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FACTORS, INFLUENCING CLIMATE CHANGE PERFORMANCE AT COUNTRY LEVEL: EVIDENCE-BASED ON PANEL DATA ANALYSIS

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ABSTRACT

This study examines the determinants of climate change performance at the country level using panel data from 2007 to 2021. The analysis employs Generalized Method of Moments (GMM) models to explore the influence of various socioeconomic, environmental, and institutional factors on climate outcomes across multiple countries, such as renewable energy consumption, GDP per capita, carbon footprint (greenhouse gas emissions), innovation (patents), and the quality of climate policies. The GMM model is employed to address potential endogeneity concerns, providing a dynamic perspective on the relationships between these factors and climate performance. The findings from the GMM model reveal that increased renewable energy consumption is strongly associated with improved climate policy performance, highlighting the critical role of renewable energy in driving climate resilience. Economic development, as measured by GDP per capita, also shows a positive relationship with climate performance, suggesting that wealthier countries are better equipped to implement effective climate policies. Innovation, represented by patent activity, emerges as a significant factor, with a strong positive impact on climate policy performance, supporting the view that technological advancement is crucial for enhancing climate outcomes. However, carbon footprints (CFP) were found to have an insignificant negative relationship with climate performance, indicating that environmental footprints alone may not directly influence policy outcomes without the support of strong institutional frameworks and innovative policies. Institutional quality, measured in the GMM model, plays a significant role in climate policy performance, reinforcing the importance of governance in driving effective climate action. The results indicate that countries with stronger institutions are more likely to implement successful climate policies, contributing to better overall climate performance. In conclusion, the GMM findings highlight the importance of renewable energy adoption, innovation, economic development, and institutional quality in enhancing climate policy performance. The study recommends that policymakers need to focus on fostering innovation, improving institutional frameworks, and promoting renewable energy adoption to achieve sustainable and effective climate outcomes.

***Keywords**: Climate Change performance, Carbon emissions, and Economic Growth*

INTRODUCTION

The Climate Change Performance Index (CCPI) is an evaluative tool that ranks countries based on climate protection efforts and progress. The CCPI, developed by German Watch, the New Climate Institute, and the Climate Action Network, measures the climate action performance of 59 countries and the European Union. It focuses on key indicators across emissions levels, renewable energy development, energy use, and climate policies to provide a comparative measure of performance among nations Burck et al., (2017), Burck et al., (2019), Burck et al., (2023). Climate Change Performance refers to a country's or region's effectiveness in mitigating climate change, reducing greenhouse gas (GHG) emissions, and fostering sustainable practices to limit global warming. This performance includes a reduction in emissions, the development of environmentally friendly infrastructure, and adoption of renewable energy sources, and the achievement of climate-related goals (Edenhofer et al., 2014).

Climate change is one of the most pressing challenges of the 21st century, with significant implications for economic stability, environmental sustainability, and societal well-being (IPCC, 2021). Addressing climate change requires comprehensive analysis to identify factors that influence a country’s climate change and resilience efforts against climate change and ultimately the climate policy performance, as these determinants shape policy effectiveness and long-term adoption and mitigation strategies. Some factors have already been discussed in the literature, which include factors, such as economic development, institutional quality, technological innovation, and energy consumption patterns. These factors have been widely discussed as critical contributors to a nation’s ability to manage climate risks (Nordhaus, 2019; Stern, 2006). Additionally, some other influencing factors for climate policy are yet to be tested in different data formats. These factors can be ecological footprints, which measure the resource consumption over the year for individuals or activity or a nation. The reduction of ecological footprints indicates the reduction of carbon emissions and waste generation. This implies that countries with lower ecological footprints will have certainly less contribution to greenhouse gas (GHG) emissions. A country must reduce carbon emissions to contribute to climate-effective policies. Stringent climate policies are also associated with strong institutions.

Moreover, the climate policy performance measures, how well a nation’s policies are aligned with climate goals. This includes policies, such as National laws mandating emission reductions, renewable energy standards, and carbon neutrality goals (Burck et al., 2023). Countries involved in multilateral agreements, such as the Paris Agreement, tend to develop stronger policies (UNFCCC, 2020). Governments prioritizing climate action create robust policies, while others may face political obstacles (Bernauer et al., 2016). Each variable within the CCPI is influenced by macroeconomic indicators and climate policies in different ways: For instance, the Greenhouse Gas (GHG) Emissions variable represents the volume of emissions from energy, industry, transportation, and agriculture. GDP and Industrial Output usually increase the GHG emissions. High-income and industrialized countries tend to have higher emissions due to energy-intensive industries (York et al., 2015). However, stringent policies and advanced technologies can mitigate these emissions. Strong carbon pricing policies implementation with carbon taxes or cap-and-trade systems can incentivize emission reductions (World Bank, 2022).

Economic policies can significantly contribute to better climate policies. For instance, countries investing in renewable energy have lower GHG emissions relative to those reliant on fossil fuels (Huang et al., 2018). Investments in energy-efficient technologies in transportation, heating, and manufacturing reduce overall energy consumption (Bhattacharyya, 2021). The share of renewables in the energy mix is a critical measure of climate performance. Policies offering financial support or tax breaks for renewable energy can accelerate the adoption of climate policies and hence reduce environmental damage (Aguilar & Cai, 2022). Studies have established that an increase in prices leads to a reduction in demand for dirty energy products. Higher costs of fossil fuels can incentivize the shift to renewable sources (Stock & Watson, 2019). Recent studies also underscored, many factors but there is still a need to examine these factors through empirical frameworks to establish robust, evidence-based policy recommendations (Ghosh, 2020).

This research uses a panel data analysis that provides an effective tool for this purpose, offering insights into cross-country variations and temporal dynamics in climate change performance. The researcher controls for unobserved heterogeneity and captures the interplay between economic, environmental, and institutional factors over time. This study uses panel data analysis to investigate the key determinants of climate change performance at the country level. This research seeks to identify actionable insights to guide policymakers in formulating more effective climate strategies by analyzing a diverse sample of countries over an extended period. The findings will contribute to the growing body of literature on climate economics and policy, offering a nuanced understanding of how countries can enhance their resilience and adaptive capacities in the face of global climate challenges.

2.0 DATA AND METHODOLOGY

2.1 Data.

The study utilizes panel data spanning from 2007 to 2021, sourced from the World Development Indicators (WDI), Global Footprint Network (GFN), and the Climate Change Performance Index (CCPI). The dataset comprises 32 countries selected based on their exemplary climate policies and data availability for key control variables during the specified period. This comprehensive panel captures critical environmental, economic, and policy indicators, enabling an in-depth analysis of the interplay between climate policy performance and selected control variables.

2.2 Model.

$$Yit = \alpha Yit - 1 + \beta 1X1it + \beta 2X2it + \beta 3X3it + \beta 4X4it + \beta 5X5it + \beta 6X6it + \mu i + \varepsilon it$$

Where, Yit Value of the dependent variable (Cps, Climate Policy Score) for entity i at time t. Climate Policy Score, evaluating the effectiveness and implementation of climate policies αYit−1. The lagged value of the dependent variable captures persistence or dynamic effects over time.

X1 Renewable Energy Consumption is taken as a percentage of total energy consumption

X2 Log Gross Domestic Product is taken in per capita terms. The Gross Domestic Product reflects economic performance.

X3 Population Density is the number of people per square kilometer of land area

X4 Patent Count as Patent applications per million people, measuring innovation levels

X5 Institutional Factors is measured as an institutional quality index score

X6 Biocapacity is the environmental capacity or amount of productive space to regenerate natural resources and is measured in terms of Global hectare acre Per capita

μi is an Unobserved, time-invariant characteristic of entity i (e.g., countries or regions).

Eit is a Random error term, varying over time and entities.

2.3 Methodology.

This study employs a quantitative research approach using a panel data set spanning 32 countries from 2007 to 2021, sourced from the World Development Indicators (WDI), Global Footprint Network (GFN), and the Climate Change Performance Index (CCPI). The primary focus is to evaluate the determinants of Climate Policy Performance (CPP), taken as the dependent variable. Independent variables include Carbon Footprint (CFP), Renewable Energy Consumption (Rec), Gross Domestic Product (GDP), Biocapacity (Bio), and Patent Applications (Pat), among others. The study applies a Generalized Method of Moments (GMM) two-step estimation technique, a robust approach for dynamic panel data models, to account for potential endogeneity issues, unobserved heterogeneity, and autocorrelation in the dataset. To ensure the suitability of the panel data for GMM estimation, several diagnostic tests are performed. A Panel Unit Root Test confirms the stationarity of the variables, while a multi-collinearity check addresses potential high correlations among independent variables. The Hansen/Sargan test of over-identifying restrictions verifies the validity of the instrumental variables, and autocorrelation tests confirm the absence of first-order and second-order serial correlations in the residuals. Post-estimation tests further validate the reliability of the GMM model. The Hansen Test for Instrument Validity ensures that the instruments used are valid and not overfitted. The Arellano-Bond test for Serial Correlation confirms the absence of second-order autocorrelation in the differenced residuals, and the Wald test assesses the joint significance of the explanatory variables. The GMM approach is chosen for its ability to handle endogeneity by using lagged values of the dependent and independent variables as instruments. The two-step GMM estimator accounts for heteroscedasticity and provides efficient estimates with robust standard errors. All diagnostic and validation tests confirm that potential issues in the panel data and model estimation were effectively resolved. This methodology ensures a rigorous examination of the factors influencing climate policy performance, contributing to evidence-based policymaking and enhancing the understanding of the dynamics of climate policy effectiveness across leading nations.

4.0 RESULTS AND DISCUSSION

4.1 Descriptive Statistics

The descriptive analysis provides insight into the key variables used in the study: Climate Footprint (CFP), Renewable Energy Consumption (Rec), Gross Domestic Product (GDP), Climate Policy Score (CPS), and Patent Applications (PAT). The averages (means) reflect the central tendencies across the panel of 32 countries from 2007 to 2021, while the range (min-max), standard deviation (SD), and skewness highlight the variability and distribution characteristics. Climate Footprint (CFP) has a mean of 0.395, indicating the average environmental footprint among the sampled nations, with moderate variability (SD = 0.3074) and a positively skewed distribution (Skewness = 1.3333), implying most countries have footprints below the mean but a few with substantially higher values. Renewable Energy Consumption (Rec), averaging 23.9349, shows significant variation (SD = 14.8137), reflecting the diverse adoption of renewable energy across nations. The distribution is slightly positively skewed (0.4619), suggesting most countries cluster near the mean with some outliers having higher adoption rates. GDP is critical for understanding economic growth, with an average of 51.2578. The wide range (-0.09 to 77.76) and high kurtosis (8.1825) indicate significant outliers and diverse economic statuses across countries, while the negative skewness (-2.0328) highlights that most countries have GDP levels clustered towards higher values. Climate Policy Score (Cps), with a mean of 3.3286 and moderate variability (SD = 0.9023), reflects varying levels of policy effectiveness. Positive skewness (0.7061) indicates most countries score below the mean, but some perform significantly better. Patent Applications (Pat), a proxy for innovation, has an average of 3.3286 with low variability (SD = 0.9023). The positive skewness (0.7061) implies that innovation is concentrated in a few countries with a high number of patents per capita.

Table no 4.1 Descriptive statistics

Stats	CFP	Rec	Gdp	Cps	Pat
Mean	0.3950	23.9349	2.5943	51.2578	3.3286
Max	1.3400	61.4000	17.8600	77.7600	6.1500
Min	0.0500	1.8000	-14.2600	-0.0900	1.4500
SD	0.3074	14.8137	3.9435	14.4787	0.9023
Variance	0.0945	219.4449	15.5510	209.6320	0.8141
Skewness	1.3333	0.4619	-0.6330	-2.0328	0.7061
Kurtosis	3.8521	2.2789	5.2600	8.1825	3.9193
p50	0.2900	22.3000	2.5950	52.6900	3.2100

4.2 Relationship between GDP, Renewable Energy, Institutional Quality and Climate Policy

The results of the study show that the Lagged Cps (Cps L1) coefficient is negative and significant (-0.09, p < 0.01), indicating that previous climate policy performance negatively influences current performance, possibly due to diminishing marginal returns or shifting policy priorities. Renewable Energy Consumption (Rec) shows A positive and highly significant relationship with a coefficient of (0.53, and a p-value < 0.01) suggesting that higher renewable energy adoption directly improves climate policy performance, emphasizing the role of the energy transition. GDP positive and a significant impact (0.12, p < 0.01) reflects that economic growth supports better climate policy implementation, possibly by providing the necessary resources and technological advancements. The Patent Applications (Pat) shows a strong positive effect (6.83, p < 0.01) highlighting the critical role of innovation in driving effective climate policies. Biocapacity (Biocap) indicates a negative coefficient (-4.08, p < 0.01) indicating that higher biocapacity might reduce urgency in implementing stringent policies, as countries with abundant resources may perceive less immediate environmental stress. The Hansen Test confirms the validity of the instruments used, ensuring the robustness of the results. The Arellano-Bond Test rules out second-order autocorrelation, validating the model's dynamic structure. The high Wald chi-square statistic (2890.77, p < 0.01) confirms the joint significance of the explanatory variables.

Table 4.2 Climate Policy, Renewable Energy, Institutional Quality and Environment

Arellano–Bond dynamic panel-data estimation	
Group variable: id Time variable: year	Number of obs = 414 Number of groups = 32 Wald chi2(6) =2890.77 Prob > chi2 = 0.0000
Number of instruments = 31	

Two-step results

Variables	Coefficient	Std. err.	Z	P>z	[95% conf. interval]	
Cps L1.	-0.09	0.01	-9.18	0.00	-0.11	-0.07
Rec	0.53	0.04	13.14	0.00	0.45	0.60
Gdp	0.12	0.01	14.93	0.00	0.10	0.13
Pat	6.83	1.34	5.09	0.00	4.20	9.46
Lo	9.51	1.05	9.05	0.00	7.45	11.57
Biocap	-4.08	0.41	-9.87	0.00	-4.90	-3.27
cons	28.37	3.70	7.68	0.00	21.13	35.62

4.3 Climate Policy, Population, and Environment a System Dynamic panel-data estimation

The results from the system dynamic panel estimation provide insights into the determinants of climate policy performance (Cps). The negative and significant coefficient for lagged climate policy scores (-0.0818, p < 0.01) suggests a diminishing marginal impact of past performance on current outcomes. This aligns with the theory of policy inertia, where the effectiveness of additional policies reduces over time due to the exhaustion of low-cost options or diminishing returns from repeated policy applications. This finding highlights the challenges of sustaining policy momentum without innovative interventions. Economic growth positively and significantly influences climate policy performance with a (coefficient value of 0.0987 and p < 0.01). This finding supports the Environmental Kuznets Curve (EKC) hypothesis, which posits that as economies grow, they initially prioritize economic development over environmental concerns. However, beyond a certain income threshold, resources and technologies are allocated to environmental improvements, resulting in stronger climate policies. Renewable energy consumption is a key positive driver of climate policy performance (coefficient = 0.448, p < 0.01). This supports the transition theory, which emphasizes the role of clean energy technologies in reducing environmental degradation and achieving sustainable development. By increasing renewable energy adoption, nations can reduce dependence on fossil fuels, aligning with the principles of sustainable energy transitions in environmental economics.

Carbon footprints (CFP) have a negative but insignificant effect on climate policy performance (-2.293, p = 0.68). This suggests that the level of carbon emissions alone may not directly prompt policy changes within this dataset. This can be explained through the tragedy of the commons framework, where collective action problems may prevent countries from implementing strong policies unless driven by external pressures or robust institutions. Innovation, as measured by patent applications, shows a strong positive and significant effect on climate policy performance (coefficient = 5.988, p < 0.01). This finding aligns with the Porter Hypothesis, which suggests that well-designed environmental policies can stimulate innovation, resulting in improved environmental and economic outcomes. It underscores the importance of fostering technological advancements to drive effective climate policies. Population density (coefficient = 0.0476, p < 0.01) and institutional quality (coefficient = 5.033, p < 0.01) also positively influence climate policy performance. These results are consistent with institutional economics theory, which highlights the role of strong institutions in managing externalities and fostering cooperative behavior. Higher population density may increase public demand for sustainable policies due to the visibility of environmental impacts in densely populated areas, supporting collective action theories. The high Wald chi-square statistic (6677.23, p < 0.01) confirms the joint significance of all variables, indicating that economic, energy, and institutional factors collectively shape climate policy performance. This reflects systems theory in environmental economics, which views policy outcomes as the result of interconnected economic, social, and environmental subsystems. These results highlight the importance of fostering economic resilience, technological innovation, and strong governance to achieve effective climate policies.

Table 4.3 Climate Policy, Population, and Environment. A System dynamic panel-data estimation

System dynamic panel-data estimation						
Group variable: id Time variable: year Number of groups = 32 Number of obs = 446 Number of instruments = 30 Wald chi2(7) = 6677.23 Prob > chi2 = 0.0000						
Two-step results						
Variables	Coefficient	Std. err.	Z	P>|z|	[95% conf. interval]	
Cps L1.	-.0818283	.0240126	-3.41	0.001	-.1288921	-.0347646
Gdp	.0986822	.0125616	7.86	0.000	.0740618	.1233025
Rec	.4479636	.0864855	5.18	0.000	.2784551	.617472
CFP	-2.292792	5.563764	-0.41	0.680	-13.19757	8.611984
Pat	5.987616	.9967975	6.01	0.000	4.033929	7.941303
Pd	.047647	.0052235	9.12	0.000	.0374091	.0578848
Ins	5.033302	.9632651	5.23	0.000	3.145337	6.921267
_cons	19.16472	6.991267	2.74	0.006	5.46209	32.86735

4.4 Discussion

The results from the system dynamic panel estimation provide critical insights into the determinants of climate policy performance (Cps), drawing on empirical evidence and theoretical foundations in environmental economics. Policy inertia, as highlighted in environmental economics, underscores the difficulty in sustaining impactful interventions without new approaches and strategies.

Economic growth emerges as a positive and significant determinant of climate policy performance. This finding supports the Environmental Kuznets Curve (EKC) hypothesis, as noted in Grossman and Krueger (1995), which posits that economic development initially leads to environmental degradation but transitions to improvement as resources are allocated toward sustainable practices. Recent studies, such as those by Cole (2004), further support the idea that economic growth facilitates investments in green technologies and policy implementation, particularly in higher-income countries.

Renewable energy consumption is found to be a key driver of climate policy performance This finding is consistent with the transition theory, which highlights the role of clean energy adoption in achieving sustainability goals. Studies like those by Sovacool (2017) and Jacobsson and Lauber (2006) emphasize that a shift toward renewable energy sources not only reduces carbon emissions but also fosters stronger policy frameworks by demonstrating the feasibility of transitioning away from fossil fuels.

Interestingly, carbon footprints (CFP) show a negative but insignificant relationship with climate policy performance. This finding suggests that high carbon emissions alone may not directly prompt stronger climate policies. Similar results are discussed in studies like Ostrom (2010), which argue that collective action problems and lack of enforcement mechanisms often hinder effective responses to environmental degradation, even in the presence of high emissions.

Innovation, measured by patent applications, has a strong positive and significant impact on climate policy performance. This aligns with the Porter Hypothesis (Porter and van der Linde, 1995), which posits that environmental regulations stimulate innovation, leading to both economic and environmental benefits. Recent studies, such as Popp et al. (2010), further corroborate that technological advancements play a pivotal role in driving the effectiveness of climate policies and enhancing their long-term viability. Institutional and population density are also significant contributors to climate policy performance. The importance of strong institutions in managing environmental externalities is well-documented in studies like Acemoglu et al. (2012), which emphasize the role of governance in fostering cooperation and accountability. Higher population density, as noted by studies like Dietz and Rosa (1997), can increase public demand for environmental action due to the immediate visibility of environmental challenges in densely populated areas. The findings align with existing literature and provide a nuanced understanding of the determinants of climate policy performance. By emphasizing the interconnected roles of economic growth, renewable energy adoption, innovation, and institutional strength, this study reinforces the importance of a multi-faceted approach to climate policy design and implementation. These results suggest that policymakers should focus on fostering innovation, strengthening institutions, and promoting renewable energy to achieve sustainable climate goals.

5.0 CONCLUSION

The findings underscore the complex interplay of economic, energy, institutional, and innovation factors in shaping climate policy performance. Economic growth and renewable energy adoption emerge as critical drivers, supporting the Environmental Kuznets Curve hypothesis and transition theory. Innovation, as evidenced by patent activity, aligns with the Porter Hypothesis, demonstrating the transformative potential of technology-driven climate policies. Strong institutions and population density further reinforce the importance of governance and collective action in addressing environmental challenges. However, the insignificant impact of carbon footprints highlights the persistent challenge of aligning high emissions with immediate policy responses, consistent with the tragedy of the commons. Policymakers should prioritize fostering green innovation, strengthening institutional frameworks, and scaling renewable energy transitions. This multi-faceted approach ensures not only the effectiveness of climate policies but also their resilience to future environmental and economic challenges, contributing to sustainable development goals.

5.1 POLICY RECOMMENDATIONS

Based on the results, the following policy recommendations are proposed. Renewable energy consumption significantly enhances climate policy performance. Governments should incentivize the transition to clean energy through subsidies, tax credits, and public-private partnerships. Policies should also focus on expanding renewable energy infrastructure and integrating it into national grids to ensure accessibility and affordability. The strong positive impact of innovation, as evidenced by patent activity, highlights the need for targeted investments in research and development (R&D). Policymakers should create frameworks that encourage technological advancements, such as funding innovation hubs, providing grants for green technologies, and protecting intellectual property to stimulate private-sector involvement. Institutional quality plays a pivotal role in climate policy success. Strengthening governance structures, ensuring transparency, and fostering accountability are essential. Policymakers should focus on building capacity in environmental regulatory bodies and enhancing coordination among stakeholders for effective implementation of policies. The diminishing returns of past policies suggest the need for continuous innovation and adaptation. Policy makers should implement dynamic strategies that are regularly evaluated and updated based on changing environmental, economic, and technological conditions. By implementing these evidence-based recommendations, policymakers can create a comprehensive framework that drives effective climate policies, ensuring alignment with sustainable development goals and global climate commitments.

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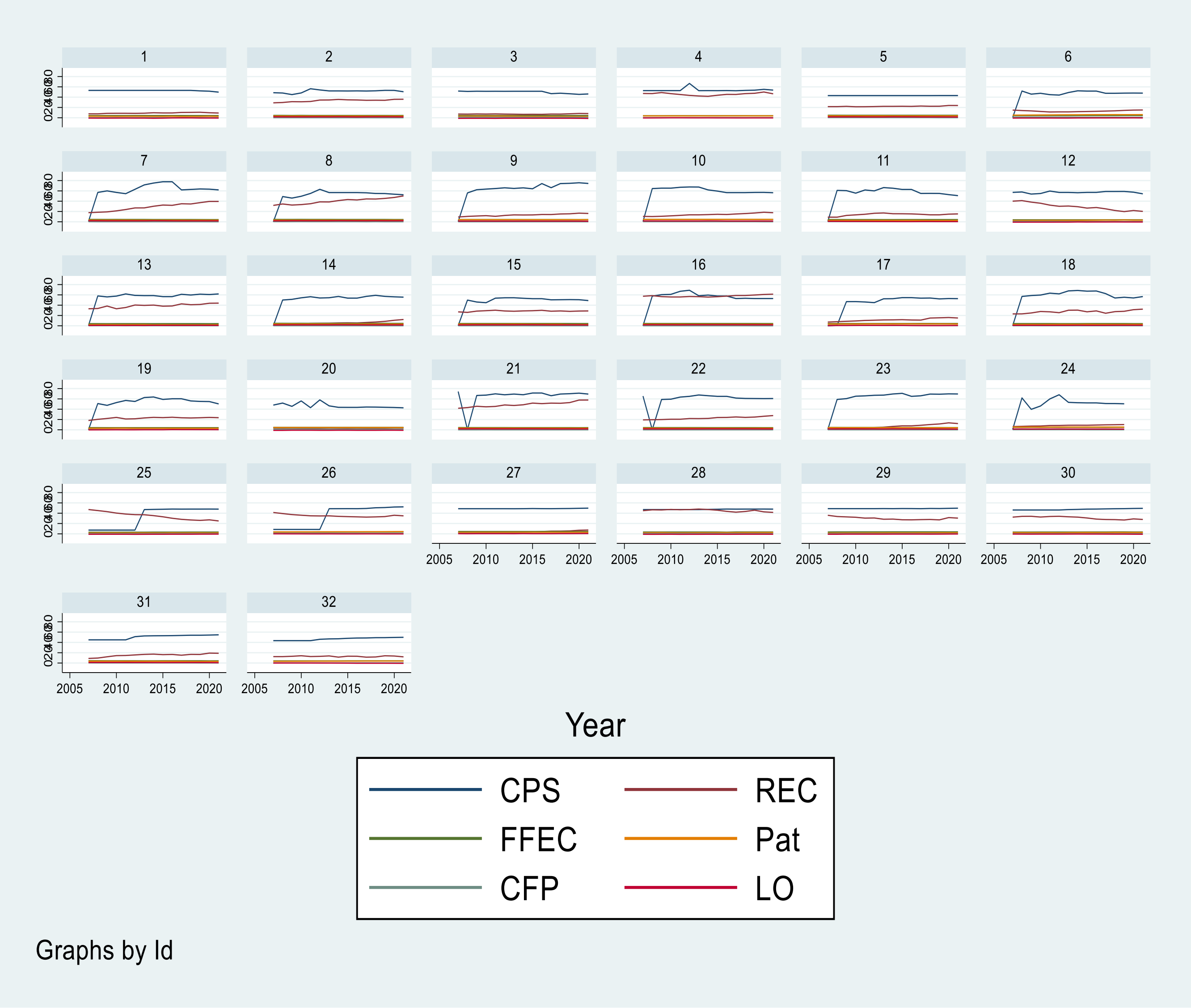
Appendix A1: Graph by panel for all important variables



Variable	**Mean**	**Std. dev.**	**Min**	**Max**	**Observations**	
Id Overall	16.46862	9.249288	1	32	N = 478 n = 32 T bar = 14.9375	
Between		9.380832	1	32		
within		0	16.46862	16.46862		
Year Overall	2013.973	4.313366	2007	2021	N = 478 n = 32 T bar = 14.9375	
Between		0.176777	2013	2014		
within		4.310292	2006.973	2020.973		
Cfp overall	0.395021	0.307396	0.05	1.34	N = 478 n = 32 T bar = 14.9375	
between		0.306323	0.06	1.208		
within		0.055354	0.177021	0.667021		
Rec	overall	23.93494	14.81367	1.8	61.4	N = 478
between	14.68032	3.373333	57.86667	n = 32		
within	3.216905	12.6416	36.42827	T	bar = 14.9375	
gdp	overall	2.594268	3.943475	-14.26	17.86	N = 478
between	1.924348	0.39	8.050667	n = 32		
within	3.455963	-12.9231	18.77427	T	bar = 14.9375	
pd	overall	96.56264	112.0677	1.35	520.73	N = 478
between	113.4174	1.802	501.9833	n = 32		
within	5.944821	56.30863	137.8686	T	bar = 14.9375	
pat	overall	3.32864	0.902253	1.45	6.15	N = 478
between	0.911758	1.736667	5.805333	n = 32		
within	0.148326	2.703307	3.895307	T	bar = 14.9375	
lo	overall	0.671548	1.04561	-1.31	2.12	N = 478
between	1.05459	-0.98267	1.990667	n = 32		
within	0.111941	0.344215	1.004881	T	bar = 14.9375	
biocap	overall	3.223912	3.118053	0.24	12.64	N = 478
between	3.149869	0.248667	12.06467	n = 32		
within	0.246044	1.903912	4.603912	T	bar = 14.9375	
cps	overall	51.25782	14.47867	-0.09	77.76	N = 478
between	7.399378	31.62067	64.90267	n = 32		
within	12.50103	-13.0848	70.20916	T	bar = 14.9375	
cdummy	overall	0.031381	0.174527	0	1	N = 478
between	0.176777	0	1	n = 32		
within	0	0.031381	0.031381	T	bar = 14.9375	