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Unpacking FDI's Impact on Growth, Employment, and Energy in Turkey: A Wavelet Analysis

Safa Hoş[1], 0000-0002-9555-1782
Hitit University, Turkey

Çağlar Sözen [2], 0000-0002-3732-5058
Giresun University, Turkey

Abstract

This study investigates the dynamic interactions between Foreign Direct Investment (FDI), Unemployment Rate (UR), Electricity Consumption (EC), and Economic Growth (EG) in Turkey over the period 1970–2022, using wavelet-based time–frequency analysis. By applying the Maximal Overlap Discrete Wavelet Transform (MODWT), the research decomposes the data into different time scales to capture short-, medium-, and long-term co-movements among these key macroeconomic variables. The findings reveal that FDI exhibits a weak negative relationship with unemployment in the short term, which turns positive in the long term, suggesting potential structural challenges in labor absorption. Meanwhile, the impact of FDI on electricity consumption becomes increasingly positive over time, indicating growing industrial and energy demands associated with foreign investments. The relationship between FDI and economic growth is found to be positive in the medium term but weakens or even reverses over longer horizons, reflecting the complex and evolving role of foreign capital in the domestic economy. These results underscore the importance of considering time-varying effects when evaluating the macroeconomic consequences of FDI. The study offers valuable insights for policymakers aiming to design effective strategies for attracting and utilizing foreign investment to support sustainable and inclusive economic development.

Keywords: Foreign Direct Investment, Economic Growth, Electricity Consumption, Wavelet Analysis, Turkey

JEL Codes: C51, F21, O40

1. Introduction

Globalization has dismantled traditional borders and reinforced economic connections between nations, leading to increased international production and foreign direct investment (FDI) (Acaravci & Akyol, 2017). This openness has enabled smoother capital flows as investments seek out more profitable markets, establishing FDI as a crucial economic marker of globalization. Through this process, the ease of capital mobility has transformed the landscape of capital access, positioning FDI as an essential source of international capital (Balcerzak & Żurek, 2011). Consequently, as globalization has expanded, so too has the importance of FDI, which now plays a pivotal role in today's global economy as a valuable

[1] Correspondence to S. Hoş safahos@hitit.edu.tr
[2] Correspondence to Ç. Sözen caglar.sozen@giresun.edu.tr

resource for capital and economic growth (EG) (Acaravci & Akyol, 2017; Balcerzak & Żurek, 2011).

As a form of international capital flow, FDI is defined as the transfer of resources from one country to another, typically in the form of capital (Agir & Rutbil, 2019). In addition, FDI can be considered a package that includes capital, technology, management, and entrepreneurship, which enables a firm to operate in a foreign market and provide goods and services (Farrell, 2008). From a traditional perspective, the purpose of FDI is to take advantage of new and larger markets. At the same time, FDI is thought to help reduce the risks that investing countries may face in their international expansion and allow them to share the experience, resources, and recognition that these countries have already developed (Botrić & Škuflić, 2006). In this context, FDI, which is one of the economic indicators of globalization, gains importance with the strengthening of the economic connections of countries and the increase in capital movements.

Multinational companies prefer different countries in order to maintain their production activities in low-cost markets and thus make production more advantageous. This preference encourages the increase in foreign investments. Multinational companies, which bring elements such as factories, facilities, experience, and technology to the countries they go to along with capital, are supported by countries that want to attract investment due to the effects of these investments, such as creating employment and supporting EG (Agir & Rutbil, 2019). The economic benefits of FDI are achieved through the increase in available capital and the strengthening of capital accumulation, but more importantly through the transfer of advanced technologies, new skills, and management practices (Lee, 2013; Limazie & Woni, 2024). The process of globalization and the increase in FDIs have gained momentum with the desire of multinational companies to continue their production activities in low-cost markets and thus make production more advantageous. In this context, after the industrial revolution, Western countries directed their capital to areas that would provide the highest profit. Initially investing in agricultural and natural resources, FDI has now spread to a wide range of areas, such as nuclear materials, technology, information systems, and the service sector. FDIs provide many benefits to host countries, such as utilization of natural resources, acceleration of EG, increase in employment level, improvement in production and management knowledge, and reduction of foreign trade deficits (Dila Tasdemir & Erdas, 2018). For this reason, some economists argue that FDI is an important growth and development tool, especially for developing countries (Cetin & Seker, 2013).

Developing economies can benefit greatly from foreign capital. In particular, FDI can contribute to the modernization of these economies by increasing their technological level. It is widely believed that FDI can be effective in solving various economic and social problems (Balcerzak & Żurek, 2011). FDI is essential for enabling less-developed nations to improve international relations and integrate more deeply into the global economy (Zugravu-Soilita, 2017). Recognizing this opportunity, many developing countries have made strides to attract foreign investors by lowering entry barriers and improving policies that influence foreign businesses (Limazie & Woni, 2024). FDI is widely regarded as a strategic tool for promoting sustainable development, so creating a conducive investment environment becomes critical to attract and retain investors (Adebayo et al., 2020). In this light, the significance of globalization and FDI extends beyond addressing economic and social challenges, playing a crucial role in enhancing the economic integration of developing nations.

Moreover, FDI contributes substantially to country development through technology transfer and the sharing of management expertise. It is recognized as a vital source of external funding and a key driver of EG for developing economies (Bose & Kohli, 2018; Hagan & Amoah, 2020). FDI's role is especially prominent across various phases of economic

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development, from initial growth stages to industrialization, modernization, and the shift toward a knowledge-driven economy. This importance is rooted in the fact that FDI stimulates broader economic activity by increasing the total investment pool (Raihan & Voumik, 2022). In developing economies, FDI stands as a crucial element for economic advancement. Amid global capital flow volatility, FDI has emerged as a dependable route to spur rapid growth in less-developed nations, supporting the efficient mobilization and sustainable utilization of capital (Raihan, 2024).

FDI is also widely regarded for its potential to positively impact employment levels. By creating new job opportunities within the host country, FDI can contribute to a decrease in URs. Foreign investments lead to the establishment of new factories, offices, and production facilities, all of which increase the demand for local labor and help lower the unemployment rate (UR). Additionally, by promoting the transfer of technology and fostering skills development, FDI improves the competence of the labor force, thereby supporting long-term employment sustainability. However, it is important to note that this relationship may vary depending on the economic structure of the host country and the sectoral distribution of FDI. In cases where developing countries lack sufficient domestic savings to support economic development, they often rely on foreign resources to bridge the gap. Specifically, FDI can have positive effects on economic variables such as national income, balance of payments, inflation, productivity, and poverty levels. Another crucial effect of FDI is its expected contribution to lowering unemployment. Unemployment, the condition where individuals capable of working are unable to find jobs, imposes significant economic and social costs. In open economies, FDI can play a pivotal role in addressing unemployment issues by creating new job opportunities, particularly through the industrial development process (Mucuk & Demirsel, 2013). It is widely acknowledged that FDI generally has a strong positive impact on the labor markets of recipient countries and can reduce URs. Thus, the relationship between FDI and unemployment remains an important and intriguing research area for economists (Balcerzak & Żurek, 2011).

Electricity consumption in developing economies is increasing rapidly, driven by EG, industrialization, and urbanization. This rising demand for electricity poses considerable challenges, both in terms of environmental impacts and the pursuit of electricity security and sustainable development goals (Ibrahiem, 2015). Emerging economies are seeking various strategies to improve electricity efficiency and transition to renewable electricity sources. While FDI stimulates EG in these countries, investments in industrial and infrastructure projects simultaneously contribute to an increase in electricity demand. Foreign investments can improve electricity production and consumption processes by increasing technological innovation and efficiency in the electricity sector. However, increased electricity consumption can pose additional challenges to environmental sustainability and electricity security. The economic benefits of FDI must therefore be balanced with electricity management and environmental impacts. In studying or modeling issues such as electricity consumption (EC) or electricity demand, it is important to better understand how FDI affects electricity consumption (Sadorsky, 2010). Therefore, understanding the determinants of electricity consumption in emerging economies is an important research topic. Consequently, identifying the factors influencing electricity consumption in emerging economies is a crucial area of research.

2. Literature Review

In the literature, numerous studies have examined the relationship between FDI and various economic and environmental variables. Li and Liu (2005) explored the connection between FDI and EG, using data from 1970 to 1999. Applying the three-stage least squares (3SLS) method, they found that FDI significantly accelerates EG, particularly in developing countries. Their study highlights the critical role of foreign capital inflows in fostering growth in these regions.

Karagöz (2011) examined the relationship between FDI, gross domestic product (GDP), and employment in Turkey over the period from 1970 to 2005. The findings suggest a long-term association between FDI and GDP, while no direct causation with employment was established, pointing to the possibility that FDI's capacity for job creation may be limited.

Koyuncu and Cınar (2009) explored how trade openness and FDI affect labor productivity in Turkey for the period 1980–2005. Findings based on the Johansen cointegration test suggest that both trade openness and FDI contribute positively to long-term labor productivity, enhancing workforce performance.

Vergil and Ayas (2009) analyzed sector-specific impacts of FDI on employment in Turkey using data from 1992 to 2006. They observed that FDI negatively influenced employment in sectors like manufacturing, financial services, and wholesale and retail trade, suggesting that FDI may, in certain industries, reduce demand for local labor.

Bülbül and Emirmahmutoglu (2010) investigated the impact of FDI on employment in Turkey's banking sector through panel regression analysis. The expansion of bank branches and assets positively affected employment across both foreign and Turkish banks, highlighting FDI's potential to create jobs in the banking sector.

Saray (2011) examined the link between FDI and employment in Turkey from 1970 to 2009 using the ARDL bounds test. The findings suggest that FDI inflows had minimal influence on employment, potentially due to the focus on sectors with limited job-creation potential.

Ekinci (2011) assessed the long-term relationship between FDI and EG in Turkey from 1980 to 2010 through Johansen cointegration analysis, revealing that FDI exerts a positive influence on long-term EG.

Dogan (2013) applied Johansen cointegration analysis to explore the FDI-EG relationship from 1979 to 2011, finding a long-term positive association that strengthens over time.

Gülmez (2015) investigated the association between EG and air pollution in 24 OECD countries from 2000 to 2012 using the Pedroni panel cointegration test. The results show a long-term connection between EG and air pollution.

Artan et al. (2015) explored the long-term relationship between EG and environmental pollution in Turkey from 1981 to 2012 using Johansen and Juselius cointegration tests, finding significant long-term

Köprücü (2016) examined the influence of FDI on EG in Turkey from 1980 to 2011 using Johansen cointegration methods, finding that FDI positively affects EG.

Uzar (2019) investigated the dynamic interplay among FDI, EG, fixed capital formation, trade openness, and carbon emissions in Turkey from 1974 to 2010 using the ARDL model, confirming the Environmental Kuznets Curve hypothesis for Turkey.

Uzar and Eyuboğlu (2019) explored the relationships among FDI, EG, electricity consumption, and trade openness in Turkey through Fourier ADL and ARDL cointegration tests. Their results indicate that FDI contributes to increased electricity consumption and that a long-term cointegration relationship exists among these variables.

Our study differs from other studies in that we use MODWT analysis to examine the relationships between FDI, carbon dioxide emissions, renewable electricity use, and EG in Turkey from a multi-temporal perspective. Unlike regression and correlation analyses commonly used in the literature, this method allows us to examine how data behave at different time frequencies. The MODWT method allows us to analyze the dynamic nature of these

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relationships and how they change over time in more depth by considering the short-, medium-, and long term effects of FDI separately. Another difference from other studies is that we consider both the economic and environmental dimensions of the interactions between the four variables simultaneously. While most studies examine and analyze a specific relationship such as EG, ER, or environmental impacts of FDI in isolation, in our study, we assess the time-varying relationships of these four important variables in a broader context. Moreover, the fact that we consider both short-term effects (for example, sudden FDI inflows can negatively affect EG) and long-term trends (the positive effects of FDI on sustainable development) together in our study allows us to assess temporary imbalances and long-term gains in the same framework, which is an important point that may be overlooked in macroeconomic analysis.

Finally, this Turkey-specific analysis provides a comprehensive overview of the relationship between Turkey's environmental policies, electricity independence goals, EG strategies, and FDI policies. This has unique implications arising from Turkey's different dynamics among emerging economies, which distinguishes our study from other studies in the literature.

To our knowledge, this paper is the first to jointly employ Maximal Overlap Discrete Wavelet Transform (MODWT) and Continuous Wavelet Transform (CWT) to explore the dynamic time-frequency interactions between foreign direct investment (FDI) and three pivotal macroeconomic indicators—economic growth, electricity consumption, and unemployment rate—in Turkey over the 1970–2022 period. While prior wavelet-based analyses (Öztürk & Acar, 2021; Apergis & Payne, 2012) have typically concentrated on a single variable pair or shorter temporal windows, we systematically compare each FDI–indicator dyad across short-, medium-, and long-term scales using high-resolution monthly data derived via a quadratic match-sum procedure. By integrating MODWT's multiscale decomposition with CWT's localized coherence and phase analysis, we reveal transient co-movements and lead–lag relationships that standard ARDL, VECM, or Fourier-based frameworks fail to capture. These findings advance the methodological frontier of wavelet applications in emerging-market macroeconomics and provide scale-specific policy insights for aligning Turkey's investment, electricity, and labor-market strategies.

3. Data And Methodology

Traditional time-domain techniques such as ARDL and VECM are well suited to uncovering long-run equilibrium and error-correction dynamics, while Fourier-based spectral methods characterize fixed-frequency behaviour. However, none can simultaneously localize transient shocks and periodic cycles in both time and frequency. Wavelet methods overcome this limitation by offering a dual decomposition: the MODWT isolates a series into orthogonal components corresponding to short-, medium- and long-term fluctuations without decimating the original timeline, and the CWT maps the evolution of inter-series coherence and phase relationships at every scale. By integrating MODWT's multiscale filtering with CWT's localized coherence analysis, one can detect ephemeral co-movements and lead–lag patterns that standard ARDL, VECM or Fourier frameworks would either smooth over or miss entirely. For an emerging economy such as Turkey—subject to both sudden external shocks and structural reforms—this comprehensive time-frequency lens is uniquely capable of revealing the scale-dependent interdependencies among foreign direct investment, economic growth, electricity consumption and unemployment.

In this study, we employ the Wavelet Coherence approach to investigate the relationships between FDI, EG, EC, and the UR over various time periods. The wavelet model, rooted in signal processing techniques, is a powerful forecasting tool, allowing for the simultaneous analysis of economic variables across both time and frequency domains. This approach provides deeper insights into the data's underlying dynamics, enhancing our understanding of the interdependencies among variables. Due to these advantages, wavelet analysis is frequently employed in examining correlations and causality within economic time series. By enabling the examination of temporal patterns within the data, wavelet transformations lead to more thorough and reliable conclusions.

In this study, key variables are defined as follows: FDI is represented by net inflows from foreign investors relative to GDP, EG is gauged through the annual GDP growth rate, EC is measured per capita, and the UR is calculated as the proportion of individuals aged 15 and above who actively sought employment within the past three months and are available to begin work within 15 days, relative to the total labor force. Table 1 presents an overview of the data sources and the periods covered for each variable.

Table 1. Information on the variables used in the study

Variable	Code	Reference	Period	Description
Foreign Direct Investment	FDI	World Bank	1970-2022 Annual	Net inflows (% of GDP)
Economic Growth	EG	World Bank	1970-2022 Annual	GDP growth (annual %)
Electricity Consumption	EC	World Bank	1970-2022 Annual *	Electric power consumption (kWh per capita)
Unemployment Rate	UR	TUIK	1970-2022 Annual	1988-2022 TUIK; 1970-1987 Kafkas, 2014; 70)

* Missing observations were completed using statistical data estimation methods.

3.1 Data

The variables in this study were originally collected on an annual basis from multiple databases. To improve the accuracy of our analysis, we applied the quadratic match-sum method (Shahbaz et al., 2018) to transform the data from annual to quarterly frequency. This approach minimizes deviations in the data points and accounts for seasonal variations, making it a reliable way to adjust data from a lower to a higher frequency (Sbia et al., 2014; Shahbaz et al., 2017). Consequently, our analysis uses monthly data for Turkey, covering January 1970 through December 2022 (1970M1–2022M12). Table 2 provides descriptive statistics for the variables on both an annual and monthly basis. Analyzing the results reveals that the annual average FDI was 0.83, with a standard deviation of 0.83, indicating considerable variation in foreign investment levels over the years. The annual average for EG is 4.63% with a standard deviation of 4.02. This data reveals that the growth rate has been highly variable over the years. In particular, the maximum growth rate reached 11.44%, while the minimum growth rate was -5.75%, indicating that in some years the economy experienced severe contractions. Regarding the UR, the average is 9.10% with a standard deviation of 1.88. The maximum UR was as high as 14.03%, while the minimum was measured at 6.3%. This indicates significant fluctuations in the labor market over the years. EC averaged 1499.67 units per year with a standard deviation of 981.30. The maximum EC was 3386 units and the minimum was 218.23 units. These data show that there are significant annual fluctuations in electricity consumption. Looking at the monthly data, FDI averages 0.07% with a low standard deviation of 0.07%. EG has a monthly average of 0.39% with a standard deviation of 0.35%. UR has a monthly average of 0.76% and EC has a monthly average of 124.97 units. These results show that especially variables such as EG and foreign investments show significant differences on annual and monthly basis and therefore periodic analysis is important.

Table 2. Descriptive statistics of variables

Period	Descriptive Statistics	FDI	EG	UR	EC
Annual	Mean	**0.83**	4.63	9.10	1499.67
	S. deviation	**0.83**	4.02	1.88	981.30
	Maximum	**3.62**	11.44	14.03	3386.00
	Minimum	**0.02**	-5.75	6.30	218.23
	Skewness	**1.39**	-0.73	0.62	0.37
	Kurtosis	**1.87**	0.29	-0.02	-1.28
	N	**53**	53	53	53
Monthly	Mean	**0.07**	0.39	0.76	124.97
	S. deviation	**0.07**	0.35	0.16	81.87
	Maximum	**0.32**	1.02	1.19	296.27
	Minimum	**0.00**	-0.56	0.50	17.43
	Skewness	**1.41**	-0.67	0.63	0.37
	Kurtosis	**4.66**	3.06	2.90	1.74
	N	**636**	636	636	636

Figure 1 shows the distribution of the variables considered in the study by months.

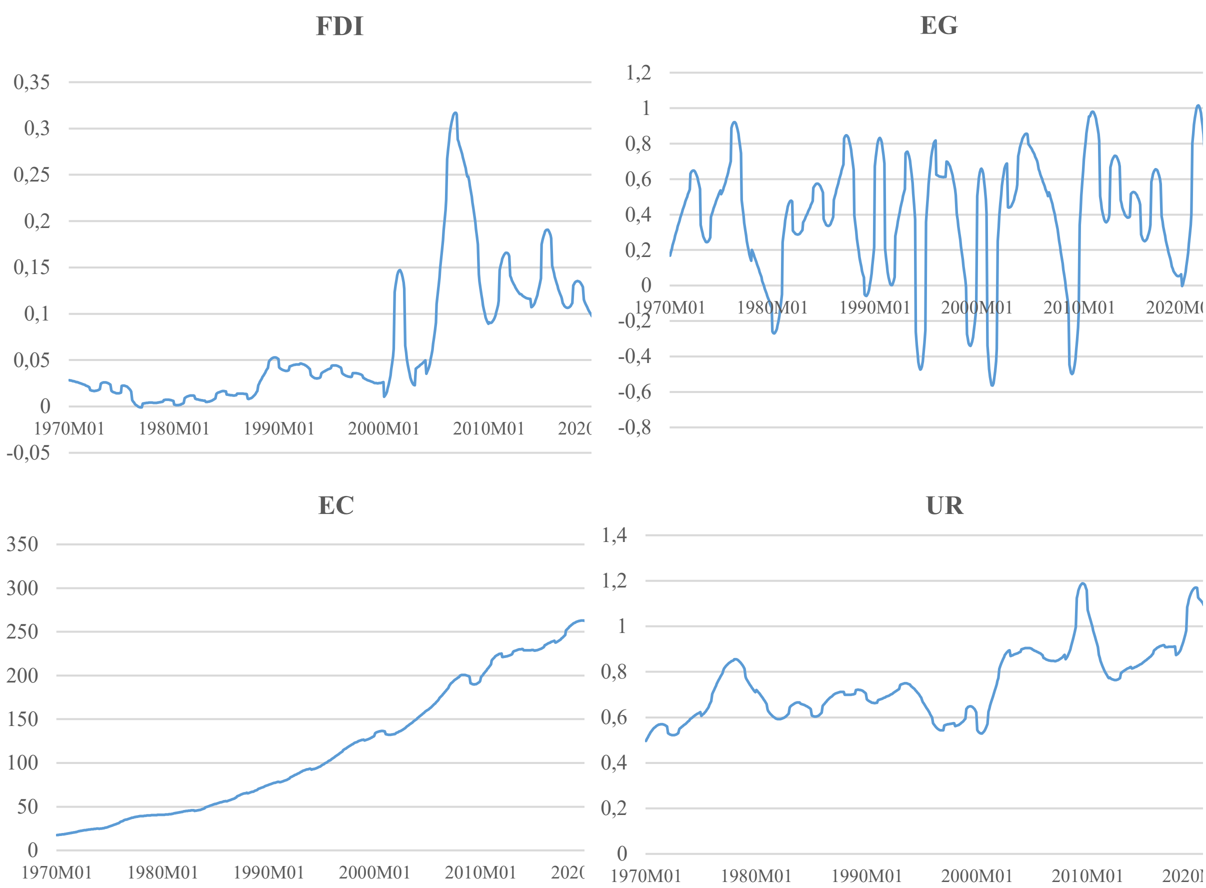

Figure 1. Distribution of Variables (1970M1-2022M12)

When the scatter plot of EC is analyzed, a continuous upward trend is observed since the 1970s. Especially after the 2000s, there has been a significant acceleration in EC and consumption has reached quite high levels towards the 2020s. This increase can be interpreted as an increase in electricity demand due to factors such as population growth, industrialization and technological developments. An analysis of the UR graph shows that it followed a fluctuating course from the 1970s to the 2020s. Especially in the early 1990s and the late 2000s, there were significant increases in the UR. After the 2008 global economic crisis, there was a sharp rise in unemployment, but it has since entered a downward trend again. It can be said that the UR is directly related to economic crises and growth rates, and especially global and local economic crises have a negative impact on the labor market. The EG graph illustrates significant cyclical variations, with certain periods where growth rates dip into negative territory, indicating phases of economic contraction. These steep downturns, especially notable in the 1980s and early 2000s, likely reflect episodes of economic crisis. In contrast, Turkey's periods of rapid expansion in the early 2000s are also prominently visible. However, since the mid-2010s, growth rates have shown increased volatility, potentially signaling underlying economic instability.

3.2 Methodology

This study leverages wavelet analysis to explore the dynamic and time-varying relationships between Foreign Direct Investment (FDI), Electricity Consumption (EC), Unemployment Rate (UR), and Economic Growth (EG) in Turkey from 1970 to 2022. Wavelet analysis offers a powerful framework for examining both short- and long-term interactions by simultaneously decomposing time series in both the time and frequency domains (Torrence & Compo, 1998; Goupillaud et al., 1984). Unlike traditional Fourier analysis, which operates on fixed frequencies, wavelet analysis can capture localized variations, making it particularly effective for non-linear and non-stationary economic data.

Among wavelet techniques, two core methods are utilized in this study: the Continuous Wavelet Transform (CWT) and Wavelet Coherence (WTC). CWT enables the decomposition of individual time series into multiple frequency components, revealing how their behavior changes over time. WTC, on the other hand, quantifies the time–frequency relationship between two series, indicating the strength and direction of their comovement. The coherence coefficient ranges from 0 to 1, with higher values indicating stronger correlations (Grinsted et al., 2004).

This study applies the Maximal Overlap Discrete Wavelet Transform (MODWT) to separate the time series into short-, medium-, and long-term components (Percival & Walden, 2000), and employs WTC to examine scale-dependent interactions between the variables. The theoretical basis for CWT, WTC, and related wavelet calculations is summarized in Appendix A.

4. Empirical Results

Figure 2 illustrates the decomposition of Turkey's FDI time series using the MODWT at $J = 6$. The prominent waves on the left capture long-term trends in FDI, highlighting significant, deep-rooted shifts within the Turkish economy. These trends often correlate with broader, enduring factors such as EG, political stability, and comprehensive macroeconomic policies, providing a clear picture of FDI's directional movement and broader upward or downward trends over time. In the middle section, components reflect medium-term fluctuations in FDI in Turkey. These patterns include cycles, seasonal factors, and economic events unique to particular years. This frequency range captures impacts from regional economic crises, political changes, or shifts in global economic conditions, which play a vital role in showing how FDI evolves over time and in revealing the dynamics behind these shifts. The right side displays low-amplitude, rapidly changing signals, representing short-term fluctuations in FDI. These high-frequency components capture factors such as sudden shifts in investor expectations, unexpected political decisions, and market shocks. Short-term economic uncertainties and abrupt market movements are particularly visible in these components. The observed decline in fluctuation amplitudes over time indicates that Turkey's FDI landscape has grown more stable. Specifically, the decrease in high-frequency component amplitudes suggests a more predictable and steady investment environment in Turkey. This trend implies that investors are facing less uncertainty, enabling them to make investment decisions in a more secure context. Thus, it appears that Turkey's investment climate has progressively become more appealing and stable over time.

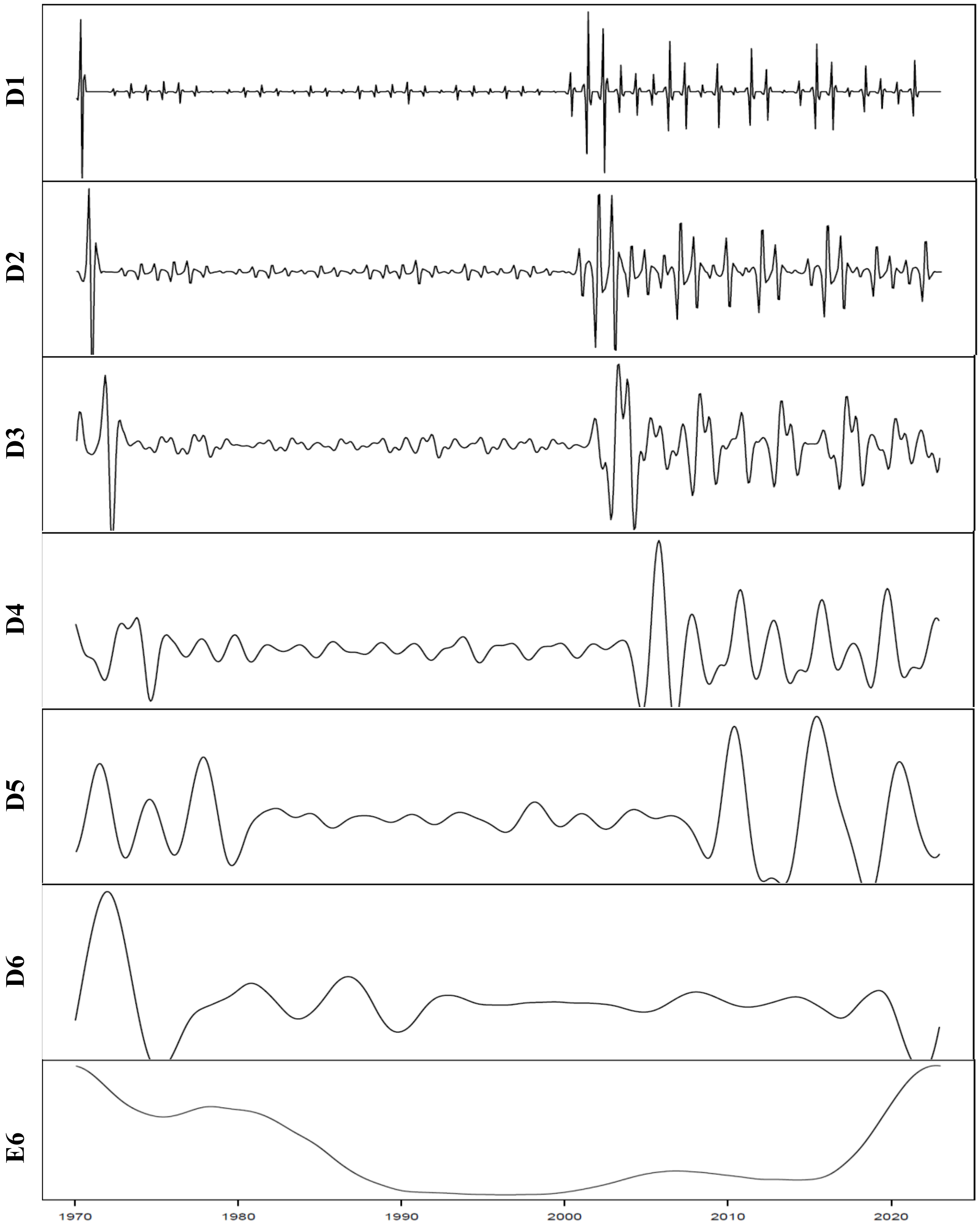

Figure 2. MODWT (discrete wavelet transform with maximal aliasing) decomposition of FDI at wavelet level J = 6

Figure 3 shows the decomposition of the EC time series at the J = 6 wavelet level using MODWT. The large amplitude fluctuation seen on the left side of the figure represents the long-term component of the EC time series. This fluctuation often reflects long-term trends in electricity consumption and large-scale economic changes. For example, increasing electricity demand over the years, technological innovations or major economic reforms can manifest themselves in these components. However, in the rest of the figure, there is a marked decrease in the amplitude of the waves and the wavelets become increasingly flatter. This implies that the short-term components in the EC time series are relatively low, meaning that short-term fluctuations and sudden changes in electricity consumption are limited. In other words, the electricity consumption time series seems to be shaped by long-term trends rather than short-term events.

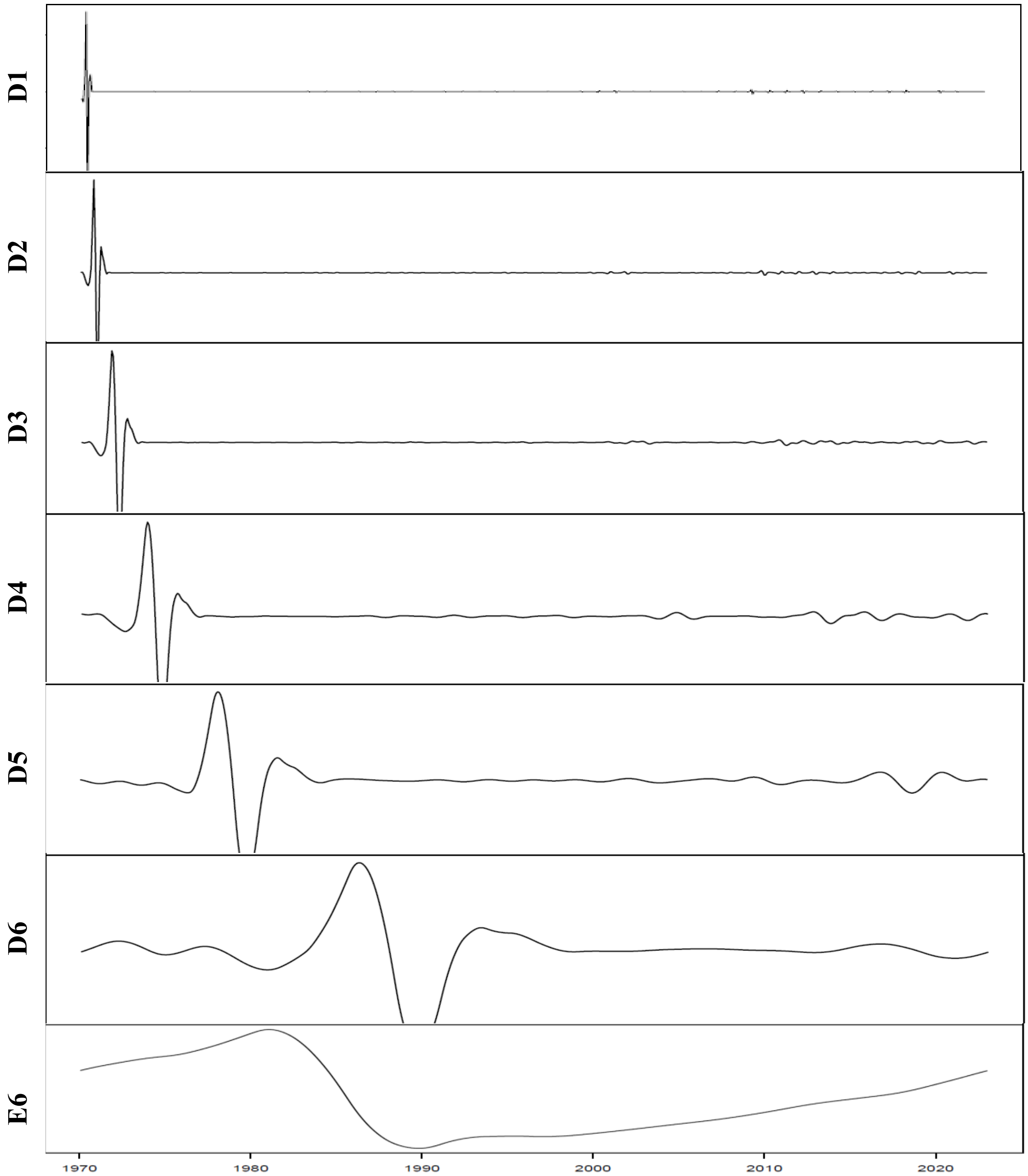

Figure 3. MODWT (discrete wavelet transform with maximal aliasing) decomposition of EC at wavelet level J = 6.

Figure 4 shows the decomposition of EG at the J=6 wavelet level using MODWT. The frequent and high amplitude fluctuations seen in the figure represent high frequency components in the EG series. Such components represent short-term fluctuations in EG, i.e. sudden and temporary changes. For example, short-term shocks, political events or temporary market fluctuations affecting EG can be observed in such high-frequency components. The figure also includes low-frequency components. These components can be seen as slower and broader fluctuations in the chart. Low-frequency components represent long-term trends or cyclical movements of EG. This refers to the general trends of EG, i.e. whether it moves in an upward or downward direction in a given period.

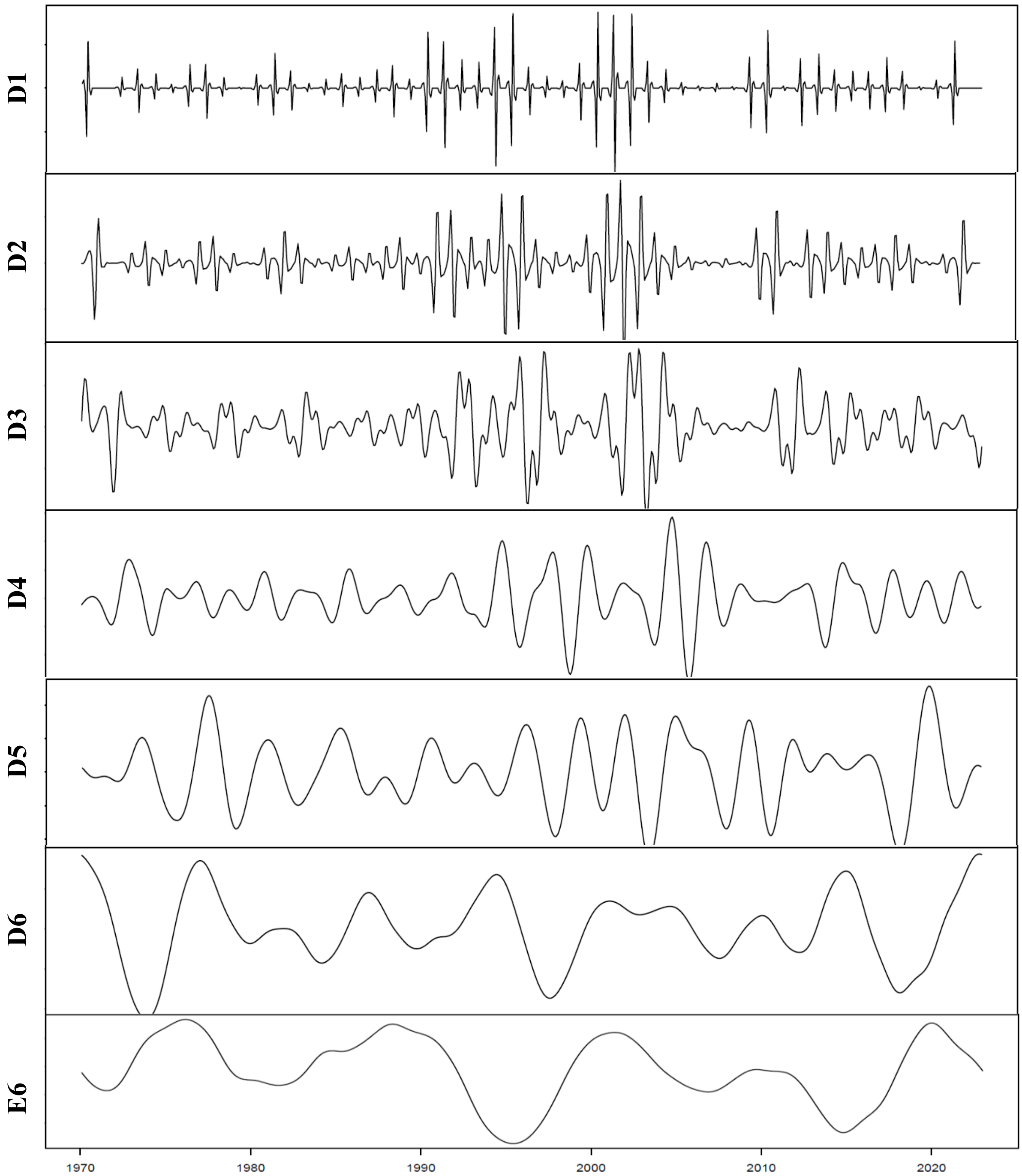

Figure 4. MODWT (discrete wavelet transform with maximal aliasing) decomposition of EG at wavelet level J = 6.

Figure 5 shows the decomposition of the UR data using MODWT applied at J = 6. The high amplitude waves at the beginning of the figure indicate short-term and sudden changes in the UR. These sudden changes can often be caused by economic shocks, policy changes or other exogenous factors.

The lower amplitude and longer period waves in the middle and the end of the figure reflect longer-term trends in the UR. These waves represent the effects of long-term factors such as EG, investment trends or structural changes. Periods when the waves are relatively flat and show no significant change represent more stable periods without large changes in the UR.

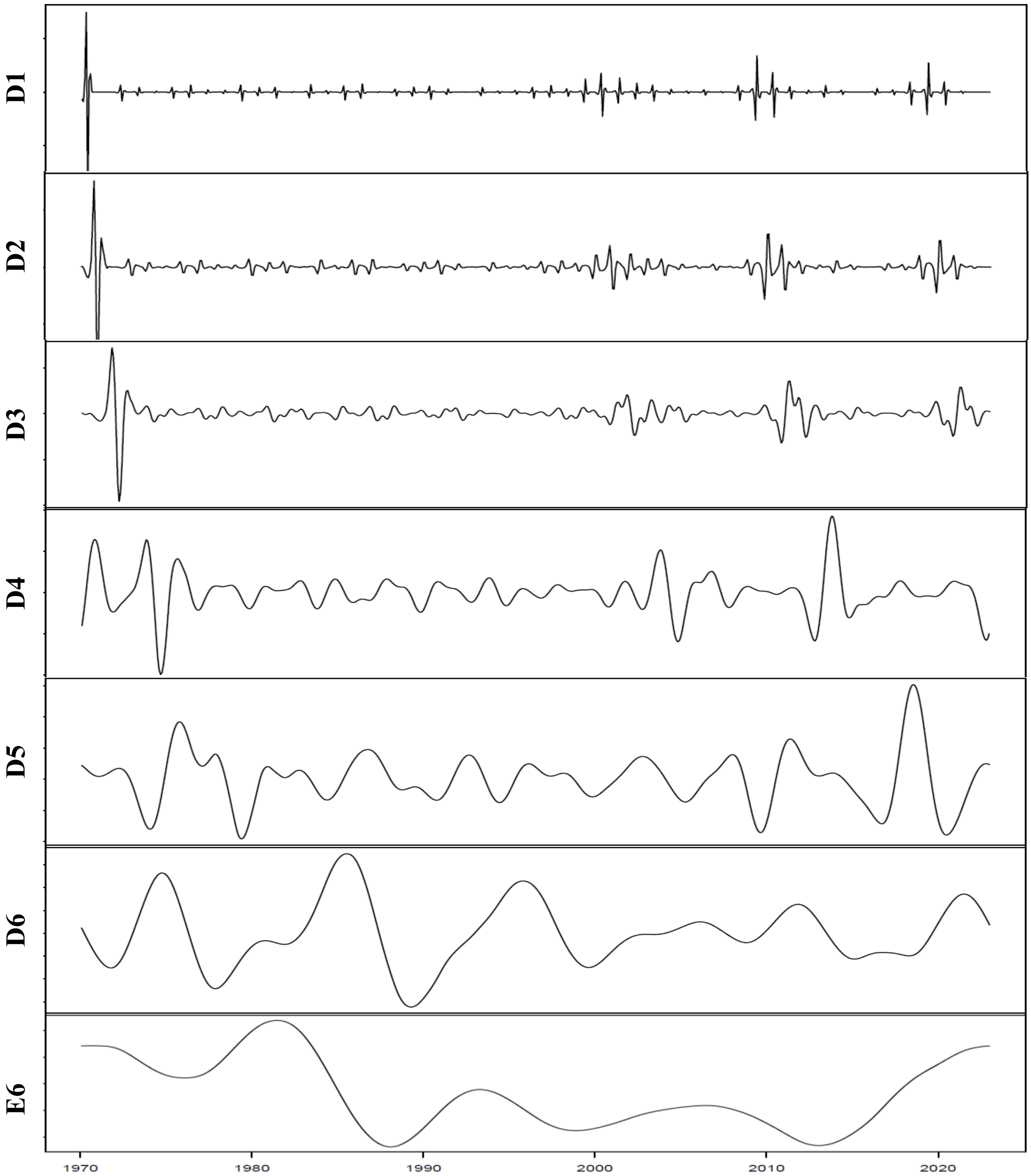

Figure 5. MODWT (discrete wavelet transform with maximal aliasing) decomposition of UR at wavelet level J = 6.

Figure 6 shows the wavelet correlation between FDI and UR in Turkey at different scales. Small wavelet scales (0-4) reflect short-run relationships. At these scales, the correlation between FDI and UR is generally negative and weak (U: close to 0). This may indicate that in the short run, FDI has no significant effect on the UR or has a weak inverse effect. In the medium-run wavelet scales (8-16), we see that the correlation remains negative but becomes

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slightly more pronounced (L: -0.2 to -0.6). This may indicate that in the medium term, FDI has a more pronounced dampening effect on the UR. In the long-run wavelet scales (32), the correlation turns positive (up to 0.4). This suggests that FDI may have had an increasing effect on the UR in the long run or that other factors may have come into play during this period. At small and medium scales, where a negative correlation is observed, it may mean that FDI reduces the UR. However, this relationship is not strong in the short and medium term. In the long run, a positive correlation emerges and a positive relationship between FDI and the UR is observed. This may indicate that FDI may have an increasing effect on the UR in the long run or that other macroeconomic variables affect this relationship. U and L represent the upper and lower bounds of the 95% confidence interval, respectively, while asterisks (*) indicate the average wavelet correlation at each scale.

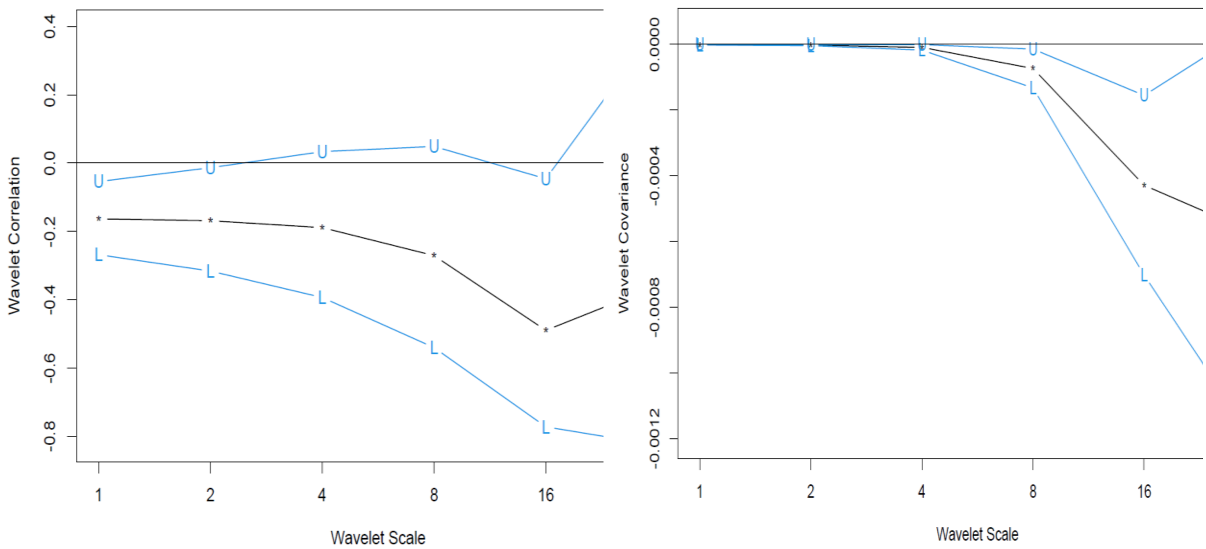

Figure 6. Wavelet covariance and correlation between FDI and UR in Turkey

Figure 7 shows the wavelet covariance and correlation between FDI and EG in Turkey at different wavelet scales. At the first few wavelet scales (1, 2, 4), the wavelet correlation generally shows a negative trend. This implies that there is an opposite relationship between FDI and EG in the short run, i.e. FDI may negatively affect EG in the short run. This may reflect the fact that sudden capital inflows can lead to short-term economic imbalances or that the market structure may not be able to adapt to rapid changes. At medium wavelet scales (8, 16), the correlation increases positively. This indicates that FDI positively affects EG in the medium term. In the medium term, it can be assumed that incoming foreign capital contributes to increasing investments, supporting employment and production. In this process, the economic structure is likely to adapt to the effects of FDI and produce positive results. At the largest wavelet scales (16, 32), the correlation starts to decline and even shows a negative trend. In the long run, it can be said that the impact of FDI on EG weakens or changes negatively. This may be due to factors such as the sustainability of foreign investments in the long run, the increasing dependence of the local economy on foreign capital, or the negative impact of FDI on competition in local sectors. The confidence bounds (U and L) represent the 95% interval for correlation estimates, and asterisks (*) denote mean correlation values across wavelet scales.

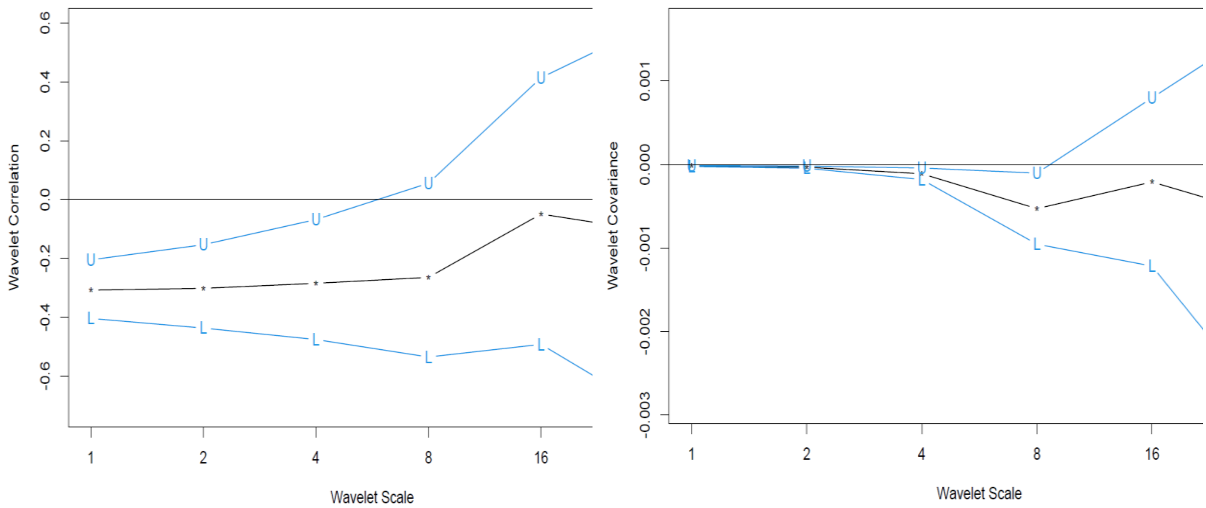

Figure 7. Wavelet covariance and correlation between FDI and EG in Turkey

Figure 8 shows the wavelet correlation between FDI and EC in Turkey at different wavelet scales. At several wavelet scales (1, 2), the correlation is quite low and even negative. This indicates a weak or inverse relationship between FDI and EC in the short run. This may suggest that FDI does not have a direct and significant impact on electricity demand in the short run or that some short-term investments may lead to a reduction in electricity consumption. At medium wavelet scales (4, 8, 16), the correlation shows a positive trend and gradually increases. This implies that FDI increases EC in the medium term, hence investment activities have a positive impact on electricity demand. Increased production capacity, new plants and expanding industry due to the arrival of foreign capital may have increased electricity demand. At the largest wavelet scale (32), the correlation is highest. This indicates that in the long run, the impact of FDI on EC is strong and positive. That is, foreign investments significantly increase electricity demand over time and this effect becomes significant in the long run. This may indicate that sustainable and long-term investments are concentrated in electricity-intensive sectors, which in turn increases EC. U and L denote the 95% confidence limits for the wavelet correlations, while asterisks (*) mark the corresponding mean correlation values at each frequency band.

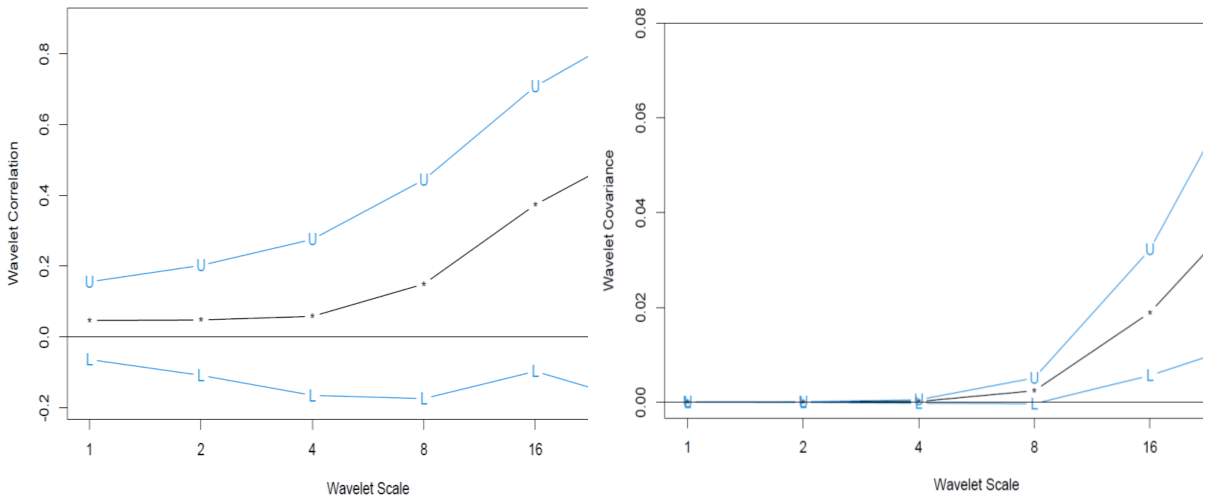

Figure 8. Wavelet covariance and correlation between FDI and EC in Turkey

Figure 9 shows the continuous wavelet power spectra of FDI, EG, EC and UR. It shows how the FDI fluctuates over different periods with respect to time and in which time periods there are significant changes. In particular, in certain time periods (between 300-500 units) the high electricity of the FDI and the periods of frequency components contributing to this electricity become evident. The strong electricity regions of the UR, especially between 300–

500-time units, indicate that there are significant long-term changes in the UR. For EC, the intense red regions observed between 200-450 time units, around periods 64 and 128, indicate that there are significant long-term fluctuations in EC in this time period.

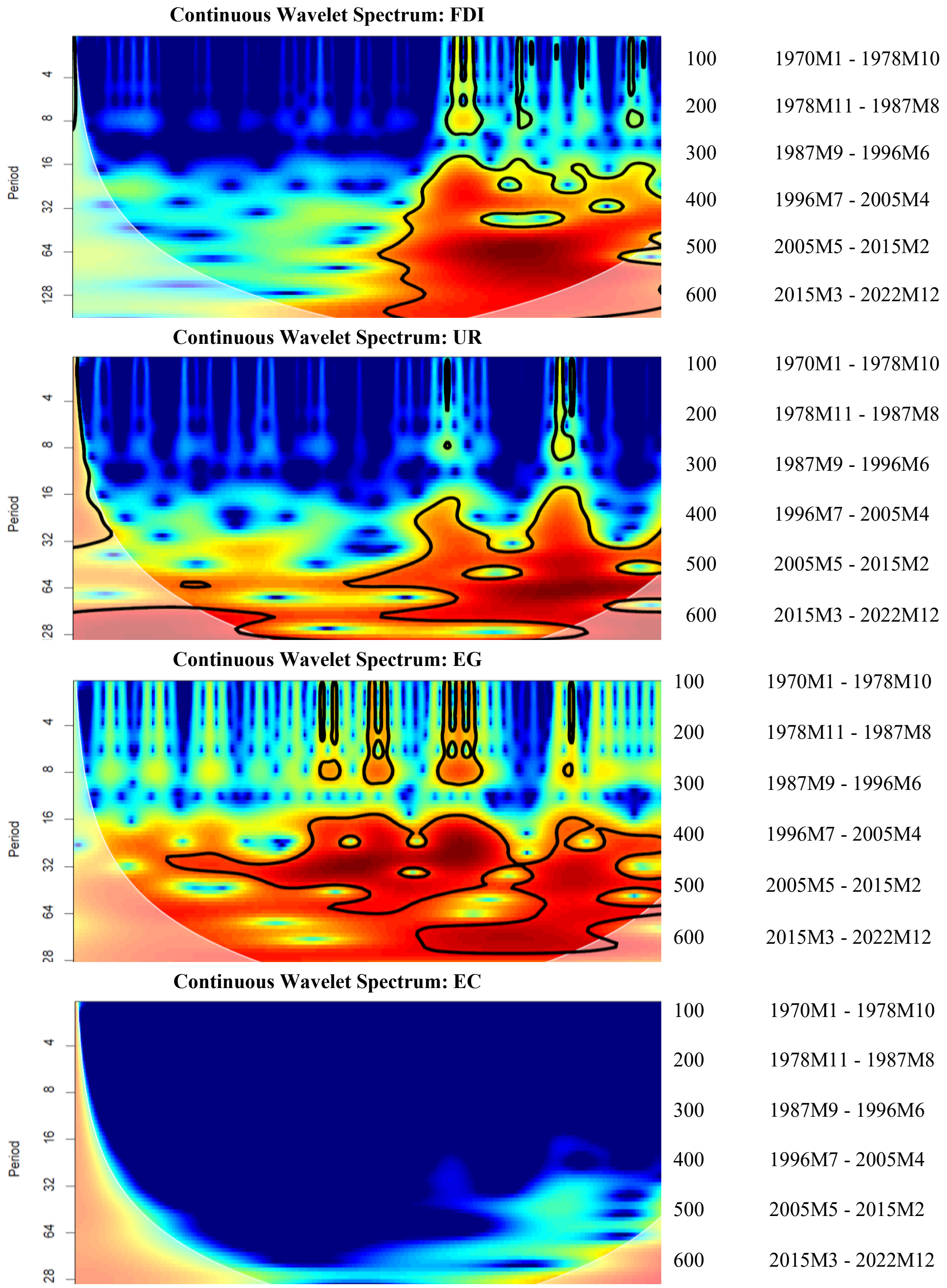

Figure 9. Continuous wavelet power spectra of FDI, EG, EC and UR

Wavelet fit analysis allows for the evaluation of the relationship between two time series both in terms of time and frequency. Figure 10 shows the Wavelet Fit between FDI and EG, EC, UR in Turkey. It shows that there is a strong relationship between FDI and EC in certain time periods and periods. The high agreement between the two variables is particularly noteworthy between time units 50-350 and periods 8-32. In these periods, it indicates that the impact of FDI on EC or these two variables act together. The relationship between FDI and EG

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in Turkey is particularly strong between time units 50-350 and between periods 8-64. This indicates that FDI has a strong relationship with EG in certain periods and possibly these two variables influence each other. In Turkey, there is a strong correspondence between FDI and UR, especially between time units 100-300, and between FDI and UR in periods 16-64. This indicates that there may be periods when FDI has an impact on the UR.

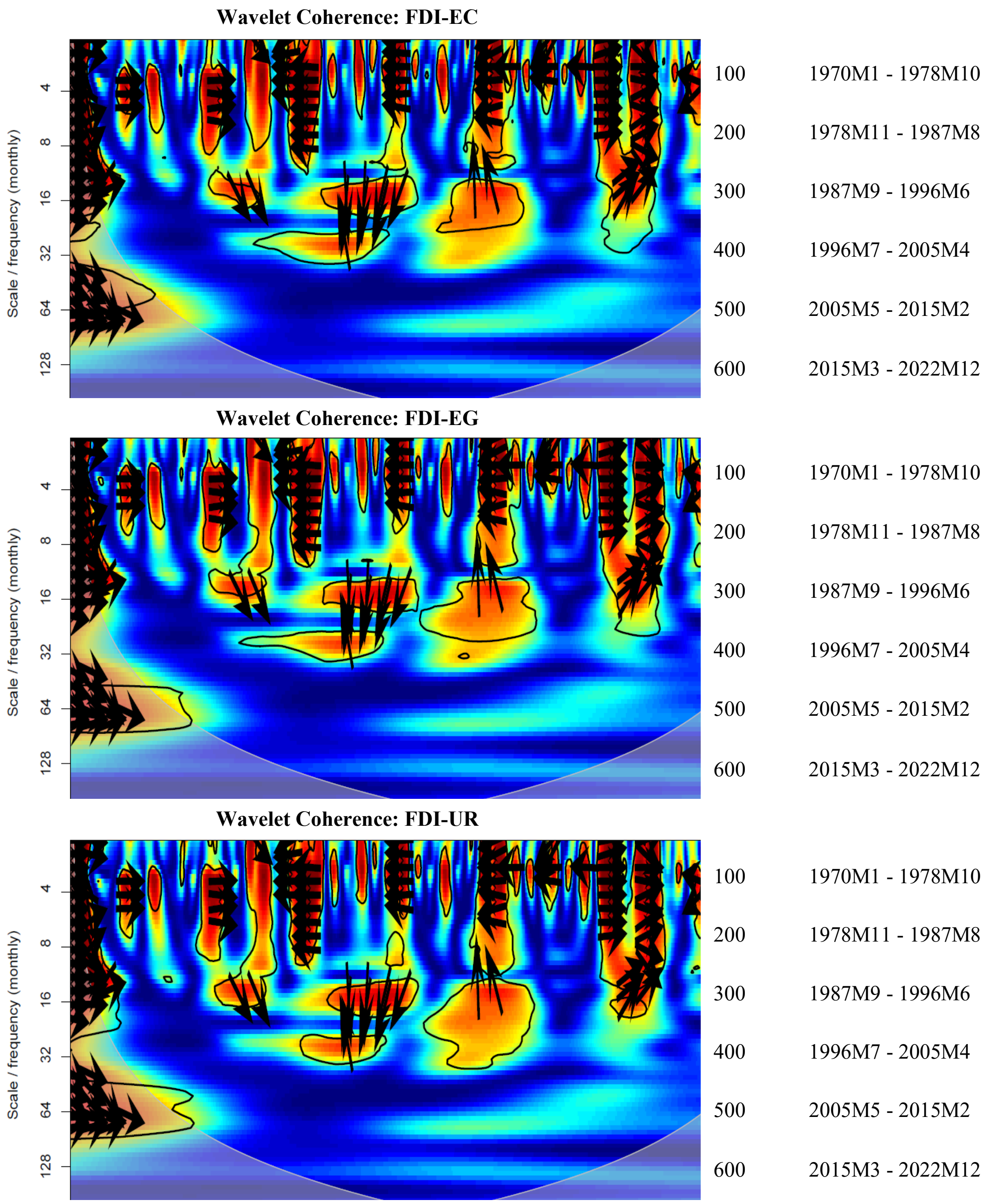

Figure 10. Wavelet Fit between FDI and EG, EC, UR in Turkey

5. Conclusion And Policy Implications

This study examines the dynamic relationships between FDI, UR, EC, and EG in Turkey from 1970 to 2022, using wavelet analysis to capture both short- and long-term effects. The findings reveal a complex interplay between these variables over different time horizons. In the short term, FDI is weakly negatively correlated with UR, but this correlation turns positive in the long run. This result aligns with the work of Mucuk and Demirsel (2013), who argue that the impact of FDI on unemployment can vary depending on the economic structure and sectoral composition of the host country.

Regarding EC, FDI's influence strengthens over time. While the short-term effect is minimal, FDI significantly drives up electricity consumption in the medium and long terms. This supports findings from researchers like Sadorsky (2010) and Ibrahiem (2015), who suggest that FDI, particularly in developing economies, often leads to increased industrial activity and infrastructure development, thereby raising electricity consumption.

The relationship between FDI and EG, however, is more nuanced. In the medium term, FDI has a positive impact on growth, but this influence weakens and even turns negative in the long term. This reflects earlier studies by Li and Liu (2005) and Dogan (2013), which emphasize FDI's growth-enhancing effects in developing countries while also cautioning that, over time, dependency on foreign capital and reduced competition in local industries may limit these benefits.

Given these findings, policymakers in Turkey and other developing economies should carefully manage FDI to maximize its benefits while mitigating its potential downsides. Attracting foreign investment can undoubtedly boost EG and improve electricity infrastructure, but it's crucial to address the challenges related to unemployment and environmental sustainability. Strategies should focus on integrating foreign investment into the local labor market and promoting energy efficiency to ensure that economic gains do not come at the expense of long-term stability and environmental health. In conclusion, this study highlights the evolving effects of FDI on key economic variables in Turkey. Future research should continue to explore these time-varying dynamics, especially regarding how FDI influences both EG and sustainability in the long term.

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Conflict of interest/Competing interests

The authors declare that they have no conflict of interest.

Data Availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

Not applicable, as this study did not involve human participants or animals.

Consent for publication

All authors have reviewed and approved the final manuscript for publication.

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Appendix A

This appendix provides the mathematical foundations of the wavelet methods employed in this study, primarily based on the works of Goupillaud et al. (1984), Torrence and Compo (1998), Grinsted et al. (2004), and Percival and Walden (2000).

(1) General form of the wavelet transform:

$$w_{k,f}(t) = \frac{1}{\sqrt{h}} w\left(\frac{t-k}{f}\right), k, f \in R, f \neq 0 \qquad 1$$

(2) Continuous Wavelet Transform (CWT):

$$W_p\,(k,f) = \int_{-\infty}^{\infty} p(t) \frac{1}{\sqrt{f}}\, \psi \left(\frac{t-k}{f}\right) dt \qquad 2$$

where $p(t)$ is the time series and ψ is the mother wavelet function.

(3) Wavelet function normalization:

$$p(t) = \frac{1}{C_w} \int_0^{\infty} \left[\int_{-\infty}^{\infty} \left| m_p(a,b) \right|^2 da \right] \frac{db}{b^2} \qquad 3$$

(4) Wavelet Power Spectrum (WPS):

$$WPS_p(k,f) \left| W_p(k,f) \right|^2 \qquad 4$$

(5) Cross-Wavelet Transform:

$$W_{pq}(k,f) = W_p(k,f)\overline{W_q(k,f)} \qquad 5$$

(6) Wavelet Coherence (WTC):

$$R^2(k,f) = \frac{\left| S(f^{-1} W_{pq}(k,f)) \right|^2}{S(f^{-1}\left| W_p(k,f) \right|^2) S(f^{-1}\left| W_q(k,f) \right|^2)} \qquad 6$$

Here, S denotes a smoothing operator in time and scale, and $R^2(k,f)$ indicates the squared wavelet coherence. A value close to 1 represents strong coherence between two time series, whereas a value near 0 indicates weak or no coherence.

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