capita, which varies systematically across both ENUE support and wavelet scales. At lower quantiles of ENUE ($\tau = 0.1$) and across all scales, EPU is associated with statistically significant reductions in energy use, with the strongest negative coefficients appearing at short- to medium-run horizons (D1–D4). This configuration consists of a familiar demand-contraction mechanism: during high-uncertainty episodes, firms reduce output, delay capital investment plans, and cut operational energy use, while households scale back discretionary energy-intensive activities (Elder & Serletis, 2010; Hamilton, 1983). Thus, the negative effect at the lower end of the ENUE distribution essentially replicates the real-world energy slowdown due to policy uncertainty.

However, one particularly notable sign change is observed at the median quantile, $\tau = 0.5$, and at the upper quantile, $\tau = 0.9$, for ENUE, primarily in medium-run scales (D3–D4) and long-run scales (D5–D6). In these ranges, the EPU coefficients substantially weaken and, in some cases, even turn slightly positive. More precisely, at $\tau = 0.9$ and long-run scales (D5–D6), the coefficient estimate flips from negative to positive. However, even with this flip, statistical significance is only achieved at the 10% level. This reversal has economic implications and can be interpreted through at least three interconnected mechanisms rather than a single story. First, consider the delayed efficiency investment hypothesis, which holds that when policy uncertainty drags on, firms and households delay investments in energy-saving technologies such as heat pumps, industrial retrofits, and smart grid infrastructure that would otherwise reduce energy intensity in the long run. So deferring those upgrades keeps an economy dependent on an older, more energy-intensive capital stock, thus preserving or even increasing aggregate energy use per capita while broader slowdowns continue (Dixit & Pindyck, 1994; Popp et al., 2010). Second, a fuel-switching reversal effect may also be at play. If uncertainty obstructs the renewable transition, as also indicated by Figure 1b, companies and utilities might resort to conventional generation, often involving more energy-intensive, fossil-fuel-based production, as a quick hedge against regulatory and supply-side pressures. Such a movement away from relatively efficient renewable technologies towards less efficient alternatives may increase aggregate energy use per capita over medium- to long-term horizons.

Third, at the upper ENUE quantile ($\tau = 0.9$), the positive coefficient may indicate a precautionary energy-stockpiling channel. In that view, energy-intensive sectors operating at high-capacity levels respond to uncertainty by accumulating energy-input buffers or locking in supply contracts, which can temporarily raise measured per-capita energy use just before the contractionary impact of uncertainty becomes apparent. Those sign changes from median to upper quantiles and from medium- to long-scale ranges do not really break this paper's core narrative. Instead, they suggest that the EPU-energy-use connection is state-dependent and strongly horizon-sensitive. When uncertainty is present, energy demand is still clearly contracted in low-energy-use states and over shorter horizons. However, in high-energy-use states and over longer horizons, countervailing forces shape the outcome. These include delayed efficiency investments, fuel-switching reversals, and precautionary stockpiling, and together they can keep aggregate energy consumption stable or even slightly increase it as macroeconomic performance worsens.

The multivariate wavelet quantile results in Figure 1 provide quite solid empirical support for the theoretical framework proposed here: EPU knocks down economic growth, and this negative influence is only partially mediated by the changes it induces in renewable deployment and overall energy use. There are also asymmetries across quantiles and scales that support the use of a distribution-sensitive time-frequency approach rather than a single-average view. The UK evidence sits within a wider international literature that continues to show how decisive policy stability can be for macroeconomic outcomes and the low-carbon energy transition.

While the predominant pattern in Figure 1a is one of negative EPU coefficients, it is important to explicitly acknowledge those instances where the estimated $\beta_{1,j}(\tau)$ approaches zero, or turns marginally positive, especially at the upper tail of the GDPPC distribution ($\tau = 0.9$) and at short-run wavelet scales (D1–D2). Although these positive coefficients are statistically insignificant, their theoretical significance warrants discussion. One way to interpret this is that during times of strong growth, high policy uncertainty may lead to small increases in certain types of economic activity. For instance, firms in already favourable conditions might accelerate their investment or production decisions before anticipated regulatory changes take effect, generating a temporary "front-loading" effect that partially offsets the contractionary channel (Bloom, 2009; Jurado et al., 2015). Another possible story is that high-growth regimes have sufficient buffers, such as healthy corporate balance sheets, strong consumer demand, and ample available credit, to absorb uncertainty shocks without much contraction in output. This resilience effect aligns with what we know from the literature on state-dependent uncertainty: macroeconomic costs of uncertainty are asymmetric. They are mostly observed in fragile or recessionary states rather than in expansionary ones (Aastveit et al., 2013). The fact that these positive coefficients do not differ statistically from zero is also important: high-growth periods are characterised more by indifference to uncertainty than by any real uplift in output due to uncertainty. These sign reversals at the upper quantiles reinforce rather than contradict this central result about where EPU damages the economy most: it is real and located at its most vulnerable point, while indicating that high-growth states are immune, rendering the uncertainty effect economically insignificant.

To better see how large the estimated effects are and if they have any statistical meaning, Table 3 shows the MWQR coefficient estimates $\beta_{1,j}(\tau)$ for EPU on GDPPC, REN, and ENUE at some selected quantiles τ=0.1,0.5,0.9, plus for short, medium, and long-run wavelet scales.

Table 3. Selected MWQR Coefficient Estimates — $\beta_{1,j}(\tau)$ for EPU on GDPPC, REN, and ENUE.

Quantiles	Short run		Medium run		Long run	
	Coefficients	SE	Coefficients	SE	Coefficients	SE
$(GDPPC \sim EPU \mid \overline{REN}, \overline{ENUE})$						
0.01	0.0121**	0.0061	-0.0166**	0.0032	0.0142**	0.0022
0.05	0.0013	0.0021	-0.0188*	0.0103	0.0115	0.0080
0.1	0.0025**	0.0012	0.0041	0.0085	0.0026	0.0128
0.2	0.0006	0.0007	0.0136**	0.0047	0.0093	0.0071
0.3	0.0002	0.0002	0.0097**	0.0030	0.0113**	0.0055
0.4	0.000	0.0001	0.0093**	0.0024	0.0132**	0.0046
0.5	0.000	0.0001	0.0090**	0.0025	0.0158**	0.0030
0.6	0.0002*	0.0001	0.0099**	0.0018	0.0173**	0.0031
0.7	0.0006*	0.0003	0.0103**	0.0022	0.0228**	0.0059
0.8	0.0011	0.0008	0.0080**	0.0029	0.0224**	0.0073
0.9	0.0013	0.0015	0.0035	0.0039	0.0232**	0.0077
0.95	0.0023	0.0034	0.0067	0.0073	0.0141**	0.0067
0.99	-0.0019	0.0049	-0.0066	0.0099	0.0168**	0.0068
$(REN \sim EPU \mid \overline{GDPPC}, \overline{ENUE})$						
0.01	0.0154	0.0184	0.0150	0.0324	-0.1738**	0.0092
0.05	-0.0081	0.0101	-0.0351**	0.0151	-0.1750**	0.0062
0.1	-0.0017	0.0082	-0.0433**	0.0148	-0.1622**	0.0074
0.2	-0.0023	0.0040	-0.0416**	0.0111	-0.1718**	0.0106
0.3	-0.0029	0.0018	-0.0462**	0.0119	-0.1821**	0.0076
0.4	-0.0016	0.0009	-0.0302**	0.0115	-0.1751**	0.0096
0.5	-0.0006	0.0013	-0.0280*	0.0166	-0.1482**	0.0182
0.6	-0.0011	0.0010	-0.0149	0.0124	-0.1132**	0.0162
0.7	-0.0002	0.0019	-0.0070	0.0095	-0.1154**	0.0179
0.8	-0.0039	0.0049	-0.0024	0.0116	-0.1012**	0.0177
0.9	-0.0029	0.0075	-0.0072	0.0140	-0.1309**	0.0280
0.95	-0.0062	0.0055	0.0061	0.0197	-0.1501**	0.0275
0.99	-0.0264	0.0225	0.0544*	0.0301	-0.1633**	0.0129
$(ENUE \sim EPU \mid \overline{GDPPC}, \overline{REN})$						
0.01	-0.0001	0.0047	0.0043	0.0089	-0.0494**	0.0029
0.05	-0.0009	0.0028	-0.0118**	0.0039	-0.0461**	0.0046
0.1	-0.000006	0.0019	-0.0083**	0.0031	-0.0413**	0.0058
0.2	-0.0013	0.0008	-0.0088**	0.0028	-0.0387**	0.0036
0.3	-0.0006	0.0004	-0.0066**	0.0028	-0.0420**	0.0009
0.4	-0.0002	0.0002	-0.0068**	0.0028	-0.0410**	0.0013
0.5	-0.000093	0.0001	-0.0084**	0.0023	-0.0369**	0.0033
0.6	-0.0002	0.0002	-0.0058**	0.0020	-0.0303**	0.0054
0.7	-0.0003	0.0004	-0.0050**	0.0022	-0.0231**	0.0055
0.8	-0.0019*	0.0010	-0.0027	0.0029	-0.0316**	0.0056
0.9	-0.0001	0.0015	-0.0001	0.0055	-0.0383**	0.0057
0.95	-0.0010	0.0016	0.0011	0.0050	-0.0413**	0.0059
0.99	-0.0011	0.0049	0.0034	0.0051	-0.0377**	0.0025

Note: * and ** indicate the 10% and 5% significance levels, respectively.

4.2. Wavelet Quantile Regression Results (Robustness Check)

Based on the multivariate evidence shown in Figure 1 on the role of energy variables as transmission channels in the EPU-growth nexus, univariate WQR results are presented in Figure 2 to check robustness. In this figure, we examine the direct relationships between EPU and the dependent variables GDPPC, REN, and ENUE, without conditioning on the full vector of controls. This makes it possible to verify whether key patterns identified within the MWQR framework hold across specifications and modelling choices, even when an approach is somewhat reduced.

In Figure 2a-c (Impact of EPU on GDPPC), the wavelet quantile estimates largely confirm that EPU has a negative, asymmetric effect on economic growth. The coefficients of EPU at lower quantiles of GDPPC, which correspond to relatively weak performance periods in the economy, are more strongly negative and often statistically significant over medium- and long-run horizons. This means that uncertainty disturbances are particularly damaging in downturns or fragile states by reinforcing contractionary forces, consistent with the "real options" view, in which firms defer investment and hiring under heightened uncertainty (Bernanke, 1983; Bloom, 2009). The fading out of the EPU effect at higher quantiles of GDPPC indicates that under better macroeconomic conditions, an economy tends to be more resistant to those uncertainty shocks, similar to results provided by Aastveit et al. (2013) as well as Jurado et al. (2015), who asserted that macro impacts due to uncertainty depend upon current state conditions intensifying during recession periods.

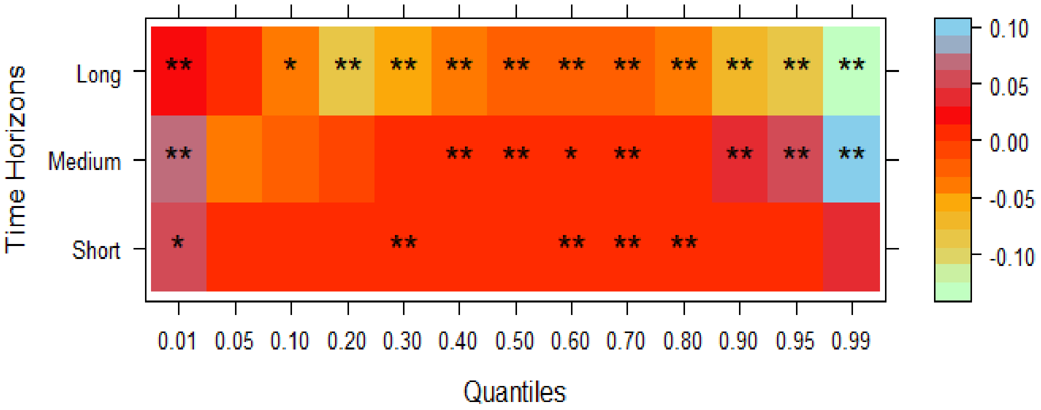

Figure 2a. The impact of EPU on GDPPC.

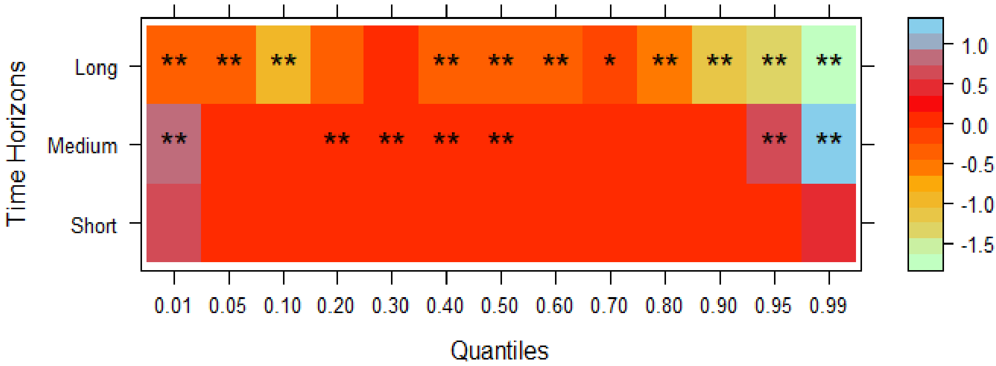

Figure 2b. The impact of EPU on REN.

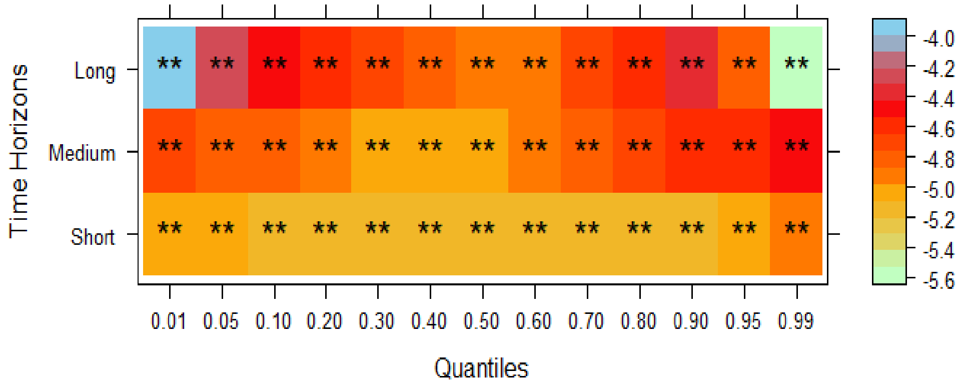

Figure 2c. The impact of EPU on ENUE.

Figure 2a-c: Wavelet quantile regression results.

Note: * and ** indicate the 10% and 5% significance levels, respectively.

Turning now to Figure 2b, which illustrates the impact of EPU on REN, the WQR results largely validate the detrimental effect of policy uncertainty on renewable energy deployment. Across several quantiles, especially in the middle and upper parts of the REN distribution, the EPU coefficients are negative and statistically significant over longer horizons. This indicates that persistent policy uncertainty diminishes long-horizon investment in renewables when one examines the distribution rather than focusing solely on averages. Consistent with most empirical evidence, policy volatility increases financing costs, delays project approvals, and undermines investor confidence in the renewable energy sector (Johnstone et al., 2010). Importantly, these patterns are still observed even in a univariate context, thereby helping to validate that the negative impact of EPU on REN is not an artefact of multivariate specification but rather a persistent structural characteristic of the UK energy transition.

In Figure 2c, which depicts the impact of EPU on ENUE, robustness checks reveal a more nuanced relationship between EPU and total energy use per capita. For lower quantiles of ENUE at shorter horizons, EPU is generally associated with decreases in energy usage, indicative of shrinking industrial output, mobility, and general demand during periods characterised by heightened uncertainty, consistent with findings that attribute uncertainty to macroeconomic and energy-demand contractions (Elder & Serletis, 2010; Hamilton, 1983). However, at intermediate quantiles and time scales, coefficient magnitudes dissipate; in some cases, they may even drift toward zero or flip sign. This form of heterogeneity would be consistent with broader discussions of the energy–growth nexus, in which direction and intensity of the energy–output relationship can vary across regimes, branches, and time spans (Apergis & Payne, 2009; Ozturk, 2010; Stern, 2004). It further suggests that while EPU has a persistent growth- and renewable-suppressive effect, its aggregate energy-use impact is more contingent, as offsetting forces may be at work, such as delayed efficiency upgrades or temporary returns to more energy-intensive equipment.

The wavelet-quantile robustness checks in Figure 2 essentially reinforce the main conclusions from the multivariate analysis, not just a detail. For one, they confirm that EPU has a state-dependent, mostly negative effect on GDPPC, with the impact stronger when growth is low. Then, they also provide consistent evidence that higher EPU slows the renewable energy transition, especially over longer horizons. Further, they show that even though EPU shapes total energy use, the direction and magnitude of this influence shift across the energy-use distribution and over time scales. Altogether, these findings place the UK results squarely in the international literature, emphasising the macroeconomic costs of policy uncertainty (Baker et al., 2016; Bloom, 2009) and the key function of stable, credible policy frameworks for keeping the low-carbon transition going (Acemoglu et al., 2012; Popp et al., 2020).

In line with the multivariate evidence, Figure 2a also shows a few moments of ambiguous or mildly positive EPU coefficients toward the top end of the GDPPC distribution ($\tau = 0.9$) and at shorter wavelet scales in the univariate WQR case. These sign flips, even if statistically insignificant, deserve a more direct mention. In the univariate setup, where the energy transmission paths are not conditioned on anything else, the positive estimates at high quantiles could partly reflect a failure to account for confounding energy dynamics. For instance, during periods of high growth, rising energy demand, together with the expansion of renewable capacity, may support output on its own. In such cases, the direct contractionary effect of EPU on GDPPC could be weakened or even reversed. This narrative is consistent with findings in the energy–growth literature, which often indicate that energy use and renewable penetration can act as separate forces for growth and thus mitigate or offset some demand-side uncertainty shocks (Apergis & Payne, 2012; Menegaki, 2011).

Also, at short-run horizons, a positive sign could capture what has been termed the "volatility effect." Brief surges in uncertainty have been known to temporarily increase precautionary production or stockpiling before longer-lasting contractionary effects through a "wait-and-see" channel at medium- and long-run horizons (Bernanke, 1983; Bloom, 2009). That these positive coefficients either disappear or become much smaller once energy controls are added into the MWQR framework illustrates why multivariate specification is critical for disentangling true structural impacts of EPU on growth. In general, such sign uncertainties do not invalidate the main conclusions of this paper; they merely sharpen the story by indicating precisely under what conditions uncertainty might be benign, namely, when the economy is otherwise doing well and when one is analysing shorter time periods.

4.3. Lessons from the Findings

The empirical results from the MWQR analysis of the macro-energy nexus in the United Kingdom offer significant lessons for researchers and policymakers. By decomposing these relationships across different time scales and the distribution of economic states, it moves beyond aggregate averages and reveals subtler channels through which policy uncertainty operates in practice.

A main takeaway: EPU acts as a strong barrier to REN, effectively blocking it. The results indicate that EPU's detrimental effect on renewables is more severe at longer horizons and higher quantiles. This means that even if short-run policy swings can be tamed, persistent uncertainty still disrupts the longer-term investment cycles that capital-intensive green infrastructure needs. For the UK, it implies that "policy locking" instruments are essential, for instance, legally binding carbon budgets or cross-party energy agreements, to insulate the energy transition from volatility stemming from the political cycle (Johnstone et al., 2010; Popp et al., 2020).

It shows that EPU does the most harm to the economy when it is already on shaky ground. The more negative coefficients at lower GDPPC quantiles indicate that uncertainty shocks have a "multiplier effect" when conditions are sliding downward. In recessions or when growth is weak, maximum policy clarity should be the government's top priority. If signals regarding fiscal paths, trade relationships, or energy subsidies are uncertain during a downturn, contraction could worsen because firms and households adopt a "wait-and-see" attitude (Baker et al., 2016; Bloom, 2009).

The study finds that growth-related uncertainty is transmitted not only through purely financial channels or simply via a "confidence" channel, but also through day-to-day energy consumption and, more broadly, energy patterns. When uncertainty is high, total energy consumption falls, as does renewable penetration; these are physical manifestations of an economic downturn. Hence, policymakers should understand that energy security and policy certainty are two sides of the same coin: a volatile policy environment leads to misallocation of energy, inefficient use, and reliance on short-term, often carbon-intensive energy fixes instead of sustained efficiency improvements.

The differences in results across wavelet scales (short-term versus long-term) and quantiles (low-growth versus high-growth) clearly suggest that macroeconomic interventions should be scale-sensitive rather than generic. For short-horizon uncertainty, liquidity support or temporary tax relief is appropriate, while long-horizon uncertainty calls for structural institutional reforms.

MWQR results further imply that UK energy and economic policy cannot follow a single calibration rule, since sensitivity to policy risk varies substantially across regimes; different tuning is needed when the economy is in a "high-growth" state than in a "low-growth" state.

Ultimately, the evidence suggests loosening the link between the energy transition and political turbulence in the UK if sustainable growth is to be achieved. The ongoing negative impact of EPU on REN suggests that market participants view the “green transition” as highly reversible, which reflects poorly on them. If policymakers empower regulators' independence and ensure visibility, clarity, and protection of routes for energy transition against sudden shifts in political messaging, then the additional risk premium on green initiatives will reduce, allowing support for more solid patterns of growth (Acemoglu et al., 2012; Aghion et al., 2016).

These insights highlight the need for a stable, long-run policy environment that prioritises sectoral stability to achieve macroeconomic resilience. Since this study precisely maps the sizes and conditions under which uncertainty bites hardest, it serves as a roadmap for more specific, practical policy steps in the post-Brexit United Kingdom, set against the backdrop of an energy crisis.

5. CONCLUSION AND POLICY INSIGHT

5.1. Conclusion

This research examines the influence of economic policy uncertainty on growth performance in the UK, considering pathways through energy consumption, namely total energy consumption and the share of renewable energy. It employed the Multivariate Wavelet Quantile Regression framework to capture the intertwined, nonlinear, and scale-dependent relationships among variables for the period 1998M1–2024M12. However, the big picture sometimes seemed disentangled.

The empirical results draw three principal conclusions; perhaps first, that EPU tends to affect economic growth asymmetrically, with more pronounced impacts at lower quantiles during weaker growth phases and over medium-to long-run horizons. Second, policy uncertainty substantially impedes the energy transition in the UK, as evidenced by a persistently negative effect of EPU on the share of renewable energy, effectively increasing the "option value of waiting" and thereby deliberately deferring capital-intensive green projects. Third, this study also confirms that energy consumption behaviour is a key transmission channel: when EPU induces contractions in energy demand and disturbances in the energy mix, macro performance is impaired. Additional robustness checks using univariate wavelet quantile regression confirm these points, showing that the uncertainty–energy–growth nexus remains robust even under slightly altered specifications.

5.2. Policy Insights

The long-run empirical results of this study provide a robust, real-world foundation for a suite of granular policy interventions tailored to the UK's institutional and economic landscape. One critical insight from the long-run negative impact of EPU on the REN is that the UK must prioritise "policy-locking" mechanisms. To reduce the real-option value of waiting that currently inhibits green investment, the government should impose binding multi-decadal deployment schedules for offshore wind and solar energy. These schedules must be insulated from the normal five-year political cycle; otherwise, firms will continue to delay. At the same time, enhancing institutional independence for bodies such as the Climate Change Committee (CCC) and Ofgem is vital; by granting these entities broader enforcement powers over the net-zero pathway, the UK can offer the long-horizon regulatory certainty needed to lower the risk premiums faced by capital-intensive renewable projects.

Also, since EPU tends to hit hardest during low-growth windows (lower GDP quantiles), this strongly indicates the presence of fast-acting countercyclical support structures. In periods of increased macroeconomic uncertainty or economic stagnation, it should be mandatory for the UK Infrastructure Bank to provide concessional financing and government-backed guarantees for renewable energy and grid storage projects. These would automatically stabilise and help ensure that the energy transition does not stall when private capital withdraws due to confusion over fiscal terms or regulatory signals. At the same time, the Industrial Energy Transformation Fund could be expanded to offer more targeted grants for energy-efficiency retrofits during downturns, addressing EPU-related reductions in energy use as indicated by ENUE in multivariate analysis.

To address fluctuations in aggregate energy demand and their feedback effects on GDP growth, the UK should implement a more visible, coordinated communication strategy among HM Treasury, DESNZ, and regulators. Empirical evidence shows that short-run uncertainty shocks immediately reduce activity. Thus, it is helpful if the government publishes stable multi-year "Energy Policy Roadmaps" with clear milestones for the phase-out of fossil fuels and the deployment of heat pumps to avoid the awkward "on-again-off-again" feel seen before with incentive schemes like the Green Homes Grant. That change matters for household confidence and business sentiment alike, as durable signals are required. If, instead of occasional subsidies, there were a shift toward continuous, predictable tax credits for building retrofits and insulation upgrades, then energy-efficiency benefits could be decoupled from normal policy-cycle zigzags.

The study concludes that enhancing energy security through domestic renewable energy storage and increasing interconnector capacity is both a green objective and a macroeconomic imperative, even if the logic may seem somewhat backward at first glance. When international energy prices fluctuate, the UK economy tends to be more vulnerable to their effects, particularly because domestic policy uncertainty can amplify them. The government can therefore reduce this external exposure to stabilise the energy growth pathway. More broadly, these results suggest that if the United Kingdom is to achieve resilient low-carbon growth, it must adopt a "predictability first" governance style: keeping the energy transition out of political discourse; countercyclical financing buffers during periods of economic fragility; and strong, unambiguous, legally binding long-run signals for green innovation rather than softly spoken but subsequently retracted commitments. In totality, this more granular approach should ensure policy stability as the bedrock of the United Kingdom's post-Brexit, post-energy-crisis economic plan.

5.3. Limitations and Future Research Areas

The empirical results in this paper yield a strong practical foundation for a menu of granular policy interventions tailored to the UK institutional and economic environment. One major conclusion from the long-run negative effect of EPU on the REN is that UK policymakers should focus on "policy-locking" mechanisms. To reduce the real-option value of waiting that currently inhibits green investment, the government should require binding multi-decadal deployment pathways for offshore wind and solar energy. Those pathways should be insulated from the normal five-year electoral cycle; otherwise, firms continue to hold off. In parallel, strengthening institutional independence for organisations such as the Climate Change Committee (CCC) and Ofgem is important; by giving these bodies wider enforcement powers over net-zero pathways, the UK can generate the long-horizon regulatory certainty needed to lower the risk premiums faced by capital-intensive renewable projects.

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REFERENCES

Aastveit, K. A., Natvik, G. J. J., & Sola, S. (2013). *Economic uncertainty and the effectiveness of monetary policy*. Norges Bank Working Paper No. 17/2013. Oslo, Norway: Norges Bank.

Acemoglu, D., Aghion, P., Bursztyn, L., & Hemous, D. (2012). The environment and directed technical change. *American Economic Review, 102*(1), 131-166. https://doi.org/10.1257/aer.102.1.131

Adebayo, T. S., Abbas, S., Olanrewaju, V. O., & Uzun, B. (2025). Unpacking policy ambiguities in residential and commercial renewable energy adoption: A novel multivariate wavelet quantile regression analysis. *Applied Economics*, 1-22. https://doi.org/10.1080/00036846.2025.2590632

Aghion, P., Dechezleprêtre, A., Hemous, D., Martin, R., & Van Reenen, J. (2016). Carbon taxes, path dependency, and directed technical change: Evidence from the auto industry. *Journal of Political Economy, 124*(1), 1-51. https://doi.org/10.1086/684581

Aguiar-Conraria, L., & Soares, M. J. (2014). The continuous wavelet transform: A primer. In L. Aguiar-Conraria & M. J. Soares (Eds.), The Oxford Handbook of Economic Forecasting. In (pp. 1–33). Oxford: Oxford University Press.

Akadiri, S. S., & Ozkan, O. (2025). Financial turbulence and decarbonisation: Evidence from energy transition materials. *Mineral Economics*, 1-28. https://doi.org/10.1007/s13563-025-00559-x

Akadiri, S. S., Ozkan, O., Ogbekene, I., & Hamza, F. (2025). Oil shocks and unexpected economic policy uncertainty: Evidence from wavelet nonparametric quantile causality. *Humanities and Social Sciences Communications*, *12*(1), 1638. https://doi.org/10.1057/s41599-025-05574-5

Ali, S., Anwar, S., & Nasreen, S. (2017). Renewable and non-renewable energy and its impact on environmental quality in South Asian countries. *Forman Journal of Economic Studies*, *13*, 177-194.

Anton, S. G., & Nucu, A. E. A. (2020). The effect of financial development on renewable energy consumption. A panel data approach. *Renewable Energy*, *147*, 330-338. https://doi.org/10.1016/j.renene.2019.09.005

Apergis, N., & Payne, J. E. (2009). Energy consumption and economic growth: Evidence from the Commonwealth of Independent States. *Energy Economics*, *31*(5), 641-647. https://doi.org/10.1016/j.eneco.2009.01.011

Apergis, N., & Payne, J. E. (2012). Renewable and non-renewable energy consumption-growth nexus: Evidence from a panel error correction model. *Energy Economics*, *34*(3), 733-738. https://doi.org/10.1016/j.eneco.2011.04.007

Baker, S. R., Bloom, N., & Davis, S. J. (2016). Measuring economic policy uncertainty. *The Quarterly Journal of Economics*, *131*(4), 1593-1636. https://doi.org/10.1093/qje/qjw024

Balcilar, M., Gupta, R., & Pierdzioch, C. (2016). Does uncertainty move the gold price? New evidence from a nonparametric causality-in-quantiles test. *Resources Policy*, *49*, 74-80. https://doi.org/10.1016/j.resourpol.2016.04.004

Bayer, P., & Aklin, M. (2020). The European Union emissions trading system reduced CO2 emissions despite low prices. *Proceedings of the National Academy of Sciences*, *117*(16), 8804-8812. https://doi.org/10.1073/pnas.1918128117

Bernanke, B. S. (1983). Irreversibility, uncertainty, and cyclical investment. *The Quarterly Journal of Economics*, *98*(1), 85-106. https://doi.org/10.2307/1885568

Bloom, N. (2009). The impact of uncertainty shocks. *Econometrica*, *77*(3), 623-685. https://doi.org/10.3982/ECTA6248

Bloom, N., Bunn, P., Chen, S., Mizen, P., Smietanka, P., & Thwaites, G. (2019). *The impact of Brexit on UK firms.* NBER Working Paper No. 26218. Cambridge, MA: National Bureau of Economic Research.

Bölük, G., & Mert, M. (2014). Fossil & renewable energy consumption, GHGs (greenhouse gases) and economic growth: Evidence from a panel of EU (European Union) countries. *Energy*, *74*, 439-446. https://doi.org/10.1016/j.energy.2014.07.008

Broock, W. A., Scheinkman, J. A., Dechert, W. D., & LeBaron, B. (1996). A test for independence based on the correlation dimension. *Econometric Reviews*, *15*(3), 197-235. https://doi.org/10.1080/07474939608800353

Caldara, D., Fuentes-Albero, C., Gilchrist, S., & Zakrajšek, E. (2016). The macroeconomic impact of financial and uncertainty shocks. *European Economic Review*, *88*, 185-207. https://doi.org/10.1016/j.euroecorev.2016.02.020

Chu, L. K., Doğan, B., Abakah, E. J. A., Ghosh, S., & Albeni, M. (2023). Impact of economic policy uncertainty, geopolitical risk, and economic complexity on carbon emissions and ecological footprint: An investigation of the E7 countries. *Environmental Science and Pollution Research*, *30*(12), 34406-34427. https://doi.org/10.1007/s11356-022-24682-2

Dixit, A. K., & Pindyck, R. S. (1994). *Investment under uncertainty.* Princeton, NJ: Princeton University Press.

Elder, J., & Serletis, A. (2010). Oil price uncertainty. *Journal of Money, Credit and Banking*, *42*(6), 1137-1159. https://doi.org/10.1111/j.1538-4616.2010.00323.x

Hamilton, J. D. (1983). Oil and the macroeconomy since World War II. *Journal of Political Economy*, *91*(2), 228-248. https://doi.org/10.1086/261140

International Energy Agency. (2022). *World energy outlook 2022.* Paris, France: International Energy Agency.

Jarque, C. M., & Bera, A. K. (1980). Efficient tests for normality, homoscedasticity and serial independence of regression residuals. *Economics Letters*, *6*(3), 255-259. https://doi.org/10.1016/0165-1765(80)90024-5

Johnstone, N., Haščič, I., & Popp, D. (2010). Renewable energy policies and technological innovation: Evidence based on patent counts. *Environmental and Resource Economics*, *45*(1), 133-155. https://doi.org/10.1007/s10640-009-9309-1

Jurado, K., Ludvigson, S. C., & Ng, S. (2015). Measuring uncertainty. *American Economic Review*, *105*(3), 1177-1216. https://doi.org/10.1257/aer.20131193

Lu, Z., Zhu, L., Lau, C. K. M., Isah, A. B., & Zhu, X. (2021). The role of economic policy uncertainty in renewable energy-growth nexus: Evidence from the Rossi-Wang causality test. *Frontiers in Energy Research, 9*, 750652. https://doi.org/10.3389/fenrg.2021.750652

Menegaki, A. N. (2011). Growth and renewable energy in Europe: A random effect model with evidence for neutrality hypothesis. *Energy Economics, 33*(2), 257-263. https://doi.org/10.1016/j.eneco.2010.10.004

Nguyen, T. C. (2022). Economic policy uncertainty: The probability and duration of economic recessions in major European Union countries. *Research in International Business and Finance, 62*, 101701. https://doi.org/10.1016/j.ribaf.2022.101701

Ozturk, I. (2010). A literature survey on energy–growth nexus. *Energy Policy, 38*(1), 340-349. https://doi.org/10.1016/j.enpol.2009.09.024

Popp, D., Newell, R. G., & Jaffe, A. B. (2010). Energy, the environment, and technological change. In B. H. Hall and N. Rosenberg (Eds.), Handbook of the economics of innovation. In (Vol. 2, pp. 873-937). Amsterdam, Netherlands: Elsevier.

Popp, D., Vona, F., Marin, G., & Chen, Z. (2020). *The jobs impact of green growth: A literature review.* OECD Green Growth Papers, No. 2020–01.

Reboredo, J. C., & Rivera-Castro, M. A. (2014). Wavelet-based evidence of the impact of oil prices on stock returns. *International Review of Economics & Finance, 29*, 145-176. https://doi.org/10.1016/j.iref.2013.05.014

Redl, C. (2017). *The impact of uncertainty shocks in the United Kingdom.* Bank of England Staff Working Paper No. 695. London, England: Bank of England.

Sadorsky, P. (2010). The impact of financial development on energy consumption in emerging economies. *Energy Policy, 38*(5), 2528-2535. https://doi.org/10.1016/j.enpol.2009.12.048

Sadorsky, P. (2012). Energy consumption, output and trade in South America. *Energy Economics, 34*(2), 476-488. https://doi.org/10.1016/j.eneco.2011.12.008

Stern, D. I. (2004). Economic growth and energy. In C. J. Cleveland (Ed.), Encyclopedia of energy. In (Vol. 2, pp. 35–51). San Diego, CA: Elsevier.

Stern, D. I. (2019). Energy and economic growth. In U. Soytaş & R. Sarı (Eds.), Routledge handbook of energy economics. In (pp. 28–46). Abingdon, England: Routledge.

Troster, V., Shahbaz, M., & Uddin, G. S. (2018). Renewable energy, oil prices, and economic activity: A Granger-causality in quantiles analysis. *Energy Economics, 70*, 440-452. https://doi.org/10.1016/j.eneco.2018.01.029