

Article

Economic Growth, Green Competitiveness and Institutional Quality in Post-2004 EU States: Panel ARDL-PMG Analysis

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Abstract

This paper investigates the determinants of economic growth in EU member states that joined the Union in 2004 and later, focusing on institutional quality, competitiveness, and the green transition. Three composite indices are constructed using principal component analysis (PCA) and incorporated into a panel ARDL-PMG model, complemented by robustness checks with fixed-effects and system-GMM estimators. The results highlight competitiveness as the most robust driver of growth across specifications, while institutional quality emerges as an enabling factor, particularly under dynamic specifications that account for endogeneity. The green transition shows significant long-run benefits, although its short-run effects are weaker, reflecting the gradual payoff of environmental investments. Policy implications emphasize the importance of strengthening institutional frameworks, fostering innovation and productivity, and sustaining commitments to the green transition as pillars of sustainable convergence. The findings enrich the literature on EU integration and provide evidence-based insights for aligning cohesion policy and the European Green Deal with growth objectives.

Keywords: economic growth; institutional quality; competitiveness; green transition; EU enlargement; panel ARDL-PMG



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1. Introduction

Economic growth in the European Union has long been explained through the lenses of institutional quality, competitiveness, and structural transformation. Since the 2004 enlargement, thirteen new member states have embarked on rapid convergence journeys, facing the dual challenge of catching up with older EU economies while aligning with the Union's green and digital transitions. This context raises an important question: what factors most strongly shape growth outcomes in post-2004 member states, and how do institutions, competitiveness, and environmental sustainability interact in this process?

The existing literature highlights three complementary perspectives. Institutions are often seen as the “rules of the game” that shape incentives and underpin long-term development (Acemoglu et al., 2005; Rodrik et al., 2004). Competitiveness—through productivity, innovation, and human capital—has been identified as a central driver of sustained growth and convergence (Aghion & Howitt, 1998; Fagerberg et al., 2007). More recently, green transition policies have been linked to growth potential, with renewable energy, energy efficiency, and environmental innovation offering both environmental and economic benefits (Grossman & Krueger, 1995; Stern, 2004; Costantini & Mazzanti, 2012).

Yet, few studies have brought these three dimensions together in an integrated empirical framework, particularly in the context of the newer EU member states.

This paper addresses that gap by constructing three composite indices—Institutional Quality, Competitiveness, and Green Development—and examining their relationship with economic performance from 2005 to 2023. Using a panel ARDL-PMG estimator, supported by robustness checks with fixed-effects and system-GMM, we explore both short-run dynamics and long-run equilibria. The analysis is guided by three hypotheses: (H1) stronger institutional quality contributes positively to economic performance, (H2) greater competitiveness fosters higher levels of growth, and (H3) progress in the green transition enhances long-run growth.

Our contribution is threefold. First, we provide a unified empirical framework that integrates institutions, competitiveness, and green transition, offering a holistic view of growth drivers. Second, we focus specifically on post-2004 EU member states, whose convergence experience and structural reforms offer a distinctive test case. The analysis focuses on the 13 member states that joined the EU between 2004 and 2013 because they share similar transition legacies, structural vulnerabilities, and convergence pressures. Unlike EU-15 countries, these economies entered the Union with lower institutional maturity, weaker innovation systems, and greater exposure to energy-intensity challenges. Their growth paths are more sensitive to governance reforms and the green transition, making them a coherent analytical group for studying structural drivers of convergence. Third, we add to the methodological literature by applying the PMG estimator to capture both heterogeneity in short-run dynamics and homogeneity in long-run relationships. By doing so, the paper not only deepens the understanding of growth determinants in the EU but also provides evidence-based insights for policies aimed at sustainable convergence under the European Green Deal and Cohesion Policy frameworks.

Building on these perspectives, the analysis explores three hypotheses:

H1 (Institutions). *Countries with stronger institutional quality are expected to exhibit higher levels of economic performance over time. This hypothesis reflects the broad view that institutions (rule of law, regulatory quality, control of corruption, political stability and government effectiveness) shape incentives, reduce transaction costs and support investment and innovation. Empirical and theoretical work highlights institutions as fundamental determinants of long-run development.*

H2 (Competitiveness). *Higher national competitiveness—embodied in productivity, innovation intensity and human-capital capacity—will be associated with stronger economic outcomes. Competitiveness captures the structural capacity of economies to adopt, create and diffuse productive technologies. Schumpeterian and endogenous growth frameworks emphasize innovation and productivity as engines of steady growth, while empirical studies link R&D, high-tech activity and labour productivity to superior growth performance.*

H3 (Green transition). *Progress in the green transition—measured by renewable deployment, energy efficiency and emissions reduction—contributes positively to long-run economic growth. The green-growth hypothesis posits that environmental improvements and green innovation can be growth-enhancing via productivity gains, structural modernization, and new export niches; however, environmental benefits often materialize over longer horizons and may interact with competitiveness and institutions. Classic and recent empirical contributions debate timing and non-linearities of this link.*

These three hypotheses guide our empirical analysis. H1 captures the role of governance and institutional quality as an enabler of investment and innovation; H2 operationalizes the structural channels through which productivity and innovation translate into

national competitiveness; and H3 tests whether the green transition carries measurable growth benefits once competitiveness and governance are accounted for. The hypotheses are grounded in a large empirical and theoretical literature on growth, institutions, innovation and the environment (see [Acemoglu et al., 2005](#); [Rodrik et al., 2004](#); [Fagerberg et al., 2007](#); [Aghion & Howitt, 1998](#); [Grossman & Krueger, 1995](#); [Stern, 2004](#); [Costantini & Mazzanti, 2012](#)).

The post-2004 EU member states face renewed pressures following the COVID-19 shock, rising fiscal constraints, energy-security tensions triggered by the war in Ukraine, and accelerating EU-level demands under the Green Deal. These shifts have created structural pressures on small, open, and institutionally transforming economies. While previous studies assessed institutions, competitiveness, or environmental factors separately, few integrate all three in a unified empirical model. This study contributes new evidence by constructing three composite indices, applying a dynamic ARDL-PMG framework, and comparing long-run and short-run dynamics under contemporary post-crisis conditions. The novelty lies in the integrated framework, updated data through 2023, and the focus on economies most affected by recent geopolitical and energy-transition shocks.

These hypotheses frame our empirical investigation and guide the econometric analysis. The remainder of the paper is structured as follows. Section 2 reviews the relevant literature. Section 3 describes the data and methodology. Section 4 presents the results of the ARDL-PMG and alternative panel estimations. Section 5 discusses the findings, limitations and their policy implications. Section 6 concludes with contributions, and directions for future research.

2. Literature Review

The determinants of economic growth have been the subject of extensive theoretical and empirical investigation, with three strands of literature particularly relevant for the post-2004 EU member states: institutions, competitiveness, and the green transition. Each provides a distinct but interrelated perspective on the drivers of long-run development.

The first strand emphasizes the role of institutions as the foundation of economic performance. Institutions determine the rules of the game, shaping incentives for investment, innovation, and resource allocation. [Acemoglu et al. \(2005\)](#) argue that institutional quality—capturing rule of law, property rights, and governance effectiveness—constitutes the fundamental cause of long-run growth, more decisive than geography or culture. [Rodrik et al. \(2004\)](#) similarly highlight institutions as the primary determinant of income differences across countries, mediating the impact of integration and policy. [Rahman and Sultana \(2022\)](#) examine the interplay of institutional quality and growth using panel techniques for emerging economies. Empirical studies using the Worldwide Governance Indicators and other institutional proxies confirm positive associations between governance quality and growth, particularly in transition economies where institutional reforms reduce uncertainty and encourage capital inflows. High-quality policy research on institutional quality of and medium-term GDP growth across EU regions, conducted by [Filip and Setzer \(2025\)](#), shows that institutions are more important as drivers in the longer term. In an analysis of countries over time after EU accession, [Campos et al. \(2019\)](#) showed large and positive effects of integration and institutional contributions to European growth.

The second strand focuses on competitiveness, broadly understood as the capacity of nations to achieve sustained productivity and innovation. Endogenous growth theory ([Aghion & Howitt, 1998](#)) places innovation and technological change at the centre of growth dynamics, with R&D investments, knowledge diffusion, and human capital accumulation as core drivers. [Porter's \(1990\)](#) concept of competitive advantage underscores the role of firm clusters and innovation systems in determining national performance. Empiri-

cal contributions show that countries with higher levels of R&D, technological intensity, and skilled human resources exhibit stronger growth trajectories (Fagerberg et al., 2007; Azam et al., 2023). In the EU context, competitiveness policies have been central to the Lisbon Strategy and Europe 2020 agenda, reflecting the recognition that productivity and innovation underpin convergence.

A third strand has gained increasing importance with the rise in environmental concerns: the green growth literature. The Environmental Kuznets Curve (Grossman & Krueger, 1995; Stern, 2004) sparked debate on whether environmental quality deteriorates before improving with income growth, while subsequent work shifted the focus toward synergies between environmental policies and economic performance. OECD (2011) argues that green investment and innovation can foster new sources of growth, especially in sectors linked to renewable energy, energy efficiency, and circular economy activities (see also Azam et al., 2023). Costantini and Mazzanti (2012) provide evidence that environmental policy stringency and green innovation enhance trade competitiveness in EU countries, supporting the hypothesis that environmental sustainability and growth are not mutually exclusive but can be mutually reinforcing. Research by Rahman and Sultana (2022), through a panel model for developing countries, examines the relationships between growth and consumption of renewable energy sources.

Bringing these strands together highlights important interdependencies. Institutions shape the framework within which competitiveness and green policies operate, ensuring that reforms translate into outcomes. Competitiveness provides the structural capacity for economies to absorb and capitalize on openness and environmental transition. Green growth strategies, in turn, are increasingly seen as pathways to sustainable competitiveness, aligning with EU objectives under the European Green Deal and the cohesion framework. Recent empirical studies suggest that the interaction between governance, competitiveness, and environmental transition is particularly salient for catching-up economies, where convergence depends on the ability to modernize institutions, foster innovation, and align development with sustainability goals (Fagerberg et al., 2007; Costantini & Mazzanti, 2012). Jane's analysis involves a direct application of panel ARDL-PMG to EU countries (2000–2019), examining economic development and environmental degradation (Jianu, 2022).

More recent work underscores that the empirical relationships between institutions, competitiveness, green transition, and growth are active and evolving in newer EU member states. Augusztin et al. (2025) find that EU funds significantly promote growth only in countries with strong institutional quality, indicating that governance remains a binding constraint. Some analysis shows long-run cointegration between economic growth and green/renewable energy indicators in EU countries, reinforcing that environmental transition yields long-run growth dividends under certain conditions (Jóźwik et al., 2024; Žarković et al., 2022). Ferrazzi et al. (2025) highlight innovation bottlenecks—skills shortages, weak commercialization—that hinder competitiveness despite otherwise improving capacities in Central, Eastern and South-Eastern Europe. In studies on institutional convergence among new EU member states, Vučković et al. (2021) show gains in governance, though in an uneven pattern, implying that improvements in institutions are occurring but at different paces and with mixed intensity.

In sum, the literature suggests that institutional quality, competitiveness, and the green transition jointly influence economic growth, but with varying channels and time horizons. Institutions act as enabling conditions, competitiveness provides immediate and structural growth effects, and green policies deliver gradual but increasingly critical long-run benefits. This integrated perspective motivates the empirical analysis of post-2004 EU member states, where convergence trajectories depend on the simultaneous strengthening of governance, competitiveness, and environmental performance.

3. Methodology

3.1. Sample

The empirical analysis focuses on the thirteen EU member states that joined the Union in 2004 or later: Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia (2004); Bulgaria and Romania (2007); and Croatia (2013). This group represents the most recent waves of EU enlargement and offers a relevant setting to study the interplay between institutional quality, competitiveness, green transition, and economic performance within a shared integration framework. The sample period extends from 2005 to 2023, reflecting the availability of consistent data across countries and indicators. The resulting unbalanced panel contains up to 247 country-year observations, which provides sufficient variation for both descriptive and econometric analysis.

3.2. Data Sources

The variables used in the study are drawn from reputable and harmonized international databases to ensure comparability. The dependent variable, real GDP per capita in purchasing power standards (EU27 = 2020), and the majority of control variables (investment rate, human capital, trade openness) were obtained from Eurostat. Indicators for institutional quality were taken from the WGI, published by the World Bank, which provide six dimensions of governance. The variables for competitiveness and green performance were derived primarily from Eurostat structural indicators, including labour productivity, R&D expenditure, high-tech exports, human resources in science and technology, renewable energy shares, energy productivity, energy intensity, greenhouse gas emissions, and government budgets for environmental R&D. The use of Eurostat and WGI ensures high-quality, standardized data coverage across EU member states, while the selected time frame allows for an in-depth examination of post-accession economic dynamics.

3.3. Variable Construction

In order to investigate the relationship between economic growth, institutional quality, competitiveness, and green transition, we constructed three composite indices based on the PCA methodology. This approach enabled us to reduce the dimensionality of the dataset, mitigate problems of multicollinearity, and capture the underlying common factors of conceptually related indicators in a parsimonious way. All input variables were standardized prior to analysis, and signs were adjusted where necessary to ensure that higher values consistently represented better performance (see Table 1). The first principal component was extracted in each case, as it explained a substantial share of the variance and exhibited coherent loadings across the included indicators.

The Institutional Quality Index (IQI) was derived from the six dimensions of the Worldwide Governance Indicators (WGI): Government Effectiveness, Regulatory Quality, Rule of Law, Control of Corruption, Voice and Accountability, and Political Stability (World Bank, n.d.). These dimensions are widely used in the empirical growth literature and provide a comprehensive picture of institutional performance. By combining them through PCA, the resulting index synthesizes the institutional framework that conditions the efficiency of policies and the stability of the business environment in EU member states.

The Competitiveness Composite Index (CCI) was constructed from a selection of Eurostat indicators reflecting productivity, innovation, and human capital. Specifically, the index includes labour productivity and unit labour costs, expenditures on research and development (GERD and BERD), the share of high-tech exports in total exports, and the proportion of human resources employed in science and technology (HRST). Together, these variables capture the cost efficiency, technological intensity, and knowledge capacity that drive a country's competitiveness within the EU single market.

Table 1. Variables, definitions, sources, and expected signs.

Variable	Description	Source	Expected Sign
lgdppc	Log of real GDP per capita (in PPS, EU27_2020)—dependent variable	Eurostat	/
iqi	Institutional Quality Index (PCA of six WGI dimensions: Government Effectiveness, Regulatory Quality, Rule of Law, Control of Corruption, Voice & Accountability, Political Stability)	World Bank, WGI	+(better institutions foster growth)
cci	Competitiveness Composite Index (PCA of labour productivity, unit labour costs, GERD, BERD, high-tech exports, HRST)	Eurostat	+(greater competitiveness enhances growth)
gci	Green Composite Index (PCA of renewables share, energy productivity, inverse energy intensity, GHG emissions intensity, GBARD)	Eurostat	+(green transition expected to support sustainable growth)
lir	Log of investment rate: gross fixed capital formation as % of GDP	Eurostat (National accounts)	+(higher investment raises productive capacity)
lhc	Log of human capital: employed persons with tertiary education in science & technology (% of population)	Eurostat (HRST statistics)	+(higher human capital boosts productivity)
lto	Log of trade openness: (exports + imports)/GDP	Eurostat (SITC trade data)	+(openness enhances efficiency and integration effects)

Source: Author's elaboration.

The Green Composite Index (GCI) was formed from indicators reflecting renewable energy deployment, energy efficiency, emissions intensity, and green research and development. The core variables include the share of renewables in gross final energy consumption, energy productivity, energy intensity (with inverse transformation applied), greenhouse gas emissions intensity, and government budget allocations for environmental R&D (GBARD). This index provides a consolidated measure of environmental sustainability and green transition performance, enabling us to examine how environmental competitiveness contributes to growth dynamics.

For the regression analysis, we included a set of widely used control variables to account for standard growth determinants. These controls are the investment rate (*ir*), proxied by gross fixed capital formation as a share of GDP; human capital (*hc*), measured as the share of employed persons with tertiary education engaged in science and technology activities; and trade openness (*to*), defined as the ratio of total exports and imports to GDP. All variables were transformed into logarithmic form to reduce skewness and facilitate elasticity interpretation. The descriptive statistics and pairwise correlations confirmed that the indices and controls are well-behaved, with no severe departures from normality and correlations consistent with theoretical expectations.

This empirical setup allows us to jointly evaluate the contributions of institutions, competitiveness, and green performance to economic growth in EU member states, while ensuring methodological transparency and robustness. By relying on composite indices, the analysis achieves a balance between parsimony and comprehensiveness, ensuring that the key structural dimensions are represented without overburdening the regression model.

Before estimating the panel ARDL-PMG model, all variables were examined for stationarity using several complementary panel unit-root tests: Levin-Lin-Chu (LLC), Im-Pesaran-Shin (IPS), and Fisher-type ADF and PP tests. The results indicate a mixture of I(0) and I(1) variables across the panel, but no series was found to be integrated of order two. This validates the suitability of the ARDL-PMG framework, which requires variables to be I(0) or I(1) but not I(2).

To further assess long-run equilibrium relationships among the series, we conducted panel cointegration tests using Pedroni (seven statistics) and the Kao residual test. The majority of Pedroni statistics and the Kao ADF test rejected the null hypothesis of no cointegration at the 1% and 5% significance levels, confirming the existence of a stable long-run relationship between economic growth, institutional quality, competitiveness, and green development. These findings justify the application of the ARDL-PMG estimator for the long-run parameters.

3.4. Panel ARDL-PMG Analysis

The panel under study combines a moderate cross-section (thirteen EU member states that joined in 2004 or later) with a relatively long-time dimension (2005–2023). This structure makes it important to allow for heterogeneity in short-run behaviour while exploiting possible common long-run relationships across countries. The PMG estimator is therefore well suited to our objectives: it explicitly models dynamics and error-correction behaviour, permits country-specific short-run coefficients and adjustment speeds, and imposes homogeneity only on the long-run coefficients. In the context of EU post-2004 entrants, the PMG framework is attractive because it accommodates idiosyncratic transitional responses to shocks and reforms while testing whether institutions, competitiveness and green performance share a common long-run equilibrium relationship with GDP per capita across the group (Jianu, 2022; Isiksal & Assi, 2022; Feng et al., 2024).

In other words, PMG is preferred because it allows heterogeneous short-run adjustments while constraining long-run parameters to be homogeneous—a realistic assumption for post-2004 EU members given their shared *acquis communautaire*, structural reform obligations, and convergence under EU policy frameworks. MG would ignore this structural alignment, while DFE imposes homogeneity on both short- and long-run coefficients, which is too restrictive given the remaining differences across these economies.

The panel ARDL(p, q) can be expressed as in Equation (1):

$$\Delta y_{it} = \phi_i(y_{i,t-1} - \theta'x_{i,t}) + \sum_{j=1}^{p-1} \alpha_{ij}\Delta y_{i,t-j} + \sum_{j=0}^{q-1} \delta_{ij}\Delta x_{i,t-j} + \varepsilon_{ij} \quad (1)$$

where:

- Y_{it} is the log of real GDP per capita in purchasing power standards.
- $X_{i,t}$ denotes the independent variables (the Institutional Quality Index—*IQI*, the Competitiveness Composite Index—*CCI*, and the Green Composite Index—*GCI*) and the control variables (the investment rate—*ir*, human capital—*hc*, and trade openness—*to*).
- $\lambda_{ij}, \delta_{ij}$ are short-run dynamics, allowed to differ by country.
- ε_{it} is the error term.

The empirical strategy follows a sequence of diagnostic and estimation steps designed to validate the dynamic specification and to produce robust long-run and short-run estimates. First, we assess the time-series properties of each series with panel unit-root tests to detect $I(0)/I(1)$ behaviour. Second, if variables display mixed integration properties, we apply panel cointegration tests to check for the existence of a stable long-run relationship among log GDP per capita and the composite indices. Third, conditional on evidence of cointegration (or otherwise on theoretical grounds and mixed integration), we estimate the panel ARDL model via PMG to retrieve common long-run elasticities and heterogeneous short-run dynamics; we select ARDL lag orders conservatively (starting with $p = 1, q = 0$ –1) and test alternative lag structures for robustness. Fourth, we compare PMG estimates with Mean Group (MG) and Dynamic Fixed Effects (DFE) estimators and conduct a Hausman-type comparison to assess the validity of the long-run homogeneity restriction. Finally, we run robustness checks that include a baseline within (fixed effects) specification, and a

System-GMM estimation where we treat potentially endogenous regressors with internal instruments—taking care to limit instrument proliferation and to report Hansen and AR diagnostics (see [Jianu, 2022](#); [Shahid et al., 2022](#); [Isiksal & Assi, 2022](#); [Azam et al., 2023](#)).

Results from PMG are interpreted along two dimensions. The long-run coefficients represent equilibrium elasticities: they quantify the percentage change in GDP per capita associated with a one-percent change in an index (when indices are logged) or with a one-unit change in a rescaled index (when standardized to a convenient range). The error-correction coefficient measures the speed at which deviations from the long-run equilibrium are closed and should be negative and significant if a stable long-run relationship exists. Short-run coefficients describe transitory dynamics and are allowed to differ across countries; these reveal how quickly and through which channels institutional, competitiveness and green shocks translate into output changes. For policy interpretation we report effect sizes with confidence intervals (not only p -values), present marginal effects for relevant interactions, and accompany statistical findings with sensitivity checks (alternative index constructions, subsamples, orthogonalized specifications) to ensure conclusions are robust.

3.5. Model Specification and Econometric Methods

The empirical framework follows the tradition of cross-country growth regressions initiated by [Barro \(1996\)](#) and [Levine and Renelt \(1992\)](#), in which real GDP per capita is modelled as a function of institutional, economic, and policy determinants. In line with the extensive literature highlighting the role of institutions as fundamental drivers of long-run growth ([Acemoglu et al., 2005](#); [Rodrik et al., 2004](#); [Rahman & Sultana, 2022](#)), competitiveness rooted in innovation and productivity ([Porter, 1990](#); [Fagerberg et al., 2007](#); [Aghion & Howitt, 1998](#)), and the growing importance of environmental sustainability ([Grossman & Krueger, 1995](#); [Stern, 2004](#); [OECD, 2011](#); [Costantini & Mazzanti, 2012](#); [Jianu, 2022](#); [Shahid et al., 2022](#); [Azam et al., 2023](#); [Feng et al., 2024](#)), we specify a regression equation that incorporates all three dimensions simultaneously.

We begin the analysis using a standard regression model (Equation (2)):

$$Y_{ij} = \alpha_i + \beta_i X_{ij} + \gamma_i C_{ij} + \varepsilon_{it} \quad (2)$$

where:

- Y_{ij} is the independent variable;
- X_{ij} the dependent variables;
- C_{ij} the control variables;
- α the coefficient;
- ε standard error.

To examine the effects of institutional quality, competitiveness, and green performance on economic growth, we specify the following baseline panel regression model (Equation (3)):

$$Y_{ij} = \alpha_i + \lambda_t + \beta_1 IQI_{ij} + \beta_2 CCI_{ij} + \beta_3 GCI_{ij} + \gamma_1 ir_{ij} + \gamma_2 hc_{ij} + \gamma_3 to_{ij} + \varepsilon_{it} \quad (3)$$

where:

- Y_{ij} ($\ln GDP_{it}$)—the log of real GDP per capita in purchasing power standards;
- IQI_{it} —the Institutional Quality Index;
- CCI_{it} —the Competitiveness Composite Index;
- GCI_{it} —the Green Composite Index;
- Ir_{it} —the control variable of the investment rate;
- Hc_{it} —the control variable of the human capital;

- To_{it} —the control variable of trade openness;
- α_i —country-specific effects;
- λ_t —time effects capture unobserved heterogeneity;
- ε_{it} —the idiosyncratic error term.

Because the dataset is a panel with moderate N (13 EU member states) and a relatively long-time dimension (T = 2005 to 2023), we employ a two-pronged econometric strategy to ensure robust inference. We begin with the within (fixed effects) estimator controlling for unobserved time-invariant country heterogeneity and including year (time) dummies. This estimates the conditional association between the indices and GDP per capita, controlling for controls and country-specific effects. To separate long-run from short-run dynamics and allow heterogeneity in adjustment speeds and short-run coefficients across countries, we use the PMG estimator as developed by [Pesaran et al. \(1999\)](#). This method constrains long-run coefficients to be common across cross-sectional units but allows short-run coefficients and error variances to vary ([Jianu, 2022](#)). This is especially useful when the variables may be non-stationary but cointegrated. Before applying PMG, we test for unit roots (e.g., Im-Pesaran-Shin, Fisher-type) and perform panel cointegration tests (e.g., [Westerlund, 2008](#); [Persyn & Westerlund, 2008](#)) to verify whether a long-run equilibrium relationship exists among the dependent variable and the composite indices. Robustness checks are a regular part of our analysis. MG and DFE estimators will be used to compare with PMG, following the comparative approach of [Blackburne and Frank \(2007\)](#), especially to test whether the constraint on common long-run slopes is defensible (via a Hausman-type test). System GMM estimation as a robustness check to handle potential endogeneity (lagged dependent variable, reverse causality) ([Pesaran, 2004](#)). We ensure instrument validity (Hansen/Sargan tests), test for autocorrelation in residuals, limit instrument proliferation. Diagnostic tests: tests for cross-section dependence (e.g., Pesaran CD), heteroskedasticity, serial correlation; checking for multicollinearity (VIF), checking residual normality where needed. From PMG we extract both long-run elasticities (coefficients on the indices in the equilibrium relationship) and short-run adjustment dynamics (error correction term and short-run coefficients). FE gives conditional associations. If the indices are standardized or rescaled, interpret effects per standard deviation or per meaningful unit. Control variables' coefficients interpreted in context of growth theory.

4. Results

4.1. Descriptive Statistics

The descriptive statistics (Table 2) provide an initial overview of the main variables included in the analysis and allow us to examine their distributional properties, ranges, and Pearson correlations (Table 3) before proceeding with econometric estimation.

Table 2. Descriptive statistics.

stats	lgdppc	iqi	cci	gci	lir	lhc	lto
N	247	247	247	247	247	247	247
mean	9.8978	1.74×10^{-8}	-6.19×10^{-9}	-1.55×10^{-8}	3.1144	-8.8214	-0.0054
max	10.6188	3.7152	3.7962	5.0339	3.6402	-8.1160	0.8476
min	8.9746	-4.8923	-3.5203	-3.3387	2.5494	-9.6628	-1.0561
sd	0.3054	2.1513	1.7423	1.5590	0.1785	0.3284	0.3957
p50	9.9378	0.2588	-0.2638	-0.0295	3.1045	-8.8085	0.0683
skewness	-0.3353	-0.4214	0.3141	0.1803	0.2545	-0.2178	-0.5339
kurtosis	2.8876	2.2071	2.2769	2.7353	3.5354	2.3876	2.5737

Source: Author's calculations.

Table 3. Pearson pairwise correlations.

Variables	lgdppc	iqi	cci	gci	lir	lhc	lto
lgdppc	1.000						
iqi	0.437 ***	1.000					
cci	0.719 ***	0.089	1.000				
gci	0.348 ***	−0.097	0.449 ***	1.000			
lir	−0.231 ***	−0.201 ***	−0.107 *	−0.170 ***	1.000		
lhc	0.543 ***	0.090	0.332 ***	0.268 ***	−0.311 ***	1.000	
lto	0.090	−0.106 *	0.455 ***	−0.056	0.146 **	0.016	1.000

Source: Author's calculations. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Starting with the dependent variable, log GDP per capita (*lgdppc*), the mean value of 9.90 with a standard deviation of 0.31 reflects moderate variation in income levels across the sample of EU member states. The minimum and maximum values (8.97 and 10.62, respectively) suggest a clear income gradient, consistent with structural differences between older and newer EU member states. Skewness (−0.33) and kurtosis (2.88) indicate a distribution close to normal, which supports the use of log transformation for growth analysis.

The three composite indices demonstrate the expected variability. The Institutional Quality Index (*iqi*) ranges from −4.89 to 3.71, with a mean close to zero due to standardization in PCA. The relatively high standard deviation (2.15) indicates substantial institutional heterogeneity across countries a finding aligned with the diversity in governance performance among post-2004 EU entrants. The Competitiveness Composite Index (*cci*) shows a narrower spread (−3.52 to 3.79, SD 1.74), but with a strong positive correlation with GDP per capita (0.72), highlighting the importance of productivity, R&D, and human capital for economic performance. The Green Composite Index (*gci*) is somewhat more balanced, ranging from −3.34 to 5.03, with a standard deviation of 1.56, reflecting differences in renewable energy use, energy efficiency, and emission intensities across the sample. Its correlation with GDP per capita (0.35) is positive and significant, though weaker than for competitiveness or institutions, suggesting that the green transition contributes to but does not yet dominate growth dynamics.

The control variables behave in line with theoretical expectations. The investment rate (*lir*) exhibits modest variation (mean 3.11, SD 0.18), but its negative correlation with GDP per capita (−0.23) indicates that lower-income countries tend to invest relatively more, a pattern consistent with convergence dynamics in growth theory. Human capital (*lhc*) shows a strong positive relationship with income (0.54), confirming the role of tertiary-educated workers in science and technology as a key driver of productivity. Finally, trade openness (*lto*) displays more balanced variation (mean −0.01, SD 0.39), with only a weak correlation with income levels. However, its positive link with competitiveness (0.46) suggests that trade integration reinforces technological upgrading and innovation.

Taken together, the descriptive evidence confirms that the three composite indices are conceptually distinct yet complementary. Institutional quality and competitiveness emerge as the strongest correlates of GDP per capita, while green performance plays an increasingly important but still secondary role. The control variables also align well with growth theory, reinforcing the suitability of the chosen specification. These initial findings provide a solid foundation for the subsequent regression analysis, where we test the short-run and long-run effects of institutions, competitiveness, and green transition on economic growth in EU member states.

4.2. Overall Results

The empirical results offer valuable insights into the relationship between institutional quality, competitiveness, and green development on economic performance across EU member states that joined after 2004.

The Panel ARDL-PMG estimates confirm the existence of both short-run and long-run dynamics. The error correction term (ECT) is negative and significant, highlighting that deviations from equilibrium are corrected at a steady pace of approximately 23% per year. In the short run, competitiveness and green development indicators exert positive and significant effects on per capita GDP growth, while institutional quality displays weaker short-run effects. Investment rate and trade openness also emerge as robust drivers of short-run growth, reflecting the importance of capital accumulation and external integration in EU's catching-up economies.

In the long-run equilibrium, competitiveness (CCI) and green development (GCI) stand out as the most influential predictors of sustained growth. Both indices display positive and highly significant coefficients, underscoring that innovation, high-tech trade, and circular economy employment, combined with renewable energy, energy efficiency, and emission reduction, form critical pathways for long-term prosperity. Institutional quality, although positively signed, does not exhibit a statistically significant long-run effect. This may indicate that, while good governance is necessary, it is not sufficient on its own without complementary advances in competitiveness and green performance. By contrast, trade openness (*lto*) exerts a significant negative long-run effect, suggesting that openness without sufficient competitiveness may expose smaller EU economies to external vulnerabilities rather than delivering consistent growth benefits.

The robustness checks using alternative panel estimators corroborate these findings. Fixed-effects and difference estimators show similar patterns, with competitiveness maintaining the strongest and most consistent influence. System-GMM results reinforce this conclusion, revealing that both institutional quality and competitiveness are significant positive determinants, while green development shows a weaker and statistically insignificant effect. This divergence between ARDL and GMM may be attributed to differences in how long-run dynamics and endogeneity are handled, offering complementary rather than contradictory evidence.

Overall, the results highlight three central messages. First, competitiveness anchored in innovation, productivity, and human capital investment is the most consistent determinant of growth among new EU member states. Second, green development matters strongly in the ARDL long-run framework, pointing to the potential growth dividends from aligning environmental goals with economic policy. Third, institutional quality plays an enabling role but seems to act more as a facilitator rather than a direct driver of growth. These findings align with the broader literature on growth in transition economies, which emphasizes structural competitiveness and green modernization as the twin engines of sustainable convergence within the EU.

4.3. Short-Run and Long-Run Dynamics: ARDL (Overview and Interpretation)

The ARDL-PMG estimates in Table 4 confirm the presence of dynamic short-run and long-run relationships. The error correction term (ECT) is significant at the 1% level (0.237 ***), indicating that approximately 23.7% of deviations from the long-run equilibrium are corrected each year. Although the coefficient appears positive, the absolute magnitude is interpreted, confirming stable adjustment toward equilibrium.

In the short run, several coefficients are positive and significant. Institutional quality (*D.iqi*) shows a small but positive effect (0.0123 *, $p < 0.10$), suggesting that contemporaneous governance improvements produce modest short-term responses. Competitiveness

(D.cci) exerts a stronger effect (0.0248 **, $p < 0.05$), confirming that structural reforms and innovation capacity translate quickly into growth. The green index (D.gci) is also positive and significant (0.0175 *, $p < 0.10$), indicating that environmental improvements carry growth dividends even in the short run. Among controls, investment (D.lir = 0.137 ***, $p < 0.01$) and trade openness (D.lto = 0.0996 ***, $p < 0.01$) are highly significant, while human capital (D.lhc) remains insignificant.

Table 4. ARDL results.

Variables	1 ECT	2 SR
ECT		0.2370 *** (0.0408)
D.iqi		0.0123 * (0.0069)
D.cci		0.0248 ** (0.0097)
D.gci		0.0175 * (0.0097)
D.lir		0.137 *** (0.0286)
D.lhc		−0.0164 (0.0826)
D.lto		0.0996 *** (0.0277)
iqi	0.0002 (0.0163)	
cci	0.0827 *** (0.0189)	
gci	0.0748 *** (0.0279)	
lir	−0.170 (0.1120)	
lhc	0.1570 (0.1110)	
lto	−0.3240 *** (0.0983)	
Constant		−2.7670 *** (0.4920)
Observations	234	234

Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

In the long run, competitiveness (0.0827 ***, $p < 0.01$) and green development (0.0748 ***, $p < 0.01$) emerge as robust positive drivers of growth, consistent with Hypotheses 2 and 3. Institutional quality, while positive (0.000273), is statistically insignificant, suggesting it functions more as an enabling condition. Trade openness shows a significant negative coefficient (−0.324 ***, $p < 0.01$), implying that high openness without strong domestic competitiveness may expose smaller economies to external vulnerabilities. Investment (−0.170) and human capital (0.157) are not significant in the long-run equilibrium. The negative and significant constant (−2.767 ***) reflects the baseline correction once all regressors are included.

4.4. Panel (Fixed/Random Effects) Results: Summary Interpretation

Table 5 reports the alternative panel estimators (FE, PMG, MG, DFE), which corroborate and nuance the ARDL results. Competitiveness (CCI) is consistently positive and

significant in FE (0.085 ***), PMG (0.215 ***), and DFE (0.083 ***), reinforcing its central role as the most stable growth determinant across specifications. The green index (GCI) shows mixed results: positive and marginal in FE and DFE, significant and negative in PMG (−0.071 ***), and insignificant in MG. This divergence highlights methodological differences—ARDL emphasizes long-run equilibria, while GMM-type models capture short- to medium-term dynamics.

Table 5. Panel Regression Results.

	FE	PMG	MG	DFE
	lgdppc	D.lgdppc	D.lgdppc	D.lgdppc
main				
iqi	−0.027 * (0.013)	−0.052 *** (0.015)	−0.169 (0.223)	0.000 (0.016)
cci	0.085 *** (0.022)	0.215 *** (0.021)	−0.865 (0.990)	0.083 *** (0.019)
gci	0.062 (0.038)	−0.071 *** (0.021)	0.772 (0.744)	0.075 *** (0.028)
lir	0.218 *** (0.055)	−0.202 ** (0.088)	−3.848 (3.537)	−0.170 (0.112)
lhc	0.017 (0.120)	−0.035 (0.063)	2.869 (2.669)	0.157 (0.111)
lto	−0.124 ** (0.048)	−0.584 *** (0.062)	−2.247 (2.161)	−0.324 *** (0.098)
_cons	9.226 *** (1.074)			
SR				
ECT		0.160 *** (0.060)	0.758 *** (0.122)	0.237 *** (0.041)
D.iqi		0.015 (0.012)	0.033 * (0.018)	0.012 * (0.007)
D.cci		0.044 *** (0.008)	0.049 *** (0.018)	0.025 ** (0.010)
D.gci		0.001 (0.015)	0.010 (0.015)	0.017 * (0.010)
D.lir		0.168 *** (0.043)	0.116 * (0.064)	0.137 *** (0.029)
D.lhc		0.035 (0.113)	0.253 * (0.136)	−0.016 (0.083)
D.lto		0.115 *** (0.041)	0.117 (0.075)	0.100 *** (0.028)
_cons		−1.623 *** (0.617)	−10.517 *** (1.785)	−2.767 *** (0.492)
N	247	234	234	234
r2	0.948			
r2_a	0.942			

Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Institutional quality (IQI) is weakly significant in FE (−0.027 *, negative) and PMG (−0.052 ***), but insignificant elsewhere. This suggests that the institutional-growth link may be fragile, sensitive to specification, and possibly mediated through competitiveness. Controls provide further nuance: investment (positive in FE, negative in PMG), human capital (mostly insignificant), and trade openness (negative and significant in FE, PMG, and DFE) together indicate that while integration boosts short-run outcomes, its long-run impact can be adverse without parallel competitiveness improvements.

The short-run dynamics in Table 5 broadly confirm the ARDL patterns. Competitiveness and trade openness exert consistent positive and significant effects in the short term, while investment maintains a strong effect (0.137 *** in ARDL, 0.168 *** in FE, 0.116 * in PMG). Institutional quality and green development show modest but positive short-run effects, though their significance varies across specifications.

Taken together, the findings highlight three clear messages. First, competitiveness—anchored in innovation, productivity, and structural reforms—is the most consistent and robust determinant of growth among the new EU member states. Second, green development plays an important role in long-run convergence, though its effects are more visible in ARDL estimates than in other panel models, suggesting a gradual payoff from environmental transformation. Third, institutional quality emerges as an enabling condition, but its direct effects on growth are fragile and often insignificant once competitiveness and green factors are accounted for. The negative long-run association of trade openness further underscores the vulnerability of smaller economies when openness is not matched by domestic competitiveness.

4.5. Robustness Checks: System-GMM

To validate the PMG long-run findings, we estimated a dynamic panel model using System-GMM (Arellano-Bover/Blundell-Bond). Given the relatively small cross-sectional dimension ($N = 13$), we applied instrument-reduction techniques to avoid overfitting. Specifically, we used collapsed instruments and limited lag depth to minimize instrument proliferation.

Diagnostic tests support model validity. The Hansen test of overidentifying restrictions indicates that the instrument set is appropriate ($p > 0.10$), while the Sargan test also fails to reject instrument exogeneity at conventional levels. The Arellano–Bond tests confirm the presence of first-order serial correlation ($AR(1), p < 0.05$) but not second-order correlation ($AR(2), p > 0.10$), which is consistent with the assumptions of GMM estimation.

The final model includes a conservative number of instruments relative to the number of countries (instrument count $< N \times T$), limiting the small-sample bias commonly encountered in dynamic panel GMM applications. The signs and significance of institutional quality and competitiveness are broadly consistent with the PMG long-run estimates, reinforcing the stability of the results. Differences in short-run coefficients are expected due to the different nature of the estimators.

5. Discussion

This study investigated how institutional quality, national competitiveness, and green transition interact with economic performance in EU member states that joined since 2004. Guided by three hypotheses—H1) stronger institutions support higher economic performance, (H2) greater competitiveness fosters growth, and (H3) green transition benefits long-run growth—we estimated a single-equation dynamic framework and complementary panel specifications. The empirical evidence delivers a consistent message: competitiveness is the most robust and immediate driver of growth, green transition exhibits meaningful long-run payoffs, and institutional quality behaves as an enabling, but context-dependent factor.

Our ARDL-PMG estimates show that competitiveness (CCI) and the green composite (GCI) are positive and highly significant in the long run, while short-run dynamics are dominated by competitiveness, green measures, investment, and trade openness. These results align with endogenous growth and innovation literature that highlights R&D, productivity and human capital as engines of convergence (Aghion & Howitt, 1998; Fagerberg et al., 2007; Shahid et al., 2022). The long-run importance of green indicators

accords with the green-growth perspective: environmental modernization and energy transition can be growth-enhancing through productivity improvements, new markets, and structural upgrading (Grossman & Krueger, 1995; OECD, 2011; Costantini & Mazzanti, 2012; Campos et al., 2019; Feng et al., 2024). The panel robustness checks (FE, MG, DFE, system-GMM) strengthen these conclusions: competitiveness retains significance across estimators, while institutional quality's significance rises when endogeneity is instrumented (system-GMM), suggesting institutions often exert an indirect or mediated effect on output—facilitating investment, innovation diffusion, and the effective use of green policies (Acemoglu et al., 2005; Rodrik et al., 2004; Rahman & Sultana, 2022; Isiksal & Assi, 2022).

Interpreting the institutional result requires nuance. Institutional quality was not a powerful direct long-run predictor in the ARDL equilibrium once competitiveness and green performance were included; yet, under system-GMM it attains statistical significance. This pattern implies that governance primarily operates as an enabling condition—it matters most where it improves the returns to investment, fosters absorptive capacity for innovation, and lowers policy uncertainty. This fits the literature that treats institutions as fundamental causes that shape the effectiveness of other growth inputs rather than as stand-alone growth engines (Filip & Setzer, 2025; Jianu, 2022; Acemoglu et al., 2005; Rodrik et al., 2004). Similarly, Vučković et al. (2021) show that while institutional convergence has occurred among newer EU members, the pace and depth remain uneven. Together, these insights reinforce the interpretation that institutions are enabling factors rather than direct short-run drivers.

The negative long-run coefficient on trade openness (*lto*) is noteworthy. It suggests that openness per se may not guarantee growth advantages for smaller or less-competitive economies; without sufficient domestic competitiveness and absorptive capacity, exposure to international competition can deliver volatile outcomes and potential deindustrialization pressures. This echoes findings that the benefits of trade liberalization depend on complementary domestic capabilities—kills, innovation systems, and institutional frameworks (Feng et al., 2024; Fagerberg et al., 2007; Aghion & Howitt, 1998).

Prioritize competitiveness-oriented structural policies. The consistent centrality of competitiveness implies that cohesion and national policies should prioritize productivity-enhancing investments: R&D support (both GERD and BERD), incentives for high-tech production and exports, and upgrading labour skills (tertiary and STEM training). These actions produce visible short- and long-run payoffs and should be front-loaded within national recovery and cohesion strategies (Aghion & Howitt, 1998; Fagerberg et al., 2007; Isiksal & Assi, 2022; Azam et al., 2023). The findings carry direct implications for Cohesion Policy design, particularly in targeting institutional capacity-building, innovation bottlenecks, and green-transition readiness. By identifying which structural dimensions exert the strongest long-run effects, the analysis provides an evidence base for allocating funds more efficiently to lagging regions and supporting faster convergence under the EU's strengthened performance framework.

Integrate green transition with competitiveness policy. Because green indicators matter strongly in the long run, policymakers must design green industrial policies that combine renewable deployment and energy efficiency with innovation incentives (e.g., green R&D subsidies, support for green SMEs, demand-side procurement). Aligning Green Deal funding with local innovation ecosystems will help convert environmental goals into competitive advantages (OECD, 2011; Costantini & Mazzanti, 2012; Feng et al., 2024). Shahid et al. (2022) documents long-run cointegration between renewable energy use and growth in EU countries, while Jianu (2022) shows the suitability of PMG models to capture these dynamics. The weaker short-run results are consistent with the gradual nature of energy transition, where structural change unfolds over decades rather than years.

Strengthen institutions to multiply returns to investments. Institutional upgrades (regulatory quality, rule of law, corruption control) should be pursued not only as ends in themselves but as enablers of investment and innovation. Administrative capacity improvements, faster public procurement processes, and transparent regulatory frameworks will increase the payoff from both competitiveness and green investments (Acemoglu et al., 2005; Rodrik et al., 2004). Although institutions may moderate the effects of competitiveness or the green transition, testing interaction terms was beyond the scope of the main model. We acknowledge this as an avenue for future research and outline strategies such as constructing interaction terms ($IQI \times CCI$, $IQI \times GCI$) or using multilevel or moderated mediation frameworks.

Manage openness with domestic capability building. Given the potential downside of openness in the absence of competitiveness, trade policies should be complemented by policies that strengthen domestic firms' capabilities (e.g., export promotion, upgrading clusters, skills training) so that integration leads to sustainable gains rather than precarious specialization.

Several limitations temper the generalizability of the conclusions and frame avenues for future work. First, the sample covers 13 post-2004 entrants with an unbalanced panel from 2005–2023; while this is appropriate for the study's focus, the modest cross-sectional size constrains statistical power and the scope of heterogeneity analysis. Second, composite indices, while parsimonious, mask within-index variation; for example, different components of the green index (renewables vs. emissions intensity) may operate through distinct channels. Third, despite using PMG and system-GMM, endogeneity cannot be fully eliminated; reverse causality and omitted variable bias may still partially influence estimates. Fourth, measurement error in some Eurostat indicators or WGI components may attenuate estimated effects. Finally, the negative long-run openness coefficient invites careful country-level case studies: cross-country averages may conceal divergent national paths where openness is clearly beneficial when accompanied by capability building.

Future research should disaggregate the indices into sectoral and sub-indicator levels, extend analysis to include older EU members for comparison, and consider spatial dependence models to capture spillovers across countries. Firm-level or regional data could further enrich understanding of how competitiveness, institutional frameworks, and green transition interact at the micro level.

Overall, the evidence supports a policy strategy combining competitiveness upgrading with a strategically managed green transition, underpinned by institutional strengthening. For future research, we recommend (a) disaggregated analysis of index components to pinpoint mechanisms, (b) case studies that trace firm-level adjustment to trade and green policies, and (c) exploration of policy interactions (e.g., how specific institutional reforms condition the returns to green subsidies). Methodologically, applying Common Correlated Effects (CCE) estimators to account for cross-sectional dependence and conducting a panel impulse-response analysis could further illuminate dynamic interactions.

6. Conclusions

This paper examined the impact of institutional quality, competitiveness, and the green transition on economic growth in the post-2004 EU member states. Using a dynamic panel ARDL–PMG framework alongside complementary panel estimators, the analysis produced three main findings. First, competitiveness emerged as the most consistent and robust determinant of growth, both in the short and long run. Second, the green transition displayed significant long-run effects, underscoring the growth potential of renewable energy, efficiency, and emissions reduction. Third, institutional quality played an enabling but less direct role, becoming significant only under specifications that addressed endogeneity.

Trade openness showed mixed results—positive in the short run but negative in the long run—highlighting the importance of matching openness with domestic competitiveness.

The contribution of this study lies in integrating three composite indices into a unified empirical framework and applying advanced panel methods to a set of economies undergoing structural convergence within the EU. The findings enrich the literature on institutions, competitiveness, and green growth, while also offering policy-relevant insights for the design of EU cohesion and Green Deal strategies.

Several limitations remain. The relatively small sample of 13 countries limits the scope of heterogeneity analysis, while the use of composite indices, although parsimonious, conceals variation across sub-indicators. Measurement error in institutional and green metrics may attenuate effects, and endogeneity cannot be fully eliminated despite the use of system-GMM.

Future research could address these limitations by disaggregating index components, conducting firm- or sector-level analyses, and applying estimators that better capture cross-sectional dependence. Likewise, they could apply panel quantile regressions to examine distributional heterogeneity, incorporate spatial spillover models (e.g., SAR, SEM) to capture regional interdependence, or test dynamic moderation models to evaluate how institutions shape the competitiveness—growth and green transition—growth relationships. Comparative studies of older and newer EU members would further clarify whether the identified drivers operate differently across development stages. Overall, the evidence suggests that fostering competitiveness and accelerating the green transition, supported by strong institutions, are critical pillars of sustainable convergence in the European Union.

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