RENEWABLE-ENERGY INVESTMENT AND MACROECONOMIC DIVERSIFICATION IN IRAQ: QUARTERLY EVIDENCE FROM AN ARDL–ERROR-CORRECTION FRAMEWORK, 2013–2024

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Abstract
Financing will be relevant to investment attraction, labor market performance, electricity mix, and economic diversification in a hydrocarbon-dependent country like Iraq due to its ongoing electricity shortages. The present study offers the first quarterly, multi-outcome econometric evidence for Iraq, considering relationships between investment in renewable energy and four development indicators, namely net foreign direct investment (FDI) inflows, unemployment, fossil fuel dependency in electricity generation, and non-oil dependency in gross domestic product (GDP), based on 48 observations from 2013Q1 to 2024Q4. Complementary unit-root tests and structural-break tests were performed to estimate outcome-specific autoregressive distributed lag (ARDL) models. The level relationships for all four equations were supported by exact small sample bounds tests. A 1% rise in renewable-energy investment led to a 0.00745-percentage-point rise in FDI, a 0.0110-point drop in unemployment, a 0.0111-point drop in fossil-fuel electricity dependence, and a 0.0208-point increase in the share of non-oil GDP. The error-correction coefficients varied between −0.539 and −0.914, which suggests that the adjustments were statistically supported and were moving towards equilibrium. The focal short- and long-run coefficients remained important following the procedures of Benjamini–Hochberg adjustment and Newey–West inference, while heteroskedasticity was observed in the unemployment equation, and the FDI robustness specification needs to be harmonized. The results from the Toda–Yamamoto tests revealed the predictable and partly bidirectional relationship between renewable investment and FDI and non-oil share from the project's start time. The results do not reveal cause-and-effect policy impact, but rather the stable equilibrium associations, and they emphasize the role of data provenance and shock-dependency in the inference process to understand conflict-affected economies.

1. Introduction

Iraq has the best potential in terms of renewable resources and is one of the most hydrocarbon-intensive in terms of economic activity and electric power generation in the Middle East. The existing power system is mainly based on thermal generation, where the thermal generation share for electricity production is estimated at approximately 96.6%, whereas the share of solar generation is marginal (Al-Kayiem & Mohammad, 2019; Al-Rikabi et al., 2025; IRENA, 2025), and the national grid suffers from chronic electricity supply, efficiency and infrastructure issues that create a strong technical case for deployment of renewables in the region due to high solar irradiance, vast land availability and promising wind resources. Regional comparisons also reveal that deployment lags are significant; while the five resource-rich countries in the Middle East are showing varying levels of advances in renewable development, Iraq (and Iran) is significantly behind the United Arab Emirates and Saudi Arabia, with conflict legacies identified as a key barrier (Abed et al., 2025). This difference is an economic one. Electricity shortages limit private sector production, negatively affect investment incentives, and increase the reliance on public spending and hydrocarbon revenues, while renewable investments could alleviate the constraint of electricity and generate new avenues for capital formation, technology transfer, and non-oil activity (Bekheet et al., 2023).

The importance of renewable investments goes beyond electricity substitution. First, visible investment in clean infrastructure can be a signal of regulatory commitment and enhance the perceived reliability of the business environment, which may be conducive to foreign direct investment. Renewable-energy development and FDI have been shown to be positively correlated in the long run in emerging economies, though the strength and form of the relationship vary by institutions, with different types of capital inflows and measures of renewable development (Goh et al., 2025; Raihan et al., 2025). Secondly, development projects may affect employment in the construction, installation, operational, and services phases. The international evidence in this body is mixed, as cross-country work suggests the labourmarket response to the shock is nonlinear and varies by country (Apergis & Salim, 2015), country-level evidence in Europe shows decreases in unemployment in the long run, but in an asymmetric pattern (Naqvi et al., 2022), country-level results in South Asia are mixed (Rahman et al., 2024), middle-income Asian economies show long-term increases in unemployment (Pham et al., 2026), and a meaningful subset of US states exposed to energy-sector displacement experienced pro-unemployment effects in the long-term (Saboori et al., 2022). Third, renewable investment could gradually decrease the share of fossil fuels in electricity generation and, in turn, increase the energy supply base, which will boost the potential for a wider energy transition in the structural and institutional context of oil-dependent exporters (Karanfil & Omgba, 2023).

These mechanisms are especially relevant in Iraq, where an economic diversification policy is a primary challenge. The IMF's recent evaluation highlights the importance of public investment, financing conditions, and structural constraints in the growth of non-oil sectors (IMF, 2025), whereas IRENA (2025) recognizes the role of renewable deployment in ensuring energy security, reducing energy supply costs, and contributing to overall economic development. However, evidence in terms of country-specific econometric links between renewable energy investment and the related capital inflows, employment, and generation mix, as well as the non-oil economy, is limited. Preexisting literature typically addresses energy use or installed capacity, conducts annual observations, and/or focuses on descriptive or prospective analysis of the energy sector for a set of countries (Bekheet et al., 2023; Al-Rikabi et al., 2025), potentially masking the specific characteristics of Iraq as a country vulnerable to conflict, oil-price dependence, and institutional regime.

This work offers a remedy to this problem, in a time-series design based on quarterly data and using outcomes as the criterion measured. It makes three contributions. First, it tests four different dimensions of development in an empirical architecture that shares and enables each development outcome to be dynamic. Second, it brings ARDL bounds testing and error-correction modeling with structural-break assessment and robust inference, stability tests, and multiplicity adjustment. Thirdly, it distinguishes between equilibrium association and temporal predictability by using the ARDL approach along with traditional Granger and Toda–Yamamoto methods. The study investigates a possible connection between the four outcomes in the short and long run, whether knowledge of the deviations from the expected relationships is adjusted over time, and whether the ordering is from investment to outcome and/or the opposite. Since the design cannot isolate exogenous variation in investment, all conclusions are made as associations and in the direction of time, not as causation.

The rest of the paper will be arranged as follows. The literature review in Section 2 provides an overview of the most recent publications and situates the Iraqi case. The conceptual framework and hypotheses are developed in Section 3. The data and econometric methodology are outlined in Section 4. The results are summarized in Section 5, the discussion is in Section 6, and the policy implications and limitations are included in Section 7.

1.1. Literature review

1.1.1. Renewable energy and foreign direct investment

An increasing amount of research links renewable-energy development to global investment flows. Goh et al. (2025) find a positive relationship between renewable energy consumption and FDI inflows in emerging Asian economies, depending on the extent of the measure and institutions. Egypt: Raihan et al. (2025), in the ARDL framework, conclude that renewable energy and FDI work synergously and strengthen the long-run growth of GDP, with a 1% increase in renewable energy

leading to a long-run increase in GDP by 1.02%. For the MENA region, the bootstrap-ARDL findings confirm cointegration between FDI inflows and renewable-energy consumption and growth in most of the seven economies studied, but with varying directions of causality across countries and specifications (Ghazouani, 2025), and more recently, ARDL evidence for Morocco additionally links renewable-energy consumption to FDI and to growth within a single dynamic framework (Fikri et al., 2025). This literature suggests a credible clean-infrastructure interpretation: credible clean-infrastructure programs lower perceived infrastructure risk and increase the size of the investable project set; however, the strength of the relationship between the clean-infrastructure program and the project is sensitive to the quality of the institutions and the type of capital flowing into the project.

1.1.2. Renewable energy and labor-market outcomes

The labor impacts of renewable growth are theoretically uncertain since the creation of jobs in renewable construction and installation, and services could offset losses from existing energy uses. Apergis and Salim (2015) find that there are country-group-specific responses, which are nonlinear for a sample of 80 countries. In a large sample of US states, Saboori et al. (2022) find pro-unemployment effects, similar to those found for established energy sectors. In contrast, Naqvi et al. (2022) determine that increased renewable-energy output brings about positive long-run unemployment reduction in European countries in an asymmetric panel setup. In South Asia, Rahman et al. (2024) employ the ARDL estimation method, together with Toda–Yamamoto causality, and record the nation-level differences in the relationship between renewable development, unemployment and growth in the region. Most recently, for the 12 middle-income Asian economies, a pooled-mean-group analysis of the match between the long-run unemployment effect and short-run employment impact of raising the share of renewables suggests that most countries have minimal short-run employment impact, but substantial long-run unemployment impact, revealing transitional labor-market costs of the energy transition (Pham et al., 2026). The balance of evidence accordingly points to a strong context-dependency regarding labor-market impacts, and calls for country-specific analysis for those economies that do not yet have a large renewable energy industry, and where the displacement pressure on incumbent energy jobs is low, such as Iraq.

1.1.3. Energy transition, electricity mix, and diversification in oil-dependent economies

In the case of oil exporters, the energy transition is intertwined with a larger structural-diversification issue. Export diversification among oil-dependent countries is clubbed together based on structural and institutional characteristics, as revealed in Karanfil and Omgba (2023), and oil-dependent countries with better diversification were less impacted by the pandemic shock. This literature suggests that renewable investment is better seen not as a stand-alone lever, but as part of a broader diversification process: availability of energy can ease a limiting factor on non-oil production, but investment in renewables will lead to structural change if and only if other factors, such as fiscal capacity, governance, and human capital, allow. Inside the electricity system, the substitution of fossil energy sources is likely to be slow when the fossil generation component is high, such as that in Iraq (Al-Rikabi et al., 2025).

1.1.4. The Iraqi context and the research gap

Studies conducted in Iraq reveal extreme electricity shortages, damaged infrastructure, significant solar and wind energy resources, and financing and grid and policy challenges as the primary obstacles to deployment (Al-Kayiem and Mohammad, 2019; Bekheet et al., 2023; Al-Rikabi et al., 2025). Comparative regional analysis shows that Iraq's renewable electricity generation potential is lagging behind its neighboring Gulf countries, notwithstanding their similar solar resources, where the shortfall is due to war, political instability, and financing concerns, and not technical potential (Abed et al., 2025). Bekheet et al. (2023) also add that investment in the hydrocarbons sector in Iraq has been the main attraction of FDI, while the old grid has been a deterrent for the electricity sector. This literature, however, is missing the quarterly econometric evidence that would provide a linkage between renewable-energy investment and both capital inflows and unemployment, as well as the generation mix and the non-oil economy—all within a shock-sensitive framework. This study provides that evidence.

1.2. Conceptual framework and hypotheses

The expected relationships are assumed to occur in four interrelated, but empirically separate channels. The investment-signaling channel suggests that if a renewable project is credible, then it is able to lower perceived infrastructure risk and cause complementary foreign investment. The labor-demand channel, which assumes that the negative effects of the displacement of jobs from existing activities are lower than the positive effects of construction, logistics, installation, and maintenance, predicts a reduction in unemployment. The generation-substitution channel foresees a gradual decrease in the share of fossil fuels due to the penetration of renewables into the power grid. Lastly, the electricity supply and diversification channel suggest that a more secure and diversified energy foundation promotes non-oil production. Oil prices and major crisis periods can alter each channel through altering fiscal space, project finance, and demand and measurement conditions.

Based on this, the following empirical hypotheses are formulated: H1: renewable-energy investment has a positive relationship with investment inflows in FDI; H2: renewable-energy investment has a negative relationship with unemployment; H3: renewable-energy investment has a negative relationship with the proportion of fossil fuels in electricity generation; and H4: renewable-energy investment has a positive relationship with the proportion of non-oil GDP. The above are associations rather than causal statements.

2. Method

2.1. Study design, period, and variables

Data was analyzed using a quantitative longitudinal design with 48 consecutive observations of the Iraqi data available for quarterly time periods from 2013Q1 to 2024Q4. In Table 1, the variable of interest was renewable-energy investment. The four dependent variables were: net FDI inflows as a percentage of GDP, unemployment as a percentage of the labor force, fossil-fuel share of electricity generation, and non-oil share of GDP. The oil price, on a worldwide scale, was added as a continuous macroeconomic control. Prespecified indicators were the conflict period and the COVID-19 period.

Table 1. Variable definitions, transformations and provenance fields

Variable	Definition / unit	Analysis form
REINV	Renewable-energy investment, USD million per quarter	LREINV = ln(REINV)
FDI	Net FDI inflows, % of GDP	Level, percentage points
UNEMP	Unemployment rate, % of labour force	Level, percentage points
FOSSIL	Fossil-fuel electricity generation, % of total	Level, percentage points
NONOIL	Non-oil GDP, % of total GDP	Level, percentage points
OILP	International oil price, USD/barrel	LOILP = ln(OILP)
CONFLICT	Prespecified conflict-period indicator	Binary fixed regressor
COVID	Prespecified pandemic-period indicator	Binary fixed regressor

Source: Author's compilation from the study dataset; variable transformations and crisis-period indicators were specified by the author.

2.2. Data audit and preprocessing

The audit covered: chronological continuity, duplicates, missing/infinite values, non-numeric values, changes in units, implausible percentages, dummy coding, positivity before logarithmic transformation, and influential observations. There were no infinite or missing observations for the principal variables. The robust median-absolute-deviation (USD 104.30 million; robust z = 3.689) was robustly screened in 2024Q3 and was not rejected due to the absence of a source error. The short-run descriptive correlation was done using first differences. The results are expressed in percentage points, and the investment has been entered in its logarithms; the focal coefficient is therefore semi-elasticities: the change in investment by 1% signifies an approximation of the focal coefficient $\beta/100$ percentage in the change in the outcome.

2.3. Integration order, breaks, and lag selection

The stationarity of the series was tested using the augmented Dickey–Fuller, Phillips–Perron, and KPSS tests (Dickey & Fuller, 1979; Phillips & Perron, 1988; Kwiatkowski et al., 1992) under intercept-only and intercept-plus-trend specifications. One endogenous break (Zivot & Andrews, 1992) was detected by Zivot–Andrews tests, and up to two breaks were detected by screening Bai–

Perron procedures (Bai & Perron, 1998, 2003). The break-trimmed tests demonstrated greater evidence of stationarity for some series than the standard tests, so the evidence of stationarity and the behavior of the first difference were used in making the decisions about integration rather than one test alone. There was no variable that was classified as I(2).

The lag orders were searched for up to 4 quarters for each outcome and selected by the Bayesian information criterion, with about 15 residual degrees of freedom. Primary specifications were selected as ARDL(1,0,0), and the results were lagged and contemporaneous LREINV and LOILP, with CONFLICT and COVID as fixed regressors.

2.4. Bounds tests, long-run coefficients and error-correction models

We used the Pesaran–Shin–Smith bounds framework for assessing a level relationship, noting the small-sample critical-value problem pointed out by Narayan (2005), and assumed that there was no deterministic trend (Pesaran et al., 2001). The Critical values of selected specifications were simulated exactly for finite samples, and the empirical simulation probabilities have been reported with a precision appropriate for the number of replications. To estimate supported equations, long-run multipliers, and restricted error-correction models were estimated. An error-correction term was only considered to be an economically plausible and statistically supported error correction parameter if it was negative. This design builds on recent single-country applications of the ARDL bounds framework to questions about renewable energy in the region (Ghazouani, 2025; Fikri et al., 2025; Raihan et al., 2025) and includes exact small-sample critical values, structural-break screening, and multiplicity control. Throughout the paper, p-values less than 0.001 are not reported at machine precision but rather as "<0.001", because extreme tail probabilities are not meaningful at this sample size.

2.5. Inference, diagnostics, and robustness

The model-based standard errors were augmented with Newey–West heteroskedasticity- and autocorrelation-consistent inference (Newey & West, 1987). Diagnostics consisted of Breusch–Godfrey serial-correlation test, Breusch–Pagan heteroskedasticity test, ARCH-LM, Jarque–Bera normality test, Durbin–Watson test, and Ljung–Box test, along with residual plots and influence measures. Recursive and OLS-based CUSUM tests were applied to gauge the stability of the parameters. Robustness variants looked at alternative choices of lags, a two-quarter cap on lag, omitting the oil-price control, omitting the crisis indicators, omitting the seasonal indicators, and an influential-quarter pulse. The FDI robustness suite is not treated as final and is not submitted because its supplied 'primary' specification has an extra dynamic regressor than the base specification; it must be re-run without this regressor before submission.

The stationary transformations were tested using conventional Granger tests. The interpretation of level VARs of order k + dmax in terms of temporal predictability only was estimated by Toda–Yamamoto modified Wald tests (Toda & Yamamoto, 1995). Benjamini–Hochberg adjustment was used individually for the four tests of the short run and the four tests of the long run (Benjamini & Hochberg, 1995). Analyses are performed in R; this is included in the final reproducibility package, which contains scripts, seeds, model objects, package versions, and session information.

3. Results and Discussion

3.1. Results

3.1.1. Descriptive patterns

The six study variables are presented 2013Q1–2024Q4 in a small-multiple panel format (two line charts per panel) in Figure 1, with two common shaded bands across all panels: the grey band indicating the pre-specified conflict period (roughly 2014–2018) and the beige band indicating the period of the COVID-19 crisis (roughly 2020–2021). The plotting of each panel is on its own vertical scale, as indicated in the caption. Renewable-energy investment starts at about USD 22 million, increases steadily to the mid-40s in 2018, and then slows down in 2019, contracting to around USD 40 million during the pandemic, and then picks up rapidly to its peak value just above USD 100

million at the end of the sample. Net inflows of FDI follow a similar trend and are projected to increase from 0.9% of GDP to approximately 1.5–1.6% by 2018–2019, before dropping slightly to near 1.3% during the pandemic and climbing to above 2.1% by 2024Q4. The unemployment rate follows suit, dropping from 16.0% to approximately 15.0% by 2019, rising back up to approximately 15.5% during the pandemic, and then returning to a low of approximately 14.2%. Apart from a brief drop down to approximately 43% during 2020-2021 due to the pandemic, the fossil-fuel share of electricity generation declines almost monotonically from 99.3% to 97.7%, and the non-oil share of GDP climbs from roughly 41.8% to 45.1%. In contrast, erratic and trendless, the oil price has dropped from about USD 90 to near USD 40 in the 2014-2016 price crash, surged above USD 100 in 2017-2018, dipped to about USD 40 at the beginning of the pandemic, and then fluctuated between roughly USD 60 and USD 100.

The same 48 quarterly observations are summarised in Table 2. The log of renewable investment (LREINV) has a mean of 3.784 (SD 0.400) and spans 3.100–4.647, equivalent to roughly USD 22–104 million in levels; FDI averages 1.464% of GDP (SD 0.303) between 0.900 and 2.144; unemployment averages 15.176% (SD 0.501) between 14.189 and 16.000; the fossil share averages 98.597% (SD 0.450) within a narrow 97.694–99.318 band; the non-oil GDP share averages 43.242% (SD 0.877) between 41.765 and 45.106; and the log oil price averages 4.293 (SD 0.260), i.e. approximately USD 40–104 in levels. As can be seen in the time-series panel, the coefficients of variation confirm that FDI (0.207) and the log renewable investment (0.0106) are the most spread out, relative to their means, while the fossil share is by far the least spread out (0.005), consistent with a near-total fossil dependency with a slowly declining trend, and the remaining variables fall in between: unemployment (0.033), non-oil share (0.020) and log oil price (0.060). The mean and median are close (e.g., 3.784 and 3.781 for LREINV, 15.176 and 15.199 for unemployment) for every series, suggesting distributions with a similar shape (and no obvious dominant outlier quarters).

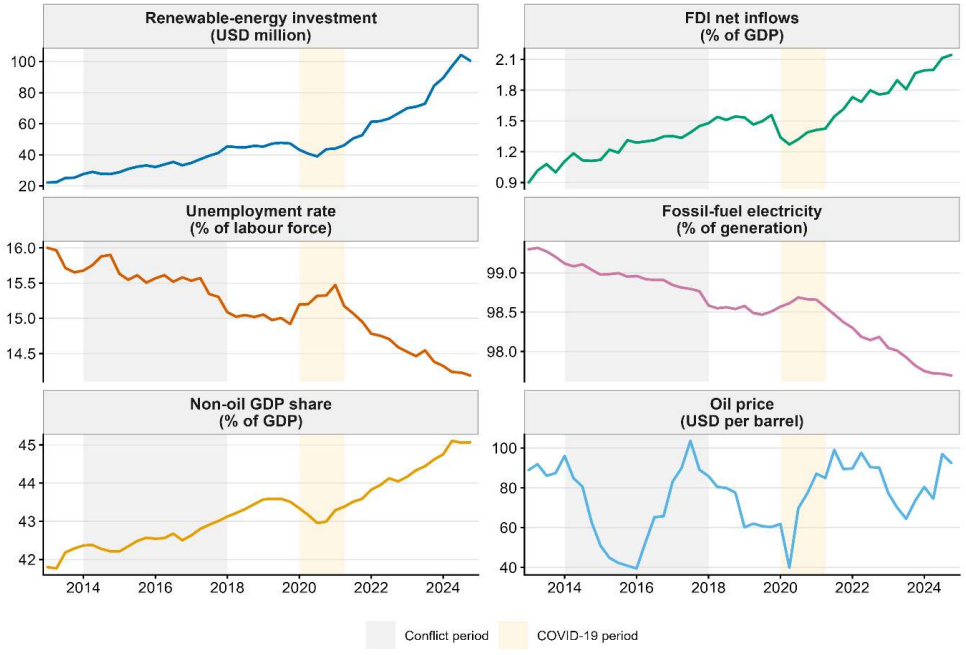


Figure 1. Quarterly trajectories of the study variables, Source: Author's visualization of the study data using R.

Table 2. Descriptive statistics, 2013Q1–2024Q4

Variable	n	Mean	SD	Min	Median	Max	CV
LREINV	48	3.784	0.400	3.100	3.781	4.647	0.106
FDI	48	1.464	0.303	0.900	1.419	2.144	0.207
UNEMP	48	15.176	0.501	14.189	15.199	16.000	0.033
FOSSIL	48	98.597	0.450	97.694	98.599	99.318	0.005
NONOIL	48	43.242	0.877	41.765	43.191	45.106	0.020
LOILP	48	4.293	0.260	3.676	4.384	4.641	0.060

Source: Author's calculations based on 48 quarterly observations using R.

The correlation matrix of the first differences of the quarterly data for the six variables as a lower triangular heat map on a red–white–blue scale (blue for negative correlation and red for positive correlation) with a diagonal of 1.00 and significant values marked with asterisks at the 10, 5, and 1% level. Changes in log renewable investment are significantly and positively related to changes in FDI (0.53***) and in the non-oil GDP share (0.65***) and significantly and negatively related to changes in unemployment (−0.59***) and in the fossil share (−0.56***) at the 1% level. The other off-diagonal cells support this pattern: the change in FDI is negatively correlated with the change in unemployment (−0.42***), and positively with the change in non-oil share (0.30**); the change in unemployment is positively correlated with the change in fossil share (0.51***) and negatively with the change in non-oil share (−0.42***); and the fossil share is negatively correlated with the non-oil share (−0.45***), with the correlation between the changes of FDI and fossil being −0.22, which is statistically indistinguishable from zero. Strikingly, the log oil price changes show almost no co-movement with the other first differences, none of which are significant (coefficients of 0.17, 0.17, 0.13, 0.06, and −0.05), indicating that short-run oil-price movements do not co-move with the domestic transition variables in Figure 2.

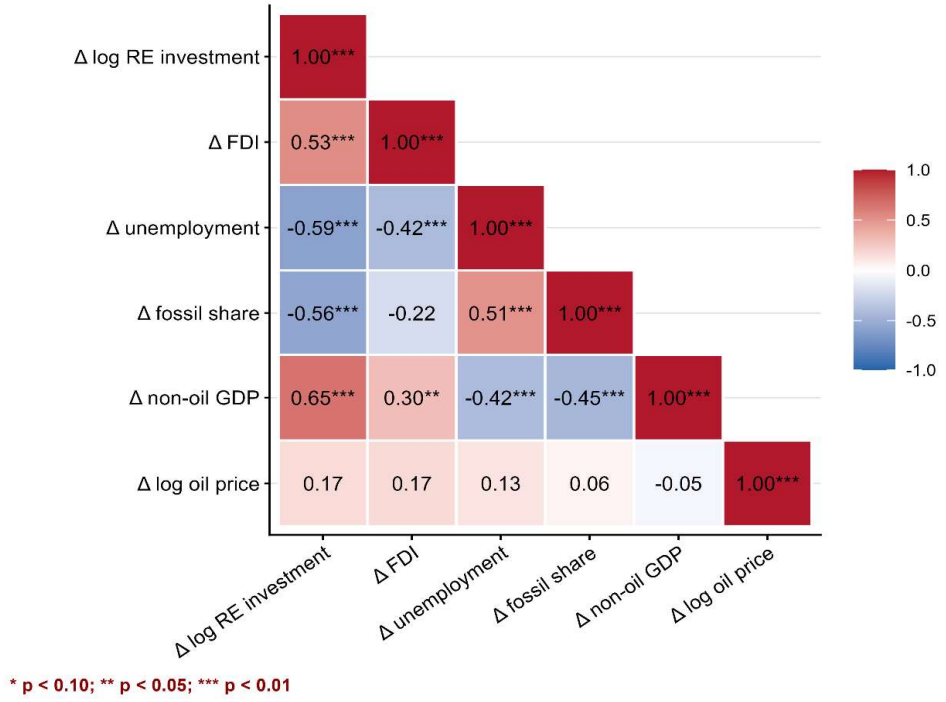


Figure 2. Correlations among first differences, Source: Author's correlation analysis using R.

3.1.2. Integration and structural breaks

This blanket classification is supported by the Zivot–Andrews single-break test. The break date has been estimated as 2019Q4 (the night before the beginning of the pandemic window) for five of the six series in comparison with 2016Q1 (the low point of the 2014–2016 price collapse) for the log oil price LREINV, FDI, UNEMP, and NONOIL. With the exception of FOSSIL (break at 2019Q4) and LOILP (break at 2016Q1), the intercept and trend break can be rejected for all other series, implying

that these series should be considered more break-stationary than difference-stationary. The I(1) label, therefore, inflates the persistence of at least some of the series and is used with a margin of caution; that is, it is not intended as a definitive label in Table 3.

The Bai–Perron multiple-break test offers an alternative view: It identifies the presence of two breaks in each of the five domestic variables, and none in log oil price. The first set of breaks is grouped between 2015Q3 (FDI) and 2017Q2 (UNEMP, FOSSIL, NONOIL), with LREINV breaking at 2017Q1. which falls within or around the conflict period and oil price crash; the second set is grouped tightly between 2021Q4 (LREINV, FDI, UNEMP) and 2022Q1–2022Q2 (FOSSIL, NONOIL), which falls within or immediately after the recovery period after the pandemic and the global energy-price shock of 2022. These dates are also in line with the regime shifts that can be seen in the quarterly panel and the shaded crisis windows, and suggest that the pandemic and its aftermath had a significant impact on the mean path of all domestic variables. There are no breaks in LOILP, and it is observed to be an erratic external series with its mean changing several times, but not significantly enough to be considered breaks under the test.

Table 3. Integration decisions and break evidence

Variable	Preferred level spec.	Level evidence	First difference	Classification	Z–A break / decision	Bai–Perron breaks
LREINV	Trend	Non-stationary	Stationary	I(1)	2019Q4 / reject unit root	2017Q1; 2021Q4
FDI	Trend	Non-stationary	Stationary	I(1)	2019Q4 / reject unit root	2015Q3; 2021Q4
UNEMP	Trend	Mixed	Stationary	I(1)	2019Q4 / reject unit root	2017Q2; 2021Q4
FOSSIL	Trend	Non-stationary	Stationary	I(1)	2019Q4 / fail to reject	2017Q2; 2022Q1
NONOIL	Trend	Mixed	Stationary	I(1)	2019Q4 / reject unit root	2017Q2; 2022Q2
LOILP	Intercept	Mixed	Stationary	I(1)	2016Q1 / fail to reject	—

Source: Author's calculations based on the ADF, PP, KPSS, Zivot–Andrews, and Bai–Perron tests performed in R.

3.1.3. Bounds tests and equilibrium adjustment

The parsimonious model with ARDL (1,0,0) is selected by the BIC for all outcomes with 41 degrees of freedom remaining. The Wald F statistics for both equations, 27.47 (FDI) and 22.55 (UNEMP), are well above the simulated upper bound for the 5% I(1) level (5.19–5.26; $p < 0.001$), and so fail to support the null hypothesis of no level relationship. The strong level of evidence for FDI and the weakest, still significant, level of evidence for FOSSIL suggest that the null hypothesis of no level relationship is rejected quite easily. The 11.63 (FOSSIL) and 19.13 (NONOIL) Wald F statistics are also strong enough to reject the simulated 5% I(1) upper bound (5.19–5.26; $p < 0.001$), with the former being the strongest test of the others. These complementary t-statistics (- −8.75 to −5.54; $p < 0.001$) provide further evidence of a non-degenerate error-correction mechanism. Therefore, all four equations do meet the criteria for a sound level relationship, and long-run and error-correction interpretations are preserved in Table 4.

Table 4. Selected ARDL models and exact bounds-test results

Outcome	Order	Residual df	F statistic	Exact 5% I(1) bound	F p-value	t statistic	t p-value	Decision
FDI	1,0,0	41	27.470	5.185	<0.001	−8.751	<0.001	Valid level relationship
UNEMP	1,0,0	41	22.552	5.235	<0.001	−8.158	<0.001	Valid level relationship
FOSSIL	1,0,0	41	11.633	5.255	<0.001	−5.535	<0.001	Valid level relationship
NONOIL	1,0,0	41	19.129	5.190	<0.001	−7.334	<0.001	Valid level relationship

Source: Author's ARDL estimates using R.

3.1.4. Short-run and long-run estimates

All focal estimates had the hypothesized sign. In the long run, a 1% rise in investment led to an increase of +0.00745 percentage points of FDI, a decrease of −0.0110 points of unemployment, a decrease of −0.0111 points of fossil dependence, and an increase of +0.0208 points of non-oil GDP. Conversely, a doubling of investment (Ln 2 = 0.693) was related to about +0.52, −0.76, −0.77, and +1.44 percentage points, respectively. The error correction coefficients were negative and statistically significant and fell between the conventional range of (−1, 0), indicating that the disequilibria were corrected by 53.9%–91.4% within one quarter. The significance of each focal short-run coefficient in Table 5 and Figures 3 and 4 was maintained using Newey–West inference. The term for the oil price was statistically significant only in the unemployment equation under conventional inference (β = 0.135, p = 0.020), and was marginally significant under HAC inference (p = 0.052).

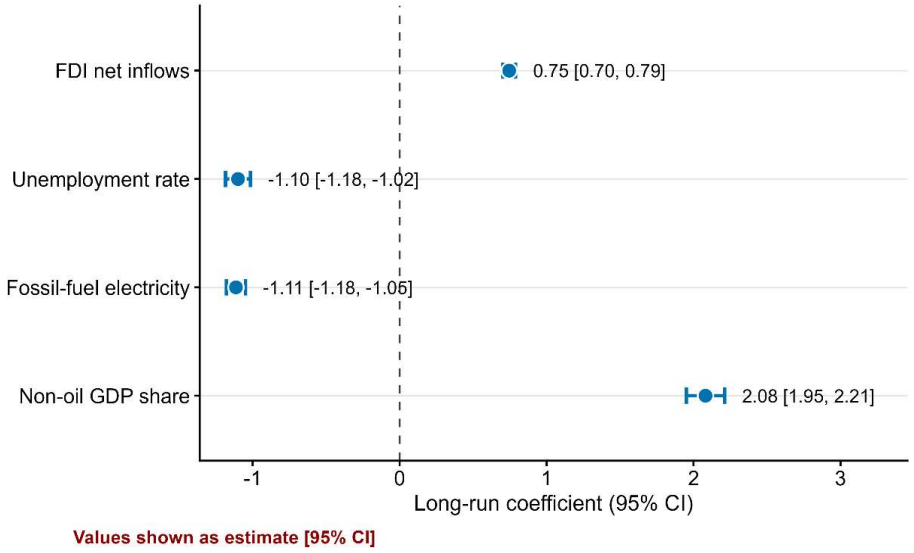


Figure 3. Estimated long-run renewable-investment coefficients, Source: Author's ARDL estimates using R.

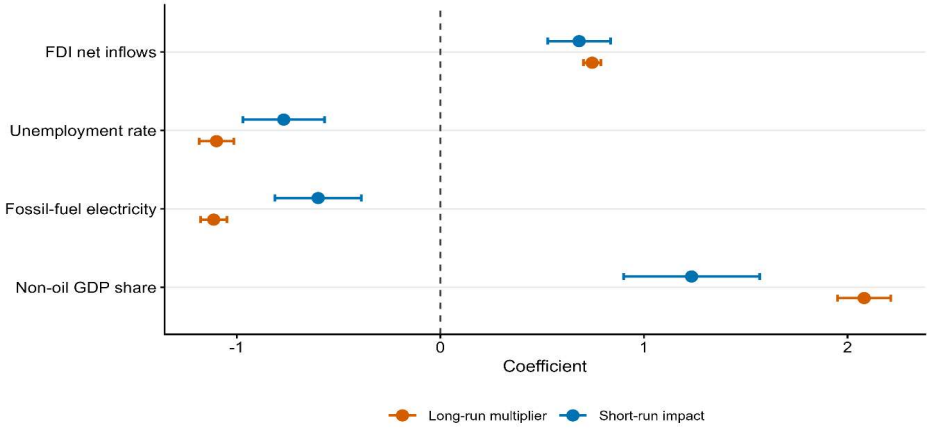


Figure 4. Short-run and long-run renewable-investment coefficients, Source: Author's ARDL–ECM estimates using R.

3.1.5. Diagnostics, stability, predictability, and robustness

There was no evidence of residual serial correlation, ARCH effects, or non-normality. The Breusch–Pagan test confirms the parallel HAC analysis, with unemployment being the only case where the test shows that the assumption of homoskedasticity is rejected (p = 0.023). Both recursive

and OLS-based CUSUM tests failed to reject parameter stability. The predictive content tests in Table 6 and Figure 5 revealed close to significant predictive content for investment to FDI (p = 0.002) and marginal evidence for the non-oil share (p = 0.095) using conventional tests. The results of the Toda–Yamamoto tests confirmed that investment-to-FDI and investment-to-NONOIL predictability were present, whereas the fossil pair was only marginally present in the forward direction and significantly present in the reverse direction. No direction was advocated for the unemployment issue. The supported directions are summarised in Figure 5.

Table 5. Focal renewable-investment estimates and error-correction coefficients

Outcome	Short-run β (SE)	95% CI	BH-adj. p	Long-run β (SE)	95% CI	BH-adj. p	ECT (SE)	Adj./quarter
FDI	0.682 (0.079)	0.527, 0.836	<0.001	0.745 (0.022)	0.702, 0.789	<0.001	−0.914 (0.098)	91.4%
UNEMP	−0.770 (0.102)	−0.970, −0.569	<0.001	−1.100 (0.043)	−1.185, −1.015	<0.001	−0.700 (0.083)	70.0%
FOSSIL	−0.600 (0.108)	−0.812, −0.389	<0.001	−1.114 (0.033)	−1.179, −1.049	<0.001	−0.539 (0.089)	53.9%
NONOIL	1.234 (0.170)	0.900, 1.568	<0.001	2.082 (0.066)	1.951, 2.212	<0.001	−0.593 (0.076)	59.3%

Source: Author's ARDL–ECM estimates using R.

Table 6. Diagnostic and temporal-predictability summary

Outcome	BG LM p	BP p	ARCH p	JB p	Rec. CUSUM p	TY: inv. → outcome	TY: outcome → inv.
FDI	0.412	0.304	0.150	0.289	0.868	χ^2 = 9.621, p = 0.002	p = 0.908
UNEMP	0.509	0.023	0.754	0.902	0.467	p = 0.166	p = 0.942
FOSSIL	0.659	0.284	0.648	0.683	0.524	χ^2 = 3.811, p = 0.051	χ^2 = 3.936, p = 0.047
NONOIL	0.672	0.155	0.497	0.565	0.262	χ^2 = 6.062, p = 0.014	p = 0.656

Source: Author's diagnostic and predictability tests using R.

The focus for UNEMP, FOSSIL, and NONOIL was the same across the robustness variants that were supplied (alternative information criteria, a two-quarter lag cap, exclusion of the oil-price control, seasonal indicators, and an influential-quarter pulse). When the unemployment bounds test was carried out without the inclusion of crisis indicators, it was inconclusive (F = 4.299, p = 0.083), meaning that the estimated labor-market equilibrium can only be achieved with the inclusion of the major shocks. The separate FDI robustness workbook was based on a different set of dynamic regressors than the primary equation, and so was not used to establish final robustness; it must be rerun using the baseline specification.

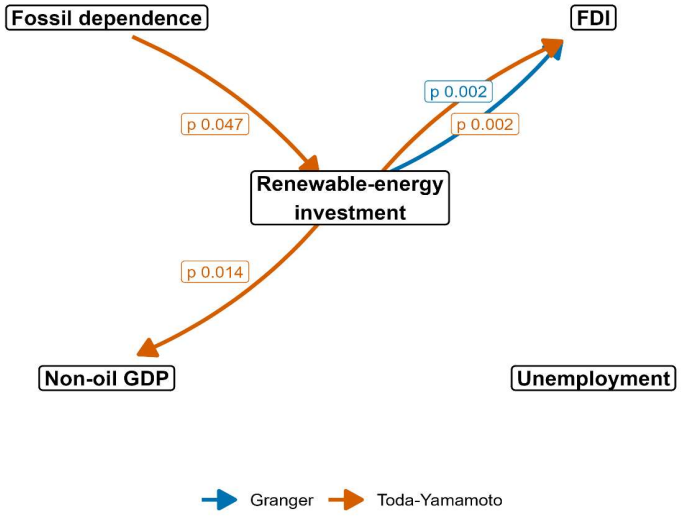


Figure 5. Network of supported temporal-predictability links, Source: Author's Toda–Yamamoto analysis using R.

3.2. Discussion

The findings show a consistent trend: increased investment in renewables is linked to increased FDI, increased non-oil share, decreased unemployment, and decreased reliance on fossil fuels. The error-correction terms are negative, with the coefficients being larger in absolute value than the contemporaneous ones, suggesting that the error terms are corrected quickly after short-run deviations. This pattern is found in renewable investments, both in their direct project expenditure, as well as in their expectations and the availability of infrastructure and complementary economic activity. However, unlike the expression of causality, the accuracy of the estimates (particularly in the small sample of 48 observations) does not make them causal. The observed relationships might still be due to shared trends, endogenous timing of projects, and feedback from the electricity system.

The positive relationship between FDI and the output level is consistent with the emerging economy evidence of Goh et al. (2025) for certain parts of the ASEAN-4 and the ARDL evidence of Raihan et al. (2025) for Egypt, where renewable energy and FDI both aids long-run output. Not directly comparable with the present magnitude, as the focal regressor is an investment flow in logarithms, not the renewable share of energy use. A plausible explanation is that visible renewable projects indicate improvements in the commitment of the country's infrastructure, which broadens the range of investable activities – a process that is relevant for Iraq, where the hydrocarbons sector has historically captured the attention of investors, while the outdated grid has prevented them from investing in electricity. A plausible explanation is that visible renewables projects signal improvements in the country's infrastructure commitment and thus widen the range of investable projects – a process that is relevant in Iraq, where the hydrocarbons sector has traditionally been the most attractive industry to invest in, while the electricity sector has proven unappealing due to the old electricity infrastructure. However, other factors, such as security, contract enforcement, the exchange rate, and the hydrocarbon cycle, all influence foreign investment in Iraq, and the aggregate specification fails to isolate these mechanisms.

The non-oil result is the largest economically, at 1.44 percentage points of increase in the share of non-oil GDP for a doubling of the investment in the quarter. This follows the policy logic of energy availability being able to ease an existing binding constraint on manufacturing and services, and on cross-country evidence, which suggests that diversification outcomes in oil-dependent economies are more dependent on structural and institutional conditions than any single sectoral policy (Karanfil & Omgba, 2023). IMF (2025) highlights the investment and financing requirements for Iraq's non-oil performance, while IRENA (2025) sees the energy transition as a chance to improve energy security and drive overall activity. However, this estimate should not be interpreted as an indication that investment in renewables provides diversification. The combined impact of fiscal expenditure, oil price fluctuations, and reconstruction can have an impact on project finance as well as non-oil output.

The negative unemployment coefficient should be read in the context of a diverse body of literature. Labor-market reactions to renewables are context and regime-dependent at the country level, as shown by Apergis and Salim (2015) and Rahman et al. (2024) for South Asia. In a large sample of US states, Saboori et al. (2022) report pro-unemployment impacts, which align with displacement and adjustment costs effects found in traditional energy industry, and Pham et al. (2026) report unemployment reducing impacts of renewable production are positive in middle income Asian economies but negative in other countries, while Naqvi et al. (2022) report that renewable production in Europe has asymmetric unemployment reducing impacts. Iraq is different because its modern renewable sector starts from a low base, and the initial investment could be focused on constructing, installing, logistics, and supporting services. This context suggests a negative association, but the result is also the most shock-sensitive: taking conflict and pandemic indicators away results in clear bounds support. Employment should not then be the principal causal argument for policy when there is no sectoral employment data and/or less identification.

The fossil-share coefficient is an indicator of progressive, not transformative, substitution. It aligns with Iraq's current situation, as fossil fuels are the dominant source for electricity production, renewables development has been significantly lower than resource potential, and renewable energy use has been significantly higher in other regions with higher institutions and financing conditions (Al-Kayiem & Mohammad, 2019; Abed et al., 2025; Al-Rikabi et al., 2025; IRENA, 2025). The Toda–Yamamoto results also show that there is a feedback effect from fossil dependence to investment.

These investment decisions are clearly influenced by the state of the generation mix and grid, and then, help to shape that mix and grid. This is a bidirectionality that is substantively plausible and will not allow for a one-way narrative.

The estimates do not suggest that the investment in renewable energy is to be considered as a policy instrument in its own right, but rather as part of a wider renewable energy diversification and electricity reform package. Consider grid reinforcing, visible procurement, predictable power-purchase agreements, and capability development in the local area in tandem with project pipelines. Since the unemployment relation is based on the control of crisis, employment goals should be accompanied by monitoring at the project level of employment duration, employment content, and domestic value added. Lastly, the feedback relationship between investment and the generation mix indicates that capacity auctions and financing should be considered in conjunction with the need in the system, and not in isolation from grid conditions. The implications are only tentative, since they are based on estimates of historical associations, but not intervention effects.

The conclusions were limited by five restrictions. First, the 48-quarter sample limits model complexity and the power of diagnostic tests. Secondly, neither ARDL nor temporal-predictability procedures can overcome the issue of endogeneity or simultaneity. Third, the role of aggregate renewable investment blends together technology, financing, and project-stage heterogeneity. Fourth, macroeconomic indicators affected by conflict can be revised and changes in measurement, so documentation of the source and frequency of construction is essential, and an unmet requirement of this manuscript. Fifth, no specification of an identical FDI robustness suite is provided, and it needs to be rerun for submission. These restrictions help encourage careful, association-oriented language and encourage future applications of project-level data, policy shocks identified from other countries, etc.

4. Conclusions

Based on quarterly data for Iraq in 2013Q1–2024Q4, this paper identifies statistically significant long-run relationships between renewable-energy investment and four macroeconomic outcomes. The higher the investment, the greater the FDI inflows, the size of non-oil GDP, the lower the unemployment, and the lower the reliance on fossil-fuel electricity. Adjustments to the expected equilibria are swift, and evidence for temporal predictability is strongest in the cases of FDI and the non-oil economy, with feedback in the electricity mix. The goal of the contribution is to record the nature, the magnitude, and the dynamic character of these linkages in the specific context of the Iraqi country, and to link these linkages with the recent international evidence on renewable finance, labor markets, and diversification in oil-dependent economies. Provenance information is required for all series to be submitted, and an FDI robustness analysis rerun is required to be consistent with the specification for final submission. With those requirements, the results offer a reliable empirical basis for a broader analysis of the topic of renewable finance within the broader energy and diversification transition in Iraq. The investment disaggregated by technology and project stage, and the analyses of the impact of policy shocks that can be identified from the outside, should be complemented with comparisons between Iraq and other countries that have expanded and started to diversify their investment portfolios in different ways. (Karanfil & Omgba, 2023; Abed et al., 2025).

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