UNIVERSIDADE BEIRA INTERIOR

Essays on Economic Growth and Socio-Economic Development: An Exploration of Interrelated Factors and Policy Implications

Henrique Viana Espinosa de Oliveira

Tese para obtenção do Grau de Doutor em Economia

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Economia
(3º ciclo de estudos)

Orientador: Prof. Doutor Vítor Manuel Ferreira Moutinho
Co-orientador: Prof. Doutor Oscar João Atanázio Afonso

Júri:
Prof. Doutor Nuno Carlos Prazeres Marques Leitão
Prof. Doutor João Oom de Souza Tovar Talles
Profª. Doutora Margarida Matias Robaina
Prof. Doutor Miguel Rocha de Souza
Prof. Doutor Víctor Manuel Ferreira Moutinho
Prof. Doutor Tiago Jorge Lopes Afonso

17 de Julho de 2024

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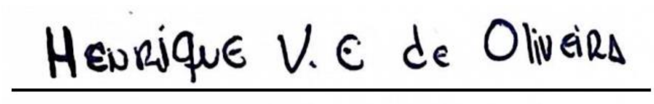

Henrique Viana Espinosa de Oliveira

Resumo

Esta tese de doutoramento faz uma análise abrangente do crescimento econômico e do desenvolvimento socioeconômico, abordando dois aspectos fulcrais de qualquer economia. A investigação explora esta relação considerando fatores para além da produção, nomeadamente o consumo de energias renováveis e não renováveis, para avaliar a existência de uma verdadeira e efectiva transição energética para uma coexistência mais harmoniosa entre preocupações económicas e ambientais. As variáveis institucionais são também incorporadas na análise para compreender os seus contributos e relevância diagnóstica. A tese está estruturada em duas abordagens principais: uma revisão teórica e uma investigação empírica.

Na abordagem teórica, é efectuada uma revisão rigorosa da literatura, que serve de base ao segmento empírico do estudo. Através de uma revisão sistemática de artigos relacionados com as Energias Renováveis, Crescimento Econômico e Desenvolvimento Econômico publicados entre 2008 e maio de 2021, utilizando a metodologia PRISMA (Preferred Reporting Itens for Systematic Reviews and Meta-Analyses), é reunida uma amostra de 111 artigos da Web of Science e 199 artigos académicos da Scopus. A análise destes artigos sublinha a predominância de metodologias quantitativas no domínio das ciências económicas. Além disso, revela uma tendência crescente na investigação sobre este tema, particularmente nas publicações pós-2015. A China surge como o principal contribuinte para este corpo de trabalho, com a revista Renewable and Sustainable Energy Reviews a ter uma relevância significativa, sendo a Sustainability a publicação mais prolífica. É notória a existência de uma lacuna de investigação, nomeadamente no que diz respeito ao consumo de energias renováveis e ao seu impacto no desenvolvimento econômico, bem como de estudos centrados nas energias renováveis e no crescimento econômico em economias menos desenvolvidas.

O segmento empírico, Abordagem (ii), é composto por três capítulos, dois dos quais se debruçam sobre a análise do crescimento econômico e um sobre o desenvolvimento socioeconômico. A primeira análise empírica utiliza um modelo de crescimento endógeno, aplicando dois modelos distintos para investigar as relações entre vários factores, incluindo o desenvolvimento financeiro, a força de trabalho, a formação bruta fixa, a estabilidade política (medida pela GEPU - Global Economic Policy Uncertainty Index), o consumo de energia, o desenvolvimento humano e o crescimento econômico. O primeiro modelo explora a relação entre o crescimento económico e estes factores,

enquanto o segundo modelo isola o impacto da força de trabalho, categorizada por diferentes níveis de educação, no crescimento econômico. Os resultados revelam que a formação bruta de capital apresenta um significado econômico e o efeito positivo esperado, enquanto a força de trabalho apresenta uma relação negativa com o crescimento econômico. A variável GEPU está inversamente associada ao PIB, o que sugere que a instabilidade ou a incerteza política afectam negativamente o crescimento econômico. O modelo 2 revela que a educação intermédia está positivamente relacionada com o crescimento econômico, enquanto a educação avançada apresenta uma relação negativa. Estes resultados sublinham os potenciais benefícios da promoção de cursos técnicos adaptados às exigências do mercado de trabalho para promover um desenvolvimento econômico sustentável.

A segunda análise empírica adopta uma perspetiva global, introduzindo a influência da globalização. Este estudo examina a relação entre o consumo de energia renovável e não renovável, o índice de globalização KOF e o crescimento económico nas economias BRICS de 1990 a 2019. Múltiplos estimadores são empregados para explorar essa relação, e a causalidade é avaliada usando o teste Dumitrescu-Hurlin. Os resultados revelam uma associação positiva entre o consumo de energia e o crescimento econômico, embora não se observe a relação esperada em forma de "U" invertido. Os efeitos cruzados do índice de globalização KOF contribuem geralmente para o crescimento econômico, embora o teste de causalidade indique uma relação neutra entre o consumo de energia e o crescimento económico.

A análise empírica final centra-se no desenvolvimento socioeconômico. Este estudo examina a intrincada interação entre vários factores socioeconômicos e o seu impacto no Índice de Desenvolvimento Humano (IDH) em 39 economias africanas de 2012 a 2022, com uma distinção entre contextos rurais e urbanos. As principais variáveis em análise incluem a dinâmica populacional, as oportunidades de emprego, os padrões de consumo de energia (renovável e não renovável), o acesso à eletricidade, a pressão ambiental e o progresso técnico. Os resultados são obtidos através de metodologias de painel dinâmico, nomeadamente a estimação com correção de viés e o método generalizado dos momentos (GMM). No meio rural, o aumento da população afecta negativamente o IDH, enquanto o aumento das oportunidades de emprego contribui positivamente. No entanto, a influência do consumo de energia, da acessibilidade à eletricidade e da pressão ambiental é negativa. Surpreendentemente, verifica-se que a corrupção está positivamente ligada ao IDH nas zonas rurais. Nas zonas urbanas, o crescimento da população tem um impacto negativo no IDH regional, ao passo que o aumento das oportunidades de emprego tem um efeito positivo. No entanto, a influência do consumo de energia, da acessibilidade à eletricidade e da pressão ambiental é negativa. Surpreendentemente, verifica-se que a corrupção está positivamente ligada ao IDH nas zonas rurais. Nas zonas urbanas, o crescimento da população tem um impacto negativo no IDH regional, enquanto o aumento das oportunidades de emprego tem um efeito positivo. Em particular, o consumo de energia (tanto renovável como não renovável) afecta positivamente o desenvolvimento urbano, o que diverge da análise rural. Além disso, as emissões de CO_2, que reflectem a pressão ambiental, apresentam uma relação positiva com o Índice de Desenvolvimento Humano urbano.

Apesar das variações nas amostras utilizadas, surge uma conclusão consistente: o consumo de energias renováveis tem um impacto positivo no crescimento económico. Este efeito é atribuído a vários factores. As energias renováveis são frequentemente produzidas localmente e menos vulneráveis às flutuações do mercado internacional em comparação com os combustíveis fósseis. Além disso, os avanços tecnológicos em curso tornam a adoção das energias renováveis cada vez mais atractiva e rentável, prometendo benefícios ainda mais substanciais para o crescimento económico no futuro.

Um desafio significativo para alcançar o crescimento econômico está relacionado com a força de trabalho, tendo sido observada uma relação negativa inesperada entre os trabalhadores e a sua contribuição para o crescimento. No entanto, uma análise mais aprofundada revela que apenas os trabalhadores com formação intermédia contribuem positivamente para o crescimento. Os trabalhadores com formação básica não cumprem os padrões de desempenho desejados e os custos dos trabalhadores com formação superior ultrapassam as suas contribuições. Para resolver este problema, é essencial investir em formação técnica que se alinhe com as exigências do mercado de trabalho.

A estabilidade política e econômica é crucial para promover o crescimento econômico. A estabilidade permite aos agentes econômicos prever as políticas governamentais e planear os investimentos, apoiando a expansão econômica. A obtenção de um crescimento sustentável exige transparência e transições políticas suaves durante as mudanças de liderança, permitindo que os mercados compreendam e prevejam as ações dos decisores políticos, contribuindo assim para o crescimento a longo prazo.

A globalização, que pode aumentar o crescimento econômico através do aumento do comércio, também expõe a economia a flutuações internacionais. Para enfrentar este desafio, recomenda-se o estabelecimento de parcerias mais profundas que vão para além do comércio. Estas parcerias devem envolver investigação em colaboração e intercâmbios de tecnologia, beneficiando todas as partes. Além disso, os intercâmbios de investigadores podem fomentar a partilha de conhecimentos com o objetivo comum de melhorar tanto a economia como a sociedade, ajudando a atenuar as potenciais desvantagens de uma maior globalização.

Este estudo utilizou o Índice de Desenvolvimento Humano (IDH) como métrica para avaliar o desenvolvimento socioeconômico. O crescimento da população mundial apresenta tendências diversas, criando um desafio na conceção de políticas para uma melhoria consistente, particularmente porque esta variável apresentou uma associação negativa com o desenvolvimento socioeconômico. Embora a criação de emprego convencional continue a ser essencial, o advento da automatização e as mudanças no mercado de trabalho introduzem novas complexidades, sublinhando a importância da formação e educação da força de trabalho para acomodar as profissões em evolução.

É interessante notar que a influência positiva inesperada das emissões de dióxido de carbono no desenvolvimento pode ser atribuída à industrialização e à atividade económica. No entanto, o principal desafio reside na transição para um crescimento económico sustentável que atenue a degradação ambiental sem pôr em causa o bem-estar geral da sociedade. É imperativo encontrar este equilíbrio delicado para alcançar a sustentabilidade a longo prazo e o desenvolvimento inclusivo em contextos académicos e políticos.

Em conclusão, esta tese navega na intrincada dinâmica do crescimento econômico e do desenvolvimento socioeconmico, englobando uma série de factores, desde o consumo de energia até às variáveis institucionais. As investigações empíricas fornecem informações valiosas sobre as relações multifacetadas em vários contextos económicos, lançando luz sobre potenciais implicações políticas e áreas para exploração futura.

Palavras-chave

Análise Bibliométrica;Economia do Desenvolvimento;Crescimento econômico; Energia;Energia renovável;Modelo de Crescimento Endógeno; apital Humano; Consumo de energia;Incerteza Política;Países BRICS; Índice de Globalização;Índice de Desenvolvimento Humano;Fatores Socioeconômicos;Economias Africanas; Desenvolvimento Rural e Urbano.

Abstract

This doctoral thesis undertakes a comprehensive analysis of economic growth and socio-economic development, addressing two pivotal aspects of any economy. The research explores this relationship by considering factors beyond production, notably the consumption of both renewable and non-renewable energies, to assess the presence of a genuine and effective energy transition toward a more harmonious coexistence of economic and environmental concerns. Institutional variables are also incorporated into the analysis to understand their contributions and diagnostic relevance. The thesis is structured into two primary approaches: a theoretical review and an empirical investigation.

In the theoretical approach, a rigorous literature review is conducted, serving as the foundation for the empirical segment of the study. Through a systematic review of articles related to Renewable Energy, Economic Growth, and Economic Development published between 2008 and May 2021, using the PRISMA (Preferred Reporting Itens for Systematic Reviews and Meta-Analyses) methodology, a sample of 111 articles from Web of Science and 199 academic articles from Scopus is assembled. The analysis of these articles underscores the predominance of quantitative methodologies within the field of economic sciences. Moreover, it reveals a growing trend in research on this subject, particularly in post-2015 publications. China emerges as the leading contributor to this body of work, with the journal Renewable and Sustainable Energy Reviews holding significant relevance, and Sustainability being the most prolific publication. Notably, a research gap is identified, particularly concerning the consumption of renewable energies and their impact on economic development, as well as studies focusing on renewable energies and economic growth in less developed economies.

The empirical segment, Approach (ii), comprises three chapters, two of which delve into the analysis of economic growth, while one focuses on socio-economic development. The first empirical analysis employs an endogenous growth model, applying two distinct models to investigate the relationships between various factors, including financial development, labor force, gross fixed formation, political stability (measured by the GEPU - Global Economic Policy Uncertainty Index), energy consumption, human development, and economic growth. The first model explores the connection between economic growth and these factors, while the second model isolates the impact of the workforce, categorized by different educational levels, on economic growth. The findings

reveal that gross capital formation displays both economic significance and the expected positive effect, whereas the labor force exhibits a negative relationship with economic growth. The GEPU variable is inversely associated with GDP, suggesting that instability or political uncertainty negatively affects economic growth. Model 2 unveils that intermediate education is positively related to economic growth, whereas advanced education demonstrates a negative relationship. These results emphasize the potential benefits of promoting technical courses tailored to labor market demands to foster sustainable economic development.

The second empirical analysis takes a global perspective, introducing the influence of globalization. This study examines the relationship between renewable and non-renewable energy consumption, the KOF Globalization index, and economic growth in BRICS economies from 1990 to 2019. Multiple estimators are employed to explore this relationship, and causality is assessed using the Dumitrescu-Hurlin test. The results reveal a positive association between energy consumption and economic growth, though the expected inverted "U" shape relationship is not observed. Cross-effects of the KOF Globalization index generally contribute to economic growth, although the causality test indicates a neutral relationship between energy consumption and economic growth.

The final empirical analysis centers on socio-economic development. This study examines the intricate interplay between various socio-economic factors and their impact on the Human Development Index (HDI) across 39 African economies from 2012 to 2022, with a distinction between rural and urban contexts. Key variables under scrutiny include population dynamics, employment opportunities, energy consumption patterns (both renewable and non-renewable), access to electricity, environmental pressure, and technical progress. Results are obtained through dynamic panel methodologies, specifically Bias-Corrected Estimation and the Generalized Method of Moments (GMM). In rural settings, a population increase adversely affects HDI, while increased job opportunities contribute positively. However, the influence of energy consumption, electricity accessibility, and environmental pressure is negative. Surprisingly, corruption is found to be positively linked with HDI in rural areas. In urban areas, population growth has a negative impact on regional HDI, while increased employment opportunities yield a positive effect. Notably, energy consumption (both renewable and non-renewable) positively affects urban development, a divergence from the rural analysis. Furthermore, CO_2 emissions, reflecting environmental pressure, exhibit a positive relationship with the urban Human Development Index.

Despite variations in the samples used, a consistent finding emerges: the consumption of renewable energies positively impacts economic growth. This effect is attributed to several factors. Renewable energies are often produced locally and less vulnerable to international market fluctuations compared to fossil fuels. Additionally, ongoing technological advancements make renewable energy adoption increasingly attractive and cost-effective, promising even more substantial benefits for economic growth in the future.

One significant challenge in achieving economic growth relates to the workforce, with an unexpected negative relationship observed between workers and their contribution to growth. However, a deeper analysis reveals that only workers with intermediate training positively contribute to growth. Basic education workers do not meet desired performance standards, and highly educated workers' costs outweigh their contributions. To address this, investing in technical training that aligns with labor market demands is essential.

Political and economic stability is crucial for fostering economic growth. Stability enables economic agents to predict government policies and plan investments, supporting economic expansion. Achieving sustainable growth requires transparency and smooth policy transitions during leadership changes, allowing markets to understand and predict policymakers' actions, thus contributing to long-term growth.

Globalization, which can enhance economic growth through increased trade, also exposes the economy to international fluctuations. To address this challenge, it is recommended to establish deeper partnerships that go beyond trade. These partnerships should involve collaborative research and technology exchanges, benefiting all parties. Furthermore, researcher exchanges can foster knowledge sharing with the common objective of improving both the economy and society, helping to mitigate the potential downsides of increased globalization.

This study employed the Human Development Index (HDI) as a metric for evaluating socioeconomic development. Global population growth demonstrates diverse trends, creating a challenge in devising policies for consistent improvement, particularly because this variable exhibited a negative association with socio-economic development. While conventional job creation remains integral, the advent of automation and shifts in the labor market introduce new complexities, underscoring the importance of workforce training and education to accommodate evolving professions.

Interestingly, the unexpected positive influence of carbon dioxide emissions on development can be attributed to industrialization and economic activity. Nevertheless, the principal challenge lies in transitioning toward sustainable economic growth that mitigates environmental degradation without jeopardizing overall societal well-being. Striking this delicate balance is imperative for achieving long-term sustainability and inclusive development in academic and policy contexts.

In conclusion, this thesis navigates the intricate dynamics of economic growth and socio-economic development by encompassing a range of factors, from energy consumption to institutional variables. The empirical investigations provide valuable insights into the multifaceted relationships in various economic contexts, shedding light on potential policy implications and areas for further exploration.

Keywords

Bibliometric Analysis;Development Economics; Economic Growth;Energy; Renewable Energy;Endogenous Growth Model;Human Capital;Energy Consumption;Political Uncertain; BRICS countries;Globalization Index;Human Development Index;Socio-economic Factors;African Economies;Rural and Urban Development.

Índice

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Lista de Tabelas

Lista de Acrónimos

ADF	Augmented Dickey-Fuller
ARDL	Auto Regressive Distributed Lag
BC	Bias Corrected Estimation
BP	British Petroleum
BRI	Belt Road Initiative
BRICS	Brazil, Russia, India, China and South Africa
CD	Cross Dependence
CIS	Commonwealth of Independent States
CS	Cite Score
DOLS	Dynamic Ordinary Least Squares
EC	Error Correction
ECM	Error Correction Model
EKC	Environmental Kuznets Curve
EPU	Economic Policy Uncertain Index
EU	European Union
FDI	Foreign Direct Investment
FE	Fixed Effects
FMOLS	Fully Modified Ordinary Least Squares
GDP	Gross Domestic Product
GEPU	Global Economic Policy Uncertain Index
GMM	Generalized Method of Moments
HDI	Human Development Index
HESs	Higher Education Systems
IMF	International Monetary Fund
IPS	Im-Pesaran-Shin
IV	Instrumental Variables
KPI	Key Performance Indicators
MENA	Middle East and North African
MG	Mean Group

ML	Maximum Likelihood
MLE	Maximum Likelihood Estimators
NARDL	Nonlinear Autoregressive Distributed Lags
OECD	Economic Cooperation and Development
OLS	Ordinary Least Square
OPEC	Organization of the Petroleum Exporting Countries
PMG	Pooled Mean Group
PRISMA	Preferred Reporting Itens for Systematic Reviews and Meta-Analyses
QML	Quasi-Maximum Likelihood
R&D	Research and Development
RE	Random Effects
RET	Renewable Energy Technologies
SJR	Scimago Journal Ranking
SLR	Systematic Literature Review
SNIP	Source Normalized Impact per Paper
TES	Thermal Energies Storage
U.S	United States
U.S.A	United States of America
UK	United Kingdom
WDI	World Development Indicators
WoS	Web of Science

Chapter 1 – General Introduction

1.1 Introduction

Economic growth and socio-economic development stand as paramount long-term objectives for nations across the globe. These two goals share a close and intricate relationship, although their interplay is not always straightforward to explicate. Socio-economic development is contingent upon economic growth, under the condition that sound political practices are enacted to facilitate this progression. It is worth noting that economic growth can transpire without commensurate improvements in the overall quality of life for the populace. Indeed, economic expansion can occur in tandem with a surge in poverty levels, provided there exists a socio-political and economic environment characterized by inadequate income distribution and a propensity to favor wealth concentration among a select segment of the population.

It is imperative to engage in discourse and scholarly investigation into the multifaceted determinants that influence economic growth, transcending the conventional metrics typically examined in macroeconomics textbooks. As a natural consequence, such efforts should inform policy formulation, ensuring that the upsurge in economic activity effectively translates into an enhanced quality of life for the broader population.

The Human Development Index (HDI) stands as a comprehensive metric designed to evaluate human development, encompassing three primary dimensions: health, education, and standard of living, as outlined by Roser (2014). The inclusion of this metric in the thesis is substantiated by the fundamental premise that economic growth should ideally culminate in broader social and economic development for the entire populace. Therefore, the examination of the intricate relationship between HDI and GDP is of paramount importance, as it provides essential insights for the formulation of sound public policies aimed at advancing human development.

The growth model postulated by Robert Solow underscores the significance of three pivotal determinants in fostering economic expansion: human capital, technological advancement, and labor. This model is recognized as an endogenous growth framework due to its emphasis on internal factors within an economy that propel long-term growth, as opposed to relying solely on exogenous elements.

The endogenous growth models applied in the context of this research are those developed by Lucas and Romer. Lucas's model delves into the notion that distinct technologies contribute to the creation of human capital and physical capital. Within this model, human capital serves as the sole input in the educational sector, denoting the skills, educational attainments, or individual talents possessed by each person.

In contrast, Romer's model introduces the concept of knowledge creation as an incidental outcome of investment (Barro & Sala-i-Martin, 2000). With an increase in physical capital, a firm becomes more proficient in production, a phenomenon termed "learning by doing" by Romer (Barro & Sala-i-Martin, 2000). However, an essential distinction between Lucas and Romer lies in their perspectives on how knowledge is generated and disseminated. Lucas contends that knowledge diffusion occurs through the conduit of human capital, while Romer suggests that it is intertwined with the participation of intellectually adept individuals (Romer, 1990). Human capital, in this context, represents the cumulative outcome of knowledge acquired through formal education or skill enhancement through practical experience.

Certainly, one of the crucial determinants that significantly contributes to economic growth is a country's infrastructure, encompassing vital elements such as the quality of its transportation networks, including roads and railways, which serve as the backbone for the efficient movement of people and goods. Additionally, the energy infrastructure, a focal point of this thesis, plays a pivotal role. However, our analysis extends beyond just energy consumption, taking into consideration the global energy transition trend. We seek to assess the relevance of the energy matrix in the context of economic growth and socio-economic development.

The relationship between energy consumption and economic activity has been a subject of extensive study, incorporating various hypotheses, including causality. These hypotheses encompass unidirectional causality from economic expansion to energy use (known as the conservation hypothesis), unidirectional causality from energy use to economic expansion (the growth hypothesis), and a bidirectional relationship (the feedback hypothesis) (Ã et al., 2010). An in-depth exploration of the individual contributions of gas, oil, coal, and renewable energy sources to GDP within energy matrices facilitates a more nuanced understanding of their impacts, thereby offering valuable insights for the formulation of effective public policies aimed at optimizing this relationship. It is worth underscoring that carbon dioxide (CO_2) emissions are a direct byproduct of fossil energy consumption. Consequently, there exists an environmental impact stemming from the confluence of energy consumption and economic growth. As such, the inclusion of carbon dioxide emissions in this research is of significant relevance, as it enables an examination of the environmental dimension in the context of economic growth and energy consumption.

This undertaking encompasses an examination of a diverse array of factors, one of which is the pervasive issue of the institutions. Uddin et al., (2023) contend that institutions play a pivotal role in shaping a nation's developmental path. Stryzhak et al., (2022) maintains that the quality of a society's institutional environment is intricately intertwined with the level of human development.

Corruption corrodes the foundation of trust, undermines the vitality of democratic institutions, impedes economic progress, and exacerbates pre-existing disparities, poverty, social cleavages, and environmental challenges (International, n.d.). Corruption can be defined as a form of misconduct within the public sector, characterized by the conduct of public officials who seek personal enrichment or that of their associates through the misappropriation or improper use of public resources under their control (Khumawala & Ramchand, 2005). From an economic standpoint, a substantial body of evidence underscores the detrimental impact of corruption on economic growth. This is primarily attributed to the fact that corruption hampers the efficiency of decision-making processes, often leading to choices influenced by non-economic factors. Consequently, the quality of information accessible to economic agents is compromised, which, in turn, results in escalated costs (Aidt, 2009; Balboa & Shinji, 2010; Khumawala & Ramchand, 2005). Corruption can effectively function as an unofficial tax on businesses, imposing a burden on their operations. This undue burden is ultimately borne by consumers in the form of elevated prices or diminished product and service quality, thereby exerting detrimental repercussions on the private sector, labor market, competition, innovation, and overall economic growth. This perspective is in line with the findings of Murphy et al. (1991), which indicate that corruption exerts adverse effects on economic growth. Furthermore, these detrimental effects tend to be more pronounced in countries beset by institutional deficiencies, as substantiated by the research of Amorim and Janielly (2018).

Nonetheless, it is important to acknowledge that there exist studies which arrive at a different conclusion, contending that corruption can, in fact, serve as a catalyst for economic growth. The "Greasing the wheels" hypothesis, as put forth by researchers such as Djankov et al. (2002), Dreher and Gassebner (2013), Huntington (1968), and Leff (1964), suggests that corruption may play a role in expediting business transactions, particularly in situations characterized by onerous regulatory constraints. Under this viewpoint, corruption is viewed as a means of lubricating the gears of economic activity, especially in contexts with extensive regulatory burdens.

Given the multitude of theoretical arguments surrounding the impact of corruption on economic growth, it is highly likely that corruption exerts a negative effect on long-term economic potential.

This thesis does not exclusively concentrate on endogenous growth, as contemporary economic dynamics have made it practically impossible for an economy to expand and progress in isolation from the global context. Consequently, globalization emerges as a pivotal factor that demands thorough comprehension, especially given the substantial increase in interactions between countries since the end of the Cold War.

Research by Dreher (2006) has revealed that globalization has a positive impact on economic growth, primarily by diminishing restrictions on economic flows. Likewise, Kali et al. (2007) have demonstrated a positive relationship between the number of trading partners and economic growth. However, Kim et al. (2016) have underscored that increased economic openness through international trade can lead to reduced short-term growth. In this light, numerous metrics are available to capture the influence of globalization on an economy, including Foreign Direct Investment (FDI) and trade openness, which is quantified as the difference between exports and imports relative to GDP. Nevertheless, in the context of this research, we have chosen to employ the KOF Globalization Index indicator, which comprehensively gauges a country's level of globalization, encompassing economic, social, and political dimensions.

1.2 Contextual Settings

In this section, we present some statistics related to the dependent variables used in the empirical analyses, specifically GDP in articles 2.1 and 2.2, and HDI in article 2.3. The data covers the following time periods: 2009-2019 for article 2.1, 1990-2019 for article 2.2. It is important to note that the analysis of economic growth in article 2.1 and 2.2 does not extend beyond 2019 due to the outbreak of the COVID-19 pandemic. This limitation is due to the potential disruptions in economic activity caused by the pandemic, which could introduce bias into the analysis. For article 2.3, the investigation period spans from 2012 to 2022. Unlike the other articles, this analysis includes the years affected by the COVID-19 pandemic because it focuses on human development, which is a broader and longer-term perspective.

In the first empirical article (2.1), we examine a diverse group of economies, which includes Australia, Brazil, Canada, Chile, Colombia, France, Germany, Greece, Ireland, Italy, Korea, Netherlands, Russia, Spain, the United Kingdom, and the USA. While these countries have varying income levels, it is important to note that none of them are classified as "poor" according to the World Bank's income classification. These countries fall into the categories of "High Income" (Australia, Canada, Chile, France, Germany, Greece, Ireland, Italy, Korea, Netherlands, Spain, the United Kingdom, and the USA), "Upper Middle Income" (Brazil), and "Upper Middle Income" (Colombia and Russia).

Significantly, these economies align with the classifications provided by central banks, exhibiting robust growth rates, largely surpassing the global average. This underscores the relevance of our investigation, as it offers an opportunity to assess and comprehend the successful strategies employed by these economies, as well as potential missteps, with the aim of replicating such practices in other nations to facilitate their prosperity.

The data pattern observed in the graph suggests an inverse movement between the EPU indicator and GDP, hinting at the possibility that economic policy uncertainty has an impact on GDP. However, it is important to note that correlation does not imply causation. Therefore, a more in-depth analysis, as conducted in investigation 2.1, is necessary to validate these observations.

The consumption of renewable energies is notably underrepresented in the energy consumption of these economies. Nevertheless, it is worth noting that during the observed period, there was an increase in the share of renewable energy consumption. This growth reflects the efforts of countries to pursue more sustainable and environmentally friendly forms of economic growth.

Article 2.2 focuses on the BRICS countries (Brazil, Russia, India, China, and South Africa), which are viewed as potential future developed economies. Notably, this group includes three economies ranked among the world's top 10: China (2^{nd}), India (5^{th}), and Brazil (9^{th}), according to World Bank data.

Data from the World Development Indicators (WDI) reveals that the proportion of renewable energy consumption in BRICS countries experienced a decline from 1990 to 2019. However, it is crucial to note that this reduction in consumption does not necessarily signify a corresponding decrease in production. In fact, data from British Petroleum (BP) indicates an increase in renewable energy production.

During the observed period, there were significant increases in renewable energy consumption in BRICS countries. Brazil witnessed a 725% increase representing a 25% of the total consumption ins 2019, while Russia saw a remarkable surge of 8,500%, despite renewable energy still constituting only 0.2% of total energy consumption in 2019. India experienced an astonishing 237,000% increase in renewable energy use, while China demonstrated an extraordinary rise of 1,600,000%, but it represents only 5.73% in 2019 of the total consumption. South Africa also showed a notable increase of 23,000% in renewable energy consumption. These substantial growth rates indicate a clear shift towards greater reliance on renewable energy sources within the BRICS nations, reflecting a global trend towards sustainability and environmentally responsible energy consumption.

As a result, non-renewable energy consumption has risen, contributing to increased environmental pressures. According to BP data, carbon dioxide emissions have followed an upward trajectory over the observed period in BRICS economies.

These statistics imply that the economic expansion of BRICS nations has placed environmental strains on the planet with the CO2 emissions. Therefore, it becomes essential to investigate the connection between renewable energy consumption and economic growth in the BRICS countries. This investigation aims to enhance our understanding of this relationship as we strive to achieve sustainable and environmentally responsible economic growth.

The third empirical article (2.3) diverges by focusing on the Human Development Index (HDI) as the variable of interest, with a specific focus on African countries. The study's sample comprises 39 countries with varying income levels, including low-income nations such as Burundi, Central African Republic, and Ethiopia, lower-middle-income countries like Algeria, Egypt, and Ghana, and upper-middle-income nations including Botswana, Mauritius, and South Africa. This diverse sample enables an in-depth examination of factors influencing human development across different income groups in Africa, shedding light on the complexities of socio-economic progress on the continent.

According to UNDP data, the average global HDI stands at 0.725. Only Algeria, Egypt, Mauritius, South Africa, and Tunisia have HDI values above this global average. These findings provide valuable insights into the state of socio-economic development on the African continent.

Within the African countries under examination in this study, the majority of the population resides in rural areas (26 of the countries). However, data from the observed period (2012-2022), when individuals are analyzed, suggests a potential rural-to-urban migration trend. The evidence indicates an upward trajectory in the percentage of individuals residing in urban areas, accompanied by a corresponding decrease in the number of people living in rural regions.

1.3 Research Questions

In order to address our overarching research questions, and considering the attributes of the panel data under examination, as well as the pertinent datasets at our disposal, we have devised the subsequent specific research questions:

1. How do endogenous growth models, specifically the Lucas and Romer models, help us understand the mechanisms behind knowledge creation and transmission and their role in fostering economic growth?
2. What is the relationship between GDP and the variables of technological progress, gross capital formation, human capital, disaggregated energy consumption, political stability, and economic development, and how do these variables collectively influence economic growth?
3. To what extent does political stability influence GDP, and how does it interact with economic growth dynamics?
4. What is the relationship between measures of globalization and Gross Domestic Product (GDP), and how do these indicators interact to impact economic growth?
5. How do patterns of energy consumption, both renewable and non-renewable, influence economic growth?
6. What is the relationship between the Human Development Index (HDI), and GDP, and how can this understanding inform the formulation of public policies aimed at promoting human development alongside economic growth?
7. What is the relationship between corruption and human development?
8. What is the role of institutions in socio-economic development?

With the articulation of these specific research questions, the primary aim is to offer policy recommendations and address the overarching questions at hand: How can the expansion of economic activity be effectively harmonized with the attainment of economic development? In light of the variables under scrutiny, what are the potential avenues that policymakers and governments should proactively adopt to enhance this relationship with efficacy?

This thesis consists of seven chapters and is presented in the form of articles/studies. The first chapter serves as an introductory section. The chapter 2 explain the doctoral thesis research model, providing a brief overview of the thesis. It includes a detailed description of the research objectives, conceptual model research design and research contribution, in summary the overall structure of the thesis.

The chapter 3 encompasses a Systematic Literature Review (SLR) that has resulted in the publication of an article in the journal Energies. This chapter critically examines the existing literature related to the topic under investigation.

Chapter 4 constitutes an empirical study that aims to enhance our understanding of the endogenous growth theory proposed by Lucas and Romer. It delves into the theoretical framework surrounding this concept and explores its implications.

Chapter 5 is another empirical study that focuses on economic growth, energy consumption, carbon emissions, and globalization. This chapter investigates the relationships among these variables and explores their dynamics within the context of the study. It is noteworthy that this chapter was presented at two international events, namely 5th Annual Conference of the Portuguese Association of Energy Economics (APEEN) 2021 and 8th International Conference on Energy and Environmental Research (ICEER) 2021. The research findings were shared with the academic community during these conferences, allowing for valuable discussions and exchanges of ideas. Additionally, a condensed version of the chapter was published as a short paper in Energy Reports (https://doi.org/10.1016/j.egyr.2022.01.031). The inclusion of these conference presentations and publication in a reputable journal adds credibility and visibility to the research conducted in this thesis.

Chapter 6 introduces a shift in the primary variable of interest, moving away from the Gross Domestic Product (GDP) and instead focusing on the Human Development Index (HDI). This chapter centers on the analysis of socio-economic development, particularly focusing on rural and urban areas.

The final chapter of this thesis comprises the general conclusions, which encompass several key aspects. It includes a summary of the main findings and results obtained throughout the research, along with their implications and significance in the broader context. The chapter also discusses the limitations encountered during the study, acknowledging any constraints or factors that may have influenced the research outcomes. Furthermore, it highlights potential avenues for future research, suggesting areas that could benefit from further investigation or exploration. Overall, this chapter provides a comprehensive wrap-up of the thesis, offering conclusive insights and reflections on the research conducted.

Chapter 2 - Doctoral Thesis Research Model

In line with the research questions elucidated above, this thesis is structured as a series of essays. The decision was made to shape the study as a compilation of articles, with each one dedicated to addressing specific research questions, aiming to offer comprehensive answers tailored to a specific sample. This approach is designed to bridge gaps in the existing literature and align with the availability of data for the study's focus.

Based on the research interest, this thesis is structured around two distinct approaches, which are further divided into four articles. The first approach entails a comprehensive literature review focusing on the central themes of the thesis, namely Economic Growth, Economic Development, and the Consumption of Renewable Energies. Three empirical articles with the primary objective of addressing the research questions through empirical analysis follow this.

1st) Approach: Economic Growth, Economic Development, and the Consumption of Renewable Energies: period of analysis 2008-2021.

1.1) Renewable Energy, Economic Growth and Economic Development Nexus: A Bibliometric Analysis, published in the Energies Journal in July 2021 (https://doi.org/10.3390/en14154578)

The primary aim of the first essay is to perform a bibliometric literature review that examines the relationship between Renewable Energy, Economic Growth, and Economic Development and to establish connections among the published literature. The study aims to use the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Page et al., (2021) through this approach it was possible to reach a sample of 111 articles selected by Web of Science and a sample of 199 academic articles selected by Scopus. In addition to the primary research objectives, this essay also serves as a comprehensive literature review focused on the central themes of the thesis.

The selection of the research period is based on the commitment of signatory countries to the Kyoto Protocol to reduce carbon emissions. The research spans from 2008, which marks the commencement of this commitment, through 2012, which signifies the conclusion of the first cycle of emissions reduction targets. This period encompasses the years of the first cycle and the subsequent period, providing a comprehensive view of the outcomes and developments in emissions reduction efforts.

2nd) Approach: The empirical approach was primarily directed at addressing the research questions within a specific period of analysis (1990-2022). This approach resulted in the creation of three distinct articles, which aimed to investigate and fill the gaps identified in the literature review conducted in the initial part of the thesis.

2.1) Exploring the Relationship Between Technological Progress, Human Capital, Political Uncertain, Energy Consumption, and Economic Growth: Evidence from a Panel Data Analysis, submitted to the Journal of the Knowledge Economy in November 2023.

The second essay, but the first empirical research, aims to investigate the endogenous economic growth, through gross capital formation, labor force with basic and advanced education, financial development as a proxy for technological progress, and energy consumption using various matrices such as Coal Consumption, Natural Gas, Oil, and Renewable Energy. The study also considers the Human Development Index and the Global Economic Policy Uncertainty Index (GEPU) to capture economic development and political stability, respectively. The analysis will focus on the Gross Domestic Product between 2009 to 2019, a period that includes the post-crisis subprime (2008) and pre-COVID pandemic (2019) period. The estimates will be conducted for 16 economies, including Australia, Brazil, Canada, Chile, Colombia, France, Germany, Greece, Ireland, Italy, Korea, Netherlands, Russia, Spain, the United Kingdom, and the USA. The data will be also obtained from public databases.

This study aims to extend the endogenous growth models developed by Lucas and Romer, which were originally built upon Solow's model. Romer's model emphasizes the role of technological spillovers, whereby knowledge is freely available to all agents in the economy, while Lucas' model asserts that technological progress is closely linked to human capital, which encompasses an individual's skills and training. In summary, this research seeks to augment Solow's model by incorporating the ideas proposed by both Lucas and Romer and further considers the impact of institutional variables on economic growth.

2.2) The Impact of Renewable and Non-Renewable Energy Sources, and KOF Globalization Measures on Economic Growth: A Study of BRICS Countries, submitted to the EconomiA Journal in July 2023.

The second empirical essay in our series seeks to identify the economic, social, and environmental determinants that influence GDP frameworks. Through a review of the relevant literature, we will identify the most significant socioeconomic determinants, as well as the impact renewable and non-renewable energy consumption, and the KOF Globalization Index on economic growth and development. Our analysis will focus on BRICS (Brazil, Russia, India, China, and South Africa) countries from 1990 to 2019, using public databases such as the World Development Indicators (WDI), the KOF Swiss Economic Institute, and data from British Petroleum (BP). To the best of our knowledge, there has been no prior research on the relationship between economic growth, renewable and non-renewable energy, and the interaction of KOF globalization measures in the BRICS group countries, namely Brazil, Russia, India, China, and South Africa.

In our proposed model of economic growth, we aim to incorporate the interactions among KOF globalization measures in economic, social, and political dimensions, building on previous studies conducted by Leal et al. (2020). Our specific goal is to explore the trade-offs between economic growth and these measures of globalization. Thus, our study has important implications for designing appropriate globalization interactions on different dimensions, while meeting the objectives of economic growth policies in the integrated BRICS countries. We also propose that significant effects may exist among these interactions of KOF globalization dimensions and economic growth, which are essential for the expansion of these economies (BRICS). Identifying such effects can inform policies and strategies that facilitate economic growth and the positive impacts of globalization.

2.3) Impact of Socio-Economic Factors on Human Development: A Dynamic Panel Analysis of African Rural and Urban Contexts, submitted to the Social-Economic Planning and Science in November 2023.

The final empirical article investigates socio-economic development, as measured by the Human Development Index (HDI), in Africa, a continent characterized by a prevalence of poverty. The study covers the period from 2012 to 2022 and aims to unravel the drivers of socio-economic development in both rural and urban contexts.

Drawing on the regional development model proposed by Boldyrev et al. (2019), the study considers a range of variables, including population, employment, consumption of both fossil and renewable energies, carbon dioxide emissions, corruption, technical progress, and access to electricity, within the rural and urban spheres. This approach represents a novel contribution to the region under investigation, thereby enhancing the significance of the research.

The proposed model seeks to elucidate, in a distinct manner for rural and urban areas, which variables genuinely contribute to enhancing the overall quality of life for the population. By comprehending these effects, the research endeavors to facilitate the development of policies and strategies aimed at effectively improving the quality of life for the African population.

The choice of these approaches is rooted in data availability and the research opportunities that emerged during the doctoral study. The thesis is structured into four peer-reviewed articles, all of which have been published or submitted to international academic journals related to social science and energy.

The first article (1.1) serves as the foundation of the thesis, delving into the Economic Growth, Economic Development, and Renewable Energy nexus. It functions as both our literature review and a guiding framework for the subsequent chapters, with the aim of exploring and addressing gaps in the existing literature.

The other three articles (2.1, 2.2, and 2.3) take an empirical approach, as previously mentioned, and focus on the examination of economic growth (2.1 and 2.2) and development (2.3). These articles investigate the intricate interactions between macroeconomic and energy variables and the variables of interest (dependent variables), shedding light on their relationships.

In summary, the thesis comprises four articles employing two distinct approaches. The selection of variables for each analysis was contingent on data availability. While some variables were included in multiple models due to their strategic relevance, it is important to note that the individuals investigated in the studies were not duplicated across the analyses.

1st Approach: Output - Economic Growth, Economic Development, and the Consumption of Renewable Energies.

1.1) Bibliometric analysis is a scientific, computer-assisted research methodology used to identify core research areas or authors and their interrelationships. This approach involves an exhaustive examination of all publications related to a specific topic or field of study (Bellis, 2009; Han et al., 2020). The study employs the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) approach (Page et al., 2021) to screen the articles. This method facilitated the selection of articles. To identify connections between the articles and uncover clusters and links between the terms and researchers, the study utilized VOSviewer software.

2nd Approach: Dependent Variables (Output): Gross Domestic Product (GDP) and Human Development Index (HDI).

2.1) This study aims to build upon the endogenous growth models introduced by Lucas and Romer, which extend Solow's model. Solow's model places significant emphasis on technological progress as the primary driver of economic growth. Romer's model goes a step further by incorporating the concept of technological spillover, which means that advancements in technology become accessible to a larger population. The analysis in this study is carried out through the application of econometric models, specifically the Generalized Method of Moments (GMM) and Bias-Corrected Estimation (BCE). The study considers the variables, including Gross Domestic Product (GDP), financial development as a proxy for technical progress, labor force with basic and advanced education, gross fixed capital formation, energy consumption (including coal, natural gas, oil, and renewable sources), the Global Economy Policy Uncertainty (GEPU) indicator, which measures political and economic stability, and the Human Development Index (HDI).

2.2) This study examines the BRICS economies spanning from 1990 to 2019. It delves into the connections between the consumption of renewable and non-renewable energy, economic growth as measured by Gross Domestic Product (GDP), and KOF globalization indicators. The primary objective is to construct three equations to gain insights into the interdependencies between these variables and the production equation. Additionally, the study examines the causality relationships among the variables under investigation. The study utilized the econometric model Autoregressive Distributed Lag (ARDL) for analysis and Dumitrescu-Hurlin Causality Test.

2.3) This study makes a valuable contribution by conducting an in-depth analysis of human development, with a primary focus on using the Human Development Index (HDI) as a key metric. Furthermore, it offers a comprehensive examination that differentiates between residents of rural and urban areas within the studied sample. Given this context, the research aims to comprehend the Differential Drivers of Human Development in Rural and Urban Areas. HDI serves as the variable of interest (dependent), while the explanatory variables encompass population, employment, consumption of non-renewable and renewable energies, CO2 emissions, access to electricity, technical progress, and corruption. The study employs two econometric approaches for estimation: Quasi-Maximum Likelihood Estimation (QMLE) and the Generalized Method of Moments (GMM). These methods are used to assess the relationships between the variables and their impact on human development, specifically in rural and urban contexts.

A comprehensive description of the data sources and methodologies employed in each article is provided in the respective sections of the individual papers. The specific method used in each analysis is outlined with a brief description below:

Gross Domestic Product (GDP):

Gross Domestic Product (GDP) serves as the dependent variable in the first two empirical articles of this thesis.

In the first empirical article (2.1), the Generalized Method of Moments (GMM) and Bias-Corrected Estimation (BCE) were applied for analysis. GMM, a widely utilized approach, is particularly effective in addressing heteroskedasticity of unknown form (Baum et al., 2003). This methodology was initially introduced by Hansen (1982). GMM stands out as a computationally efficient method for estimating model parameters, offering consistent and asymptotically distributed estimators. It serves as a valuable alternative to the maximum likelihood estimator, especially when dealing with scenarios involving dependence on the probability distribution (Salkind, 2013). Additionally, GMM helps mitigate dynamic panel bias, which can occur due to the correlation between the variable $y_{i,t-1}$ and fixed effects, potentially leading to biased estimators. The bias-corrected (BCE) estimator is designed to tackle the bias arising from dynamic panel data models. It accomplishes this by adjusting moment conditions while preserving the low variance property of Fixed Effects (FE) and Random Effects (RE) estimators. The BCE estimator is particularly well-suited for higher-order autoregressive models and provides versions for both FE and RE specifications. It offers the advantage of a well-defined asymptotic distribution and facilitates the computation of standard errors. Additionally, robust techniques are available to adjust standard errors when dealing with cross-sectional dependence, as highlighted by Kripfganz and Breitung (2022).

The second empirical article (2.2) employs an alternative methodology to estimate the relationships with GDP, utilizing the Autoregressive Distributed Lag (ARDL) approach. In situations where there is a natural order of variables, with one variable considered as the response variable to the others, a single-equation ARDL model can simplify the analysis and enhance inference efficiency, as highlighted by Kripfganz and Schneider (2018). The choice of ARDL is justified by it is ability to produce reliable results even with a limited sample size, which is the case in this study. Additionally, it offers the advantage of conducting the limit test regardless of whether the explanatory variables are purely integrated of order zero (I(0)), purely integrated of order one (I(1)), or co-integrated, as explained by Narayan and Narayan (2005). The ARDL model can be conveniently transformed into the Error-Correction (EC) form, which separates the long-term relationship from the short-term dynamics. When dealing with nonstationary variables, the long-term relationship embedded in an EC model corresponds to a cointegrating relationship, as elucidated by Kripfganz and Schneider (2018). Furthermore, this procedure ensures empirical robustness for both the short and long-term, as demonstrated by Shahbaz et al. (2018). We also apply the Dumitrescu and Hurlin (DH) test, this test is valuable in accounting for the two observed dimensions of heterogeneity in the data: the heterogeneity of causal relationships and the heterogeneity of the regression model (Dumitrescu & Hurlin, 2012). The extension proposed by Dumitrescu and Hurlin (2012) aims to detect causality in panel data, building upon the original framework introduced by Granger (1969). The DH test assesses the presence of causality by examining the significant effects of past values of variable x on the current value of variable y. Therefore, the null hypothesis can be formulated as follows: $H_0: \beta_{i1} = \cdots = \beta_{ik} = 0 \quad \forall_i = 1, \dots, N$ (Lopez & Weber, 2017). This null hypothesis suggests no causality across all individuals in the panel. The DH test acknowledges that causality may exist for some individuals but not necessarily for all. Thus, the alternative hypothesis is expressed as: $H_1: \beta_{i1} = \cdots = \beta_{ik} = 0 \ \forall_i = 1, \dots, N_1;\ \beta_{i1} \neq 0 \ or \dots or \ \neq \beta_{ik} = 0 \quad \forall_i = N_1 + 1, \dots, N$ (Lopez & Weber, 2017).

Human Development Index (HDI):

In this last article (2.3), there is a change in the dependent variable, as it shifts from GDP to HDI. Similar to the approach used in article 2.1, the GMM method is applied in these estimates with some differences. Dynamic panel data analysis commonly deals with causal relationships that evolve over time, reflecting the dynamics of the underlying phenomena (Ullah et al., 2018). To address these dynamic relationships, estimation techniques for dynamic panel data incorporate lagged dependent variables as explanatory factors. These lagged values of dependent variables serve as instruments to mitigate endogeneity. These instruments are often termed 'internal instruments' because they originate from the established econometric model (Ullah et al., 2018). However, an excessive number of instruments relative to the cross-sectional sample size can introduce finite-sample biases in coefficient and standard error estimates, potentially weakening the effectiveness of specification tests (Roodman, 2009). To mitigate this issue and reduce the number of instruments, researchers typically employ two approaches. First, they limit the number of lags used as instruments. Second, they opt for using standard instruments instead of GMM-type instruments (Kripfganz, 2020). Two primary transformation methods are commonly used: the first-difference transformation, often referred to as the one-step GMM, and the second-order transformation, known as the two-step GMM. The one-step difference estimator has certain limitations. For instance, if the most recent value of a variable is missing, applying the first-difference transformation can result in a significant loss of observations (Roodman, 2009). Additionally, this method demonstrates efficiency only under the assumption of homoscedasticity in the data. Even when homoskedasticity is present, it's important to note that the one-step sys-GMM can still be inefficient (Kripfganz, 2020). We also employ the Quasi-maximum Likelihood Estimation (QMLE) is a method used to estimate parameters in linear dynamic panel-data models, especially when dealing with a limited time horizon and a substantial number of cross-sectional units (Kripfganz, 2016). Given the specific context of this research, which involves a limited time horizon and a large sample size comprising numerous countries, QMLE is a suitable methodology to employ. This approach aligns well with the given circumstances and is well-suited for obtaining meaningful estimations in the context of linear dynamic panel-data models. The QML estimators offer an attractive alternative to other estimation approaches in terms of efficiency and finite-sample performance, provided that all underlying assumptions are met (Kripfganz, 2016). Both random and fixed effects QML estimators can be seen as limited-information maximum-likelihood estimators. They fall within the framework of structural equation modeling or full-information maximum-likelihood approaches and incorporate multiple cross-equation constraints (Kripfganz, 2016). These QML estimators are consistent and offer significant efficiency advantages. However, there is a trade-off between efficiency and robustness. This approach can become inconsistent if the explanatory variables (apart from the lagged dependent variable) are not strictly exogenous with respect to the idiosyncratic error component. Additionally, if unaccounted serial correlation beyond the first-order autoregressive term exists, the consistency of the estimators is compromised (Kripfganz, 2016).

References

(Chapter 1 and 2)

Ã, I. O., Abdoli, G., Farahani, Y. G., Abosedra, S., Dah, A., Ghosh, S., Ahmed, M., Azam, M., Akadiri, S., Bekun, F. V., Taheri, E., Akadiri, A., Akinlo, A. E., Ameyaw, B., Oppong, A., Abruquah, L. A., Ashalley, E., Apergis, N., Payne, J. E., … Andrews, D. W. K. (2010). A literature survey on energy – growth nexus. Energy Policy, 38(1), 340–349. https://doi.org/10.1016/j.enpol.2009.09.024

Aidt, T. S. (2009). Institutions and Economic Development. Institutions, Transition Economies, and Economic Development, April, 113–126. https://doi.org/10.4324/9780429499760-9

Oliveira, Janielly Amorim de. Corrupção e crescimento econômico. 2017. 20 f. Trabalho de Conclusão de Curso (Bacharelado em Ciências Econômicas) —Universidade de Brasília, Brasília, 2017.

Balboa, J. D., & Shinji, T. (2010). Corruption and development, revisited.

Barro, R. J., & Sala-i-Martin, X. (2000). Book Economic Growth. In Analysis (Vol. 7).

Baum, C. F., Schaffer, M. E., & Stillman, S. (2003). Instrumental Variables and GMM: Estimation and Testing. The Stata Journal: Promoting Communications on Statistics and Stata, 3(1), 1–31. https://doi.org/10.1177/1536867x0300300101

Bellis, N. De. (2009). Bibliometrics and Citation Analysis: from the Science Citation Index to Cybermetrics. In The Scarecrow Press Inc. https://doi.org/10.1087/20100312

Boldyrev, Y., Chernogorskiy, S., Shvetsov, K., Zherelo, A., & Kostin, K. (2019). A mathematical model of regional socio-economic development of the russian arctic zone. Resources, 8(1), 1–10. https://doi.org/10.3390/resources8010045

Djankov, S., La Porta, R., Lopez-de-Silanes, F., & Shleifer, A. (2002). The Regulation of Entry. Quarterly Journal of Economics. 117-1, pp. 1–37. Duggan,. The Quarterly Journal of Economics, CXVII(February), 437–452. https://doi.org/10.1162/003355302753399436

Dreher, A. (2006). Does globalization affect growth? Evidence from a new index of globalization. Applied Economics, 38(10), 1091–1110. https://doi.org/10.1080/00036840500392078

Dreher, A., & Gassebner, M. (2013). Greasing the wheels? The impact of regulations and corruption on firm entry. Public Choice, 155(3–4), 413–432. https://doi.org/10.1007/s11127-011-9871-2

Dumitrescu, E., & Hurlin, C. (2012). Testing for Granger non-causality in heterogeneous panels. Economic Modelling, 29(4), 1450–1460. https://doi.org/10.1016/j.econmod.2012.02.014

Granger, C. W. J. (1969). Methods, Investigating Causal Relations by Econometric Models and Cross-spectral. Econometrica, 37(3), 424–438.

Han, J., Kang, H. J., Kim, M., & Kwon, G. H. (2020). Mapping the intellectual structure of research on surgery with mixed reality: Bibliometric network analysis (2000–2019). Journal of Biomedical Informatics, 109(June), 103516. https://doi.org/10.1016/j.jbi.2020.103516

Hansen, lars peter. (1982). Large Sample Properties of Generalized Method of Moments Estimators. Econometrica, 50(4), 1029–1054.

Huntington, S. P. (1968). Political order in changing societies. In Political Order in Changing Societies. https://doi.org/10.5771/0506-7286-1970-2-257

What is corruption? (s.d.). Transparency.org. https://www.transparency.org/en/what-is-corruption

Kali, R., Méndez, F., & Reyes, J. (2007). Trade structure and economic growth. Journal of International Trade and Economic Development, 16(2), 245–269. https://doi.org/10.1080/09638190701325649

Khumawala, S., & Ramchand, L. (2005). Country Level Corruption and Frequency of Issue in the U.S. Market. Journal of Public Budgeting, Accounting & Financial Management, 341–364.

Kim, D. H., Lin, S. C., & Suen, Y. B. (2016). Trade, growth and growth volatility: New panel evidence. International Review of Economics and Finance, 45(32), 384–399. https://doi.org/10.1016/j.iref.2016.07.006

Kripfganz, S. (2016). Quasi–maximum likelihood estimation of linear dynamic short-T panel-data models. Stata Journal, 16(4), 1013–1038. https://doi.org/10.1177/1536867x1601600411

Kripfganz, S. (2020). Introduction System GMM Postestimation Special features Summary Generalized method of moments estimation of linear dynamic panel data models. http://www.kripfganz.de/stata/

Kripfganz, S., & Breitung, J. (2022). Bias-corrected estimation of linear dynamic panel data models (pp. 1–15).

Kripfganz, S., & Schneider, D. C. (2018). ARDL : Estimating autoregressive distributed lag and equilibrium correction models. London Stata Conference September 7, 2018, 1–44.

Leal, P. H., Marques, A. C., & Shahbaz, M. (2020). The role of globalisation, de jure and de facto, on environmental performance: evidence from developing and developed countries. Environment, Development and Sustainability, 0123456789. https://doi.org/10.1007/s10668-020-00923-7

Leff, N. H. (1964). Economic Development Through Bureaucratic Corruption. American Behavioral Scientist, 8(3), 8–14. https://doi.org/10.1177/000276426400800303

Lopez, L., & Weber, S. (2017). Testing for Granger causality in panel data. 4, 972–984. https://doi.org/10.1177/1536867X1801700412

Murphy, K. M., Shleifer, A., & Vishny, R. W. (1991). The Allocation of Talent: Implications for Growth. The Quarterly Journal of Economics, 106(2), 503. https://doi.org/10.2307/2937945

Narayan, P. K., & Narayan, S. (2005). Estimating income and price elasticities of imports for Fiji in a cointegration framework. Economic Modelling, 22(3), 423–438. https://doi.org/10.1016/j.econmod.2004.06.004

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. PLoS Medicine, 18(3), e1003583. https://doi.org/10.1371/journal.pmed.1003583

Romer, P. M. (1990). Endogenous Technological Change. The Journal of Political Economy, Vol. 98, No. 5, Part 2: The Problem of Development: A Conference of the Institute for the Study of Free Enterprise Systems. (Oct., 1990), pp. S71-S102.

Roodman, D. (2009). A Note on the Theme ofToo Many Instruments. Oxford Bulletin of Economicsand Statistics, 1, 135–158. https://doi.org/10.1111/j.1468-0084.2008.00542.x

Roser, M. (2014). Human Development Index (HDI). Published Online at OurWorldInData.Org. Retrieved from: "https://Ourworldindata.Org/Human-Development-Index" [Online Resource].

Salkind, N. (2013). Generalized Method of Moments. Encyclopedia of Measurement and Statistics. SAGE publications. https://doi.org/10.4135/9781412952644.n185

Shahbaz, M., Chaudhary, A. R., & Shahzad, S. J. H. (2018). Is energy consumption sensitive to foreign capital inflows and currency devaluation in Pakistan? Applied Economics, 50(52), 5641–5658. https://doi.org/10.1080/00036846.2018.1488059

Stryzhak, O., National, S. K. K., Tupa, M., & Rodzik, J. (2022). Relationship Between the Level of Human Development and Institucional Quality. Economics & Sociology, 15(2), 274–295. https://doi.org/10.14254/2071-789X.2022/15-2/1

Uddin, I., Ahmad, M., Ismailov, D., Eid, M., Akhmedov, A., Khasanov, S., & Ul, M. (2023). Research in Globalization Enhancing institutional quality to boost economic development in developing nations : New insights from CS-ARDL approach. Research in Globalization, 7(June), 100137. https://doi.org/10.1016/j.resglo.2023.100137

Ullah, S., Akhtar, P., & Zaefarian, G. (2018). Dealing with endogeneity bias: The generalized method of moments (GMM) for panel data. Industrial Marketing Management, 71(January), 69–78. https://doi.org/10.1016/j.indmarman.2017.11.010

Chapter 3 – Renewable Energy, Economic Growth and Development Economic Nexus: A Bibliometric Analysis[1]

3.1 Introduction

The investigation of what drives economic growth and development is a theme that will never cease to be relevant in academia. The nexus between economic growth/development and energy consumption is a subject that has been extensively explored over the years. For example, recent studies have delved into this relationship, including those by Ã et al. (2010), Ahmed and Azam (2016), Dogan and Deger (2018), Esen and Bayrak (2017), Fang et al. (2017), Kablamaci (2017), Pastén et al. (2015), Tang, Xu, Deng, Hongmei, Zhang, Baosheng, Snowden, Simon, and Höök (2016), and Yu, Tiffany Hui Kuang, Huang, Meng Chen, and Huarng (2016). These studies highlight a significant relationship between energy consumption and economic growth, providing crucial insights for the development of policies and strategies based on the behavior of economic growth in relation to energy consumption.

As carbon dioxide emissions have increased, research has begun to link this rise with increased economic activity, prompting investigations into the role of energy consumption. Notable studies in this area include those by Jamel and Abdelkader (2016), Abdul Rauf et al. (2018), and Sekrafi and Sghaier (2018). Mardani et al. (2019) conducted a bibliometric review on this topic and concluded that there is bidirectional causality between economic growth and CO2 emissions, indicating that efforts to reduce emissions may also impact economic growth (Mardani et al., 2019).

It is clear the existence between a difficulty in reconciling economic activity and energy consumption with the conservation of the environment; it is clear the need to encourage sustainable economic growth. Having exposed this, the present work proposes to build a bibliometric review that takes into account studies investigating the relationship between Renewable Energy, Economic Growth and Development Economic Nexus in order to understand which direction this field of study is taking.

The present work makes use of the Scopus database to search keywords, title and abstract that are related to the terms Renewable Energy, Economic Growth and Development Economic between the years 2008 and May 2021. The selection of the articles used in the research was made through the

[1] Oliveira, H., & Moutinho, V. (2021). Renewable energy, economic growth and economic development nexus: A bibliometric analysis. *Energies*, *14*(15). https://doi.org/10.3390/en14154578

PRISMA methodology, this work was also proposed to quantify the impact of the papers and journals that published on the subject in the period, and finally, an analysis was made, with the help of VOSviewer software, cluster and links between the terms used and the researchers. To the best of our knowledge, there is no research that has proposed to analyze on Renewable Energy, Economic Growth and Development Economic publications. Therefore, the present study is relevant because it analyzes the trends, origins and gaps to be explored on a theme that has become more relevant each year.

The remainder of this study is structured as follows. Section 2 presented a brief literature review. Section 3 discusses research methodology of the paper; Section 4 presents results and findings of this paper based on the study aims. Section 5 of this paper attempted to discuss the obtain findings and results and Section 6 provides some conclude remarks, limitations of this study, and suggestions for future papers.

3.2 Literature Review

In this section, a brief literature review on bibliometric review and systemic review is made. Wu et al. (2021) and Shi & Yin (2021) set out to study the footprints of degradation, one focusing on environmental degradation itself Wu et al. (2021) and the other through the carbon footprint Shi & Yin (2021). Studies differ methodologically; Wu et al. (2021) is a bibliometric analysis, while Shi & Yin (2021) is a systematic review. Wu et al. (2021) researched the keywords "water footprint", "carbon footprint", "land footprint", "biodiversity footprint", "chemical footprint", "nitrogen footprint", "phosphorus footprint", "PM2.5 foot- print", "PM10 footprint" and "ozone footprint" in the Web of Science (WoS) database for the period 1986-2019, after screening processes reached a sample of 4352 articles. The results indicate that the U.S. and China are the countries that have developed the most research on the subject in the period and those with the highest number of cooperation among themselves. In addition, it was emphasized that "water footprint", "carbon footprint" are the most studied terms in relation to the other used in the research. Finally, the authors concluded that the most recent research focuses on the carbon footprint related to supply production chains, greenhouse gas emissions, water consumption in agriculture and environmental issues related to construction (Wu et al., 2021). While the study proposed by Shi & Yin (2021), we used the same database, but for the 1992-2019 interval and searched only the keyword "carbon footprint", obtaining a sample of 7450 articles. The results indicate that research on the subject began to grow in 2008 and 4 topics were "international trade", "life cycle assessment", "ecological footprint", and "supply chain". There has also been a very large interaction between US and European Union (EU) research, but in recent years, research from China has been increasing and standing out. The Journal of Cleaner Production is the most prominent. Finally, research in Economics, Economic, and Political seems to be the most recent ascendant (Shi & Yin, 2021) themes. B. Yu et al. (2021) developed a systematic review on carbon leakage with the following questions, what are the generation channels and the factors of the leakage? What methodologies are used to evaluate the leak? Which topics need more attention to formulate more effective climate policies? (B. Yu et al., 2021). The research used the keywords "carbon leakage" "carbon leakage" "emission transfer" in the WoS database for the period 2000-2020, with screening techniques reached

407 articles for research. The researchers concluded that many studies have focused on the loss of competitiveness of the intense emission sectors, caused mainly by international trade, and there is not enough debate about the negative leak channel. In addition, the authors point to the absence of quantitative methodologies for carbon leaks (B. Yu et al., 2021).

With the intention of providing an overview of the work done on the Environmental Kuznets' Curve (EKC), Bashir et al. (2021) proposed a bibliometric analysis. Using the WoS database, he analyzed the publications made among 1999-2010 and with the PRISMA approach, reached a sample of 1775 articles to study. The results of the study indicate that research has grown exponentially in recent years, and that China, the U.S., Turkey and Pakistan are the countries with the highest academic production on the subject. In addition, the authors surveyed the journals that published the most in the period being Environmental Science and Pollution Research, Journal of Cleaner Production, Ecological Economics, and Energy Policy, while the author with the most publications is Muhammad Shahbaz (Bashir et al., 2021). Also in the topic EKC, Koondhar et al. (2021) used the WoS database to make a study of publications on the subject in the last two decades (1999-2019), of a universe of 59,225 documents were investigated in this research 2,384. The results found by the authors, based on co-citation, indicate that the most relevant journal in this topic is Ecological Economics, in addition, of the 10 most relevant journals 7 are published by Elsevier. The countries with the highest number of citations are China, USA and Turkey the same order obtained by Bashir et al. (2021). The most influential researcher is Muhammad Shahbaz, the same result obtained by Bashir et al. (2021). And not coincidentally the most relevant institution is the Beijing Institute of Technology, where Muhammad Shahbaz is a professor (Koondhar et al., 2021).

In order to evaluate how discourse and research on collaborative consumption has evolved De las Heras et al. (2021) proposed a bibliometric review and a network analysis. The keywords "shared economy", "sharing economy", "collaborative economy", "collaborative consumption" and "peer economy", were searched in WoS for the period 1978 to 2020, the research generated a sample of 2152 documents. The results indicate that China and the U.S. are the publishing leaders, but despite the large number of works of China, the references in this field are USA and Europe. The most relevant researcher is Russell Belk. Finally, it was concluded that it is a multidisciplinary field, since studies on the subject were found in 120 categories of the 236 that Web of Science has (De las Heras et al., 2021).

Ghobakhloo et al. (2021) proposed a systemic and bibliographic review on industry 4.0, the study used two databases for the survey of Scopus and WoS articles published until 2020, the terms used for research were "Industry 4.0", "Industrie 4.0" and "Fourth Industrial Revolution", following PRISMA protocols, a sample of 745 articles was obtained. The authors concluded that industry 4.0 is motivated by profit; the value of digital transformation is materialized as corporate profit. In addition, the authors pointed out factors that can determine success or failure depends on favorable conditions such as government incentives and an abundance of resources for the digital transition in Industry 4.0 to be achieved (Ghobakhloo et al., 2021).

With the objective of detailing at what stage and what are the current research trends on Thermal Energies Storage (TES), Borri et al. (2021) elaborated a bibliometric analysis on the subject. The Scopus database was used for the research that used all available coverage until September 21, 2020. The authors divided the results of the research into three categories, including buildings, districts, and roads and bridges (Borri et al., 2021). As far as buildings are, the results indicated that it is and the most studied category, the USA was the country to publish the first relevant studies on the subject and the most researched line is the demand for cooling by optimized control techniques. While in Europe, of latent heat thermal energy storage through passive techniques and demand side management strategies, in China there is a focus on material study, and economic analysis seems to be the trend of the most recent studies for buildings. Studies on TES applied to districts began to increase in 2013 and are led by Europe; TES at district level has been investigated at system level, mainly applications of solar systems and cogeneration systems; the most recent studies have investigated economics and techno-economic. Finally, studies applied to roads and bridges do not attract many researchers, Norway, Japan and China are the countries with the most Publications (Borri et al., 2021). Ding et al. (2021), did a bibliometric study between 2000 and 2019 on TES in order to understand the trend and future of this field of research. The authors' analysis points out that latent-heat TES has been the focus in recent years, but thermochemical TES and its hybrid TES technologies appear to be the next focus of researchers (Ding et al., 2021).

A bibliometric and systematic review was proposed by Bortoluzzi et al. (2021). To understand the standards of key performance indicators (KPI) and multicriteria decision-making models (MCDM/A) in the context of renewable energy technologies (RET). Moreover, answer the following questions "Is there a pattern in the use of performance criteria to select and assess RET performance?"; "Is there a pattern in the use of multicriteria models for decision making to select and assess RET performance?". To find these answers, 142 articles from the WoS database were selected between 1998 and 2019. The authors concluded that there is a growth trend in this research, mainly from 2015. According to authors, the results of this study demonstrated a preference in the use of synthesis models rather than overlap, the importance of considering political and technical indicators beyond those related to the Triple Bottom Line in decision-making, and the importance of MCDM/A in achieving the sustainable development goals of the United Nations agenda (Bortoluzzi et al., 2021).

A mapping of a 21st century problem, poverty energy, was proposed by Xiao et al. (2021), so a bibliometric analysis was made, using the Web of Science database and for the 1999-2019 temporal sample, they obtained 1018 articles in the sample. The results show that 2003 is the founding year of energy poverty research, 982 institutions developed research on the subject. In addition, the results indicated that the largest cooperation occur between UK, the USA, Australia, and Italy. Among the periods Energy Policy is that publishes on the subject the longest, while Renewable and Sustainable Energy Reviews publishes the studies with greater influence; and Sovacool is the researcher with the highest number of publications and the most influential. Finally, the authors pointed out 4 gaps that should be research trend in the coming years, they are Energy Poverty in Developing Countries, Impacts of Energy Poverty on Vulnerable Groups, Root Causes of Energy Poverty, and Consequences of Emission Reduction Policies (Xiao et al., 2021).

With the proposal to analyze simultaneous occurrence of publications by year, keyword trends, co-citations, bibliographic coupling and analysis of co-authorship, countries and institutions and to have to understand the trends of research on sustainability and tourism Cavalcante et al. (2021), a bibliometric review was used. With the analyses proposed by Cavalcante et al. (2021) concluded that there is significant growth in studies relating tourism and sustainability; Spain is the most influential country in a non-coincidental way, the author with the largest number of studies is the Spanish Xavier Font. Sustainability is the journal with the most publications in the period studied (1997-2020), while Griffith University is the institution that contributes the most on the subject (Cavalcante et al., 2021).

There are no generalized studies alone, Adedayo et al. (2021) made a bibliometric analysis for Nigeria and the publications on energy directed to the country among 1974-2019 on the Basis Scopus. The results indicate an exponential growth from 2016, since the average increased from 113 publications per year among 2006-2015 and increased to 326 among 2016-2019. Nigerian researchers, on this topic, contribute more South Africa, Malaysia, the United States and the United Kingdom institutions. In addition, most studies are renewable energies (solar energy, wind energy and biomass energy) and not on the main energy matrix in the country (gas and hydro energy) (Adedayo et al., 2021).

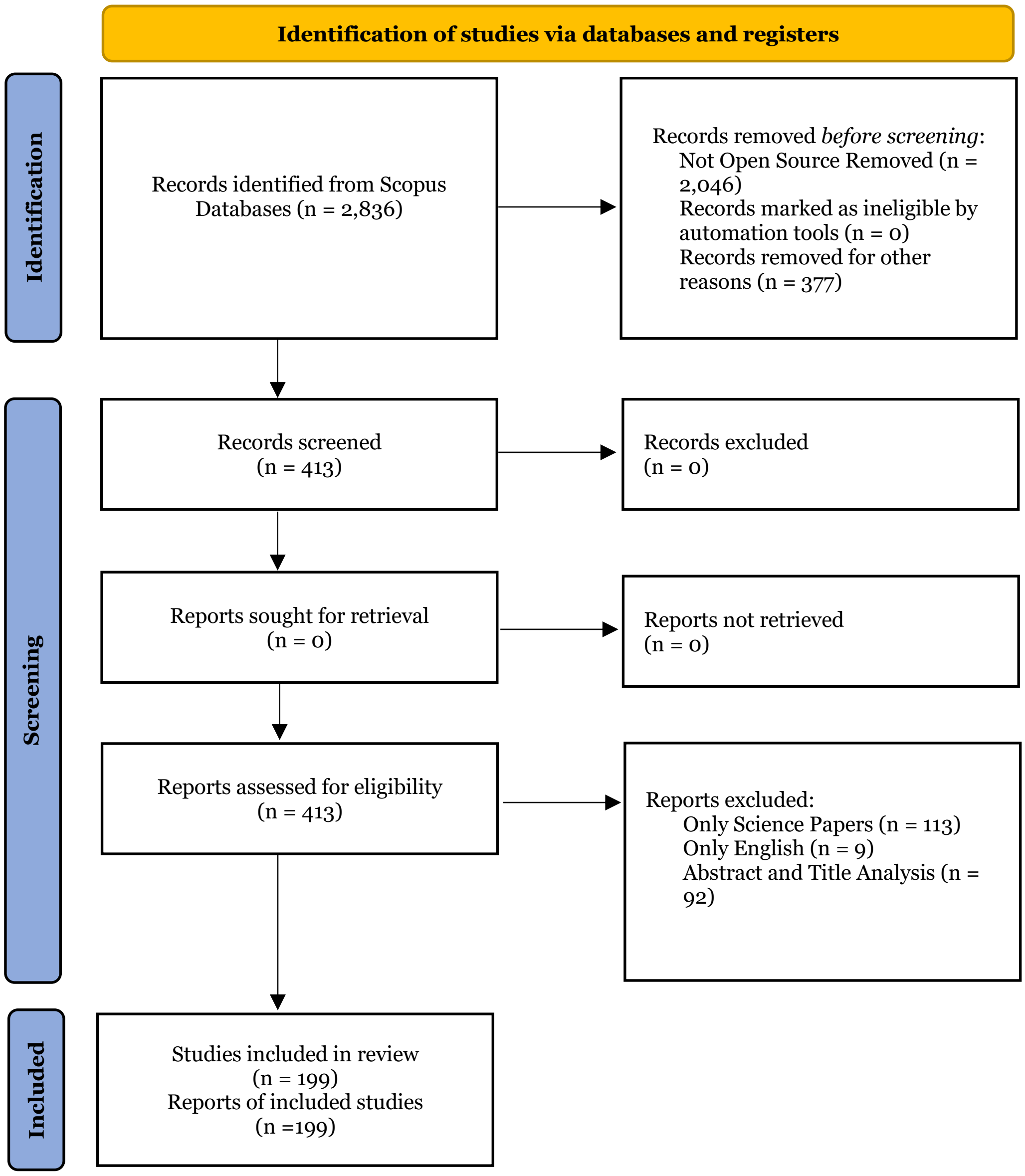
3.3 Methodology

In this section is explained the database, period and methodology applied in the selection of the investigated articles and the techniques applied for analysis. There are several databases for scientific document searches, for example, Web of Science (WoS), Google Scholar, and Scopus. This investigation chose to use the database provided by Scopus for the period 2008 to May 21, 2021.

The first step of this investigation was the choice of the sample, using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology, proposed by Page et al. (2021). The PRISMA methodology is a guideline developed to deal with unsatisfactory systematic reviews, this focus on making the research transparent, so the researcher needs to be aware of the reason for the review being done, what was done, and finally, what was found (Page et al., 2021).

First, all the works in the Scopus database relating to the words Renewable Energy, Economic Growth and Development Economic were identified, the search with these words was directed in keywords, title and abstract, so that said, 2836 documents were identified. With the identification made begins the screening stage, being made the choice to analyze only open source documents, which, so far, was 790, so there was a reduction of 2046 documents. A second stage of screening was to exclude the research areas that are not related to the focus of the investigation of this research, considering only the fields of study Environmental Science, Energy, Social Sciences, Economics, Econometrics and Finance, and Business, Management and Accounting, with this restriction 377 documents eliminated, totaling 413 with the possibility of entering the study. Then, we limit the types of documents; we take into account only articles, with 300 articles, in addition, also limited to the English language, which caused the exclusion of 9 articles, making 291 eligible. Finally, an analysis was made of the abstracts, titles and keywords of these 291 articles to define which ones would be considered for the investigation of this systematic review, based on the information found, 92 articles were disregarded, so 199 articles for analysis were included, as can be seen on the Figure 3.1. The protocol applied to the Scopus database can be found in the appendices of this research.

Figure 3.1 – Identification of Studies Via Database



After defining the investigated studies, this research analyzes the information of the articles, considering some indicators number of publications, h-index and citations, as was done in (Merigó & Yang, 2017). However, it is important to emphasize that the literature does not yet have an accurate and conclusive methodology for evaluating articles, journals, etc. Moreover, being able to determine their value. This field of research, which tries to measure the value of an article, researcher, or even the institution, is criticized. A criticism pointed out by Merigó & Yang (2017), assumes that an article published in a journal of greater relevance should have a value higher than one published in a median journal, but this is the challenge, since each article, regardless of where it is published will be assigned the same value (Merigó & Yang, 2017). The databases, trying to work around these difficulties, for example the Scopus database, have 3 metrics that are based on the citations received to assign quantitative values, whether to the author, article, journal or institution, are CiteScore (CS), SCImago Journal Ranking (SJR) the Source Normalized Impact per Paper (SNIP).

The CiteScore from Scopus is similar to the impact factor calculated by the Web of Science (WoS). The difference occurs only in the period used to make the calculation, the CS considers number of citations in the last 3 years and dive by the number of publications in the same period, while the calculated by WoS is based on the interval of the last 2 years. Still, according to Merigó & Yang (2017), these metrics are not 100% reliable, since it is possible to circumvent them using self-citations (Merigó & Yang, 2017). Another Scopus metric used to rank journals is the SJR, which measures the weighted citations received by the journal; the weighting of the citation takes into account the subject field and the prestige (SJR) of the journal it cites.

As a certificate that auto citations are a problem for these metrics, the same problem should be taken into account when the absolute number of citations is considered as metric. However, in this case, when dealing with works already conceptualized this problem tends to be smaller, since it is expected that reputable articles are more cited, intuitively there is a number of citations much higher than the number of articles (Merigó & Yang, 2017), since they are considered as references. In this sense, the number of citations can be taken into account with the purpose of measuring the influence of an institution, author or journal (Merigó & Yang, 2017). Still, there may be flaws, for example a great article recently published and that has not yet become popular, or even a research that done in a very specific scientific field.

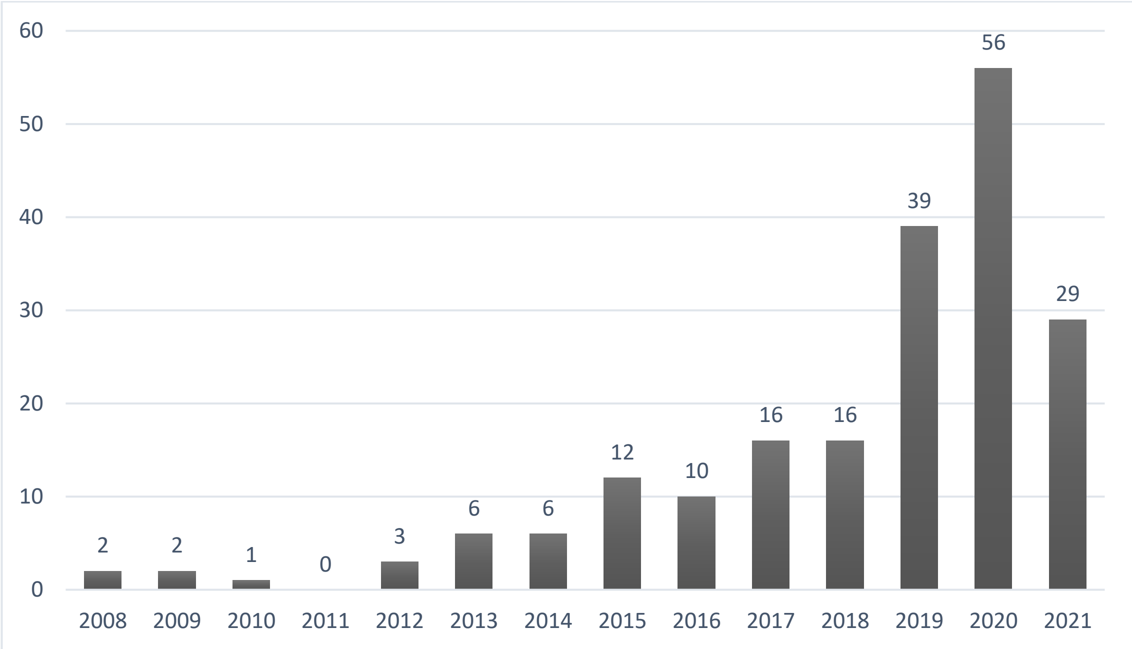
Finally, there is the h-index, proposed by Hirsch (2005), which combines the number of publications and citations. Taking this research as a reference, which has an h-index of 34; this tells us that at least 34 articles published in the period investigated received 34 or more citations. Just as the other metrics, also have criticisms. For example, an extreme case pointed out by Merigó & Yang (2017), if a researcher publishes more than 100 articles and 3 receive more than 1000 citations, while the rest is not cited, the index of this researcher will be only 3 Merigó & Yang (2017). Intuitively, it is possible to conclude that this hypothetical researcher has an academic relevance much higher than 3. Despite the criticisms, this index is useful, and relevant in academia, therefore, it is appropriate to the scope of this research in the criterion of evaluating the relevance of a research, researcher, journal or institution.

In addition, with the help of VOSviewer software, a textual analysis is made in order to identify the relationships between articles, keywords and researchers. In this way, identify the main activities present on the Renewable Energy, Economic Growth and Development Economic theme. The VOSviewer software, allows a relationship network construction between the articles published in the period.

3.4 Results and Discussions

In this section, we analyze and discuss the information from the sample. Starting with a temporal reading of the evolution of publications in the years investigated. The following Figure 3.2 informs us of the annual amount of articles published on the subject from 2008 until May 2021.

Figure 3.2 - Number of Annual Publications (2008-May/2021)

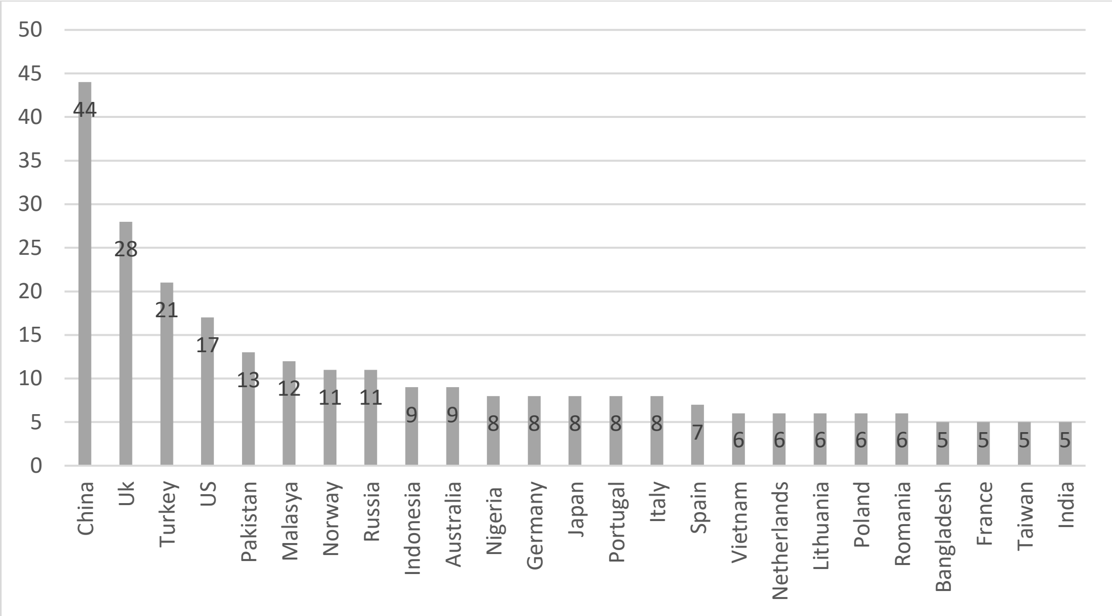


Source: prepared by the authors with data from Scopus.

The X-axis represents the years of research, while the Y-axis represents the amount of articles published. It is easy note that exists a growth trend, with the exception of 2010, 2011 and 2016 every year the number of articles published annually grew. The considerable increase in publications in the last 5 years is remarkable; these years concentrate 78.39% of the papers published in the period. Despite the drop in the number of articles from 2020 to 2021, it is more likely to be due to the sampling period of the research, since it does not include the year 2021 as a whole, so we cannot consider as an indictment of a drop in publications. It is possible that at the end of the year 2021 there will be a number of publications similar to 2020, considering that the theme continues with the growth trend.

In Figure 3.3, we chose to make a geographical analysis, that is, identify how many and which countries have the most publications on the subject in the period. At first, when considering any number of publications we obtained 63 countries with research published in this theme of 194 existing countries; this informs us that only 32% of nations develop research on Renewable Energy, Economic Growth and Development Economic, up to the moment of this research. However, it should be noted that this does not mean that only 30% of the countries in the world were investigated in relation to this theme, only that the research is concentrated in around 30% of the countries. In order to facilitate understanding, we did not consider all 63 countries; we chose to make a minimum count of publications, this 5 being, so the following graph considers only those countries that had more than 5 publications during the period of the development of this work.

Figure 3.3 - 25 Countries with more publications between 2008-May/2021



Source: prepared by the authors with data from Scopus.

Only 25 countries have more than 5 articles published, immediately note China as an outlier, the number of Chinese production is bigger than the others countries, China is responsible for 22.11% of publications in the period. Another attention-calling factor is that on all continents there is at least one country with at least 5 publications on the subject, except Latin America.

Being a multidisciplinary research area, many journals publish about this theme, 74 periodic have been published on the period. In table 3.1, the periodic are ranked according to the metrics stipulated by the Scopus database.

Table 3.1 - Source Ranking

R	Journal Name	H-Index	Citations	Publications	Porcentage	>200	>100	>50	<50	CS	SJR
1	Renewable and Sustainable Energy Reviews	295	74	4	2.010	0	0	1	3	30.4	3.632
2	Global Environmental Change	177	228	1	0.503	1	0	0	0	20.2	4.304
3	Water Research	303	28	1	0.503	0	0	0	0	15.6	2.932
4	Renewable Energy	191	45	4	2.010	0	0	0	4	10.8	2.052
5	Resources, Conservation and Recycling	130	37	1	0.503	0	0	0	1	14.6	2.215
6	Journal of Industrial Ecology	102	332	1	0.503	1	0	0	0	12.8	1.808

7	Energy Economics	152	87	3	1.508	0	0	0	3	2.7	0.977
8	Energy Policy	217	774	15	7.538	0	3	3	9	10.2	2.168
9	Science of the Total Environment	244	443	9	4.523	0	2	1	6	10.5	1.661
10	Journal of Environmental Management	179	24	2	1.005	0	0	0	2	9.8	1.321
11	Entrepreneurship and Sustainability Issues	25	5	1	0.503	0	0	0	1	7.0	1.171
12	Enviromental Sciences Europe	35	5	1	0.503	0	0	0	1	4.8	1.774
13	Progress in Planning	48	24	1	0.503	0	0	0	1	8.4	0.913
14	Urban Studies	147	0	1	0.503	0	0	0	1	6.6	1.618
15	Mitigation and Adaptation Strategies for Global Change	71	25	1	0.503	0	0	0	1	5.9	1.112
16	Technological and Economic Development of Economy	47	119	3	1.508	0	0	1	2	6.0	0.622
17	British Journal of Management	108	21	1	0.503	0	0	0	1	6.8	1.522
18	Aerosol and Air Quality Research	55	7	1	0.503	0	0	0	1	5.9	0.965
19	Financial Innovation	18	66	1	0.503	0	0	1	0	4.2	0.847
20	New Political Economy	56	42	1	0.503	0	0	0	1	5.4	1.748
21	Environmental Science and Pollution Research	113	144	16	8.040	0	0	0	16	5.5	0.788
22	Energy Reports*****	33	113	6	3.015	0	0	0	6	2.7	0.977
23	Energy Strategy Reviews****	33	414	3	1.508	1	0	0	2	7.8	1.336
24	Energy Journal	77	9	1	0.503	0	0	0	1	4.4	1.480
25	Review of International Political Economy	70	15	1	0.503	0	0	0	1	3.6	1.823
26	Climate and Development	35	1	1	0.503	0	0	0	1	4.8	1.047
27	Journal of Security and Sustainability Issues	23	34	3	1.508	0	0	0	3	3.1	0.375
28	Environmental and Resource Economics	92	0	1	0.503	0	0	0	1	4.2	1.401
29	International Journal of Energy and Environmental Engineering	30	16	1	0.503	0	0	0	1	3.9	0.528
30	Borsa Istanbul Review	21	0	1	0.503	0	0	0	1	4.3	0.684
31	Energy, Sustainability and Society	25	43	2	1.005	0	0	0	2	4.2	0.658
32	Environment, Development and Sustainability	56	2	2	1.005	0	0	0	2	3.8	0.548
33	Sustainability (Swistezerland)*	85	383	39	19.598	0	0	0	39	3.2	0.581
34	Economic Analysis and Policy	29	21	1	0.503	0	0	0	1	3.6	0.776
35	Energy Exploration and Exploitation	30	22	2	1.005	0	0	0	2	2.8	0.489

36	International Journal of Energy Economics and Policy**	33	99	17	8.543	0	0	1	16	3.5	0.371
37	Journal of International Studies	17	4	1	0.503	0	0	0	1	3.7	0.541
38	Journal of Sustainable Development of Energy, Water and Environment Systems	14	11	1	0.503	0	0	0	1	3.7	0.400
39	Environmental and Climate Technologies	17	5	1	0.503	0	0	0	1	2.3	0.326
40	Journal of Economics, Finance and Administrative Science	13	0	1	0.503	0	0	0	1	1.4	0.308
41	Atmosphere	37	3	1	0.503	0	0	0	1	2.9	0.698
42	Frontiers in Energy Research****	30	6	5	2.513	0	0	0	5	2.6	0.641
43	Thermal Science	43	3	2	1.005	0	0	0	2	2.4	0.495
44	EAM: Ekonomie and Management	22	9	1	0.503	0	0	0	1	2.3	0.322
45	Environmental Economics and Policy Studies	23	6	1	0.503	0	0	0	1	2.9	0.483
46	Structural Change and Economic Dynamics	48	1	1	0.503	0	0	0	1	3.5	0.621
47	Polish Journal of Environmental Studies	54	6	3	1.508	0	0	0	3	2.4	0.366
48	Asia and the Pacific Policy Studies	14	14	2	1.005	0	0	0	2	2.7	0.533
49	Environment and Development Economics	62	2	1	0.503	0	0	0	1	2.8	0.787
50	Energy Sources, Part A: Recovery, Utilization and Environmental Effects	45	34	1	0.503	0	0	0	1	3.3	0.319
51	Emerging Markets Finance and Trade	34	47	1	0.503	0	0	0	1	2.6	0.444
52	International Journal of Innovation and Sustainable Development	20	8	1	0.503	0	0	0	1	3.9	0.528
53	International Journal of Renewable Energy Development	12	5	2	1.005	0	0	0	2	3.9	0.528
54	Economic Annals - XXI	14	1	1	0.503	0	0	0	1	1.5	0.234
55	Economy of Region	14	0	2	1.005	0	0	0	2	1.9	0.351
56	Geojournal	12	28	1	0.503	0	0	0	1	2.2	0.232
57	Cogent Economics and Finance	16	112	1	0.503	0	1	0	1	2.0	0.252
58	Management and Marketing	11	1	1	0.503	0	0	0	1	1.9	0.218
59	Social Science	19	11	1	0.503	0	0	0	1	2.3	0.239
60	Latin American Economic Review	8	50	1	0.503	0	0	1	0	2.4	0.346

61	Banks and Bank System	16	0	1	0.503	0	0	0	1	1.0	0.216
62	Comparative Economic Research	8	5	1	0.503	0	0	0	1	1.3	0.195
63	Geography, Environment, Sustainability	8	1	1	0.503	0	0	0	1	1.2	0.286
64	International Organisations Research Journal	7	6	1	0.503	0	0	0	1	1.1	0.295
65	Copenhagen Journal of Asian Studies	13	0	1	0.503	0	0	0	1	1.2	0.175
66	Pakistan Development Review	26	7	1	0.503	0	0	0	1	1.0	0.143
67	Environmental and Socio-Economic Studies	3	4	1	0.503	0	0	0	1	0.6	0.381
68	Informação e Sociedade	6	0	1	0.503	0	0	0	1	0.4	0.256
69	Wit Transactions on Ecology and the Environment	21	4	2	1.005	0	0	0	2	0.6	0.142
70	Russian Journal of Economics******	12	1	1	0.503	0	0	0	1	0.2	NA
71	Environment and Planning C: Government and Policy[2]	69	9	1	0.503	0	0	0	1	3.5	0.998
72	European Research Studies Journal*[3]	34	44	1	0.503	0	0	0	1	2.6	0.274
73	Journal of Reviews on Global Economics[1]	6	12	1	0.503	0	0	0	1	0.2	0.227
74	Ekonomica Vilniaus Universitetas	NA	1	1	0.503	0	0	0	1	NA	NA
	Total		4163	199	100						

*Listed since 2009; **Listed since 2011; ***Listed since 2012; ****Listed since 2013; *****Listed since 2014; ******Listed since 2015; [1]Coverage period 2016-2019; [2]Listed until 2017; [3]Listed until 2018; R= Ranking; >200 Number of articles with more than 200 citations; >100 Number of articles with more than 100 citations; >50 Number of articles with more than a 50 citations; <50 Number of articles with less than a 50 citations.
Source: prepared by the authors with data from Scopus.

Table 3.2 - General Citation on Renewable Energy, Economic Growth and Development Economic on Scopus

General Citation on Renewable Energy, Economic Growth and Development Economic on Scopus		
	2008-May/2021	
Citations	Number of Papers	% of Papers
≥ 400 citations	1	0.503
≥ 200 citations	2	1.005
≥ 100 citations	6	3.015
≥ 50 citations	9	4.523
≤ 50 citations	149	74.874
Total	199	83.920

Source: prepared by the authors with data from Scopus

Table 3.2 above shows us the amount of articles in the area were cited in some way in the research period, there are a total of 167 articles, it should be noted that it is a number lower than the total sample that is from 199, this occurs, because some articles (32 or 16.080%) have not yet been cited. When analyzing the citations, it is perceived that the number is low when compared to other research areas, in which there are articles that have more than 1000 references, in this sample no article reached such a number. It was clear that most of the published works have less than 50 citations, this number in the future should change, and it is expected that there will be an increase in articles with more than 50 citations, since it is notorious the increase in publications on the subject in recent years.

Taking into account the total h-index (34) of this research, it is noted that it is not a high value, it is only comprises 17.085% of the sample. That it is expected that the number of articles with more than 400, 200, 100 and 50 citations is expected to be raised, since, as previously in this study, a growth trend is observed in research with Renewable Energy, Economic Growth and Development Economic.

Table 3.3 shows us the most cited articles in the research period, in one of the criteria selected to determine relevance; these are the 20 most relevant papers in the period. It is noted that a good distribution in the journal ranking, which may be an indication that good works on the subject can be found in most journals listed in this research. Another point is that most of these 20 articles are post-2015, which reinforces the hypothesis that research on the subject still has a growth horizon ahead.

Table 3.3 - Most Cited Articles in the Period (2008-May/2021)

Journal	JR	TC	Title	Author(s)	Year
Energy Strategy Reviews	23	405	The role of renewable energy in the global energy transformation	Gielen, Dolf Boshell, Francisco Saygin, Deger Bazilian, Morgan D. Wagner, Nicholas Gorini, Ricardo	2019
Journal of Industrial Ecology	6	332	How circular is the global economy?An assessment of material flows, waste production, and recycling in the European union and the world in 2005	Haas, Willi Krausmann, Fridolin Wiedenhofer, Dominik Heinz, Markus	2015
Global Environmental Change	2	228	Energy, land-use and greenhouse gas emissions trajectories under a green growth paradigm	Van Vuuren, Detlef P. Stehfest, Elke Gernaat, David E.H.J. Doelman, Jonathan C. (...)	2017
Science of the Total Environment	9	131	Dynamic impact of trade policy, economic growth, fertility rate, renewable and non-renewable energy consumption on ecological footprint in Europe	Alola, Andrew Adewale Bekun, Festus Victor Sarkodie, Samuel Asumadu	2019
Energy Policy	8	127	China in the transition to a low-carbon economy	Zhang, Zhong Xiang	2010
Cogent Economics and Finance	57	112	Effect of economic growth on CO_2 emission in developing countries: Evidence from a dynamic panel threshold model	Aye, Goodness C. Edoja, Prosper Ebruvwiyo	2017

Science of the Total Environment	9	103	Modelling coal rent, economic growth and CO2 emissions: Does regulatory quality matter in BRICS economies?	Adedoyin, Festus Fatai Gumede, Moses Iga Bekun, Festus Victor Etokakpan, Mfonobong Udom Balsalobre-lorente, Daniel	2020
Energy Policy	8	101	The energy and CO2 emissions impact of renewable energy development in China	Qi, Tianyu Zhang, Xiliang Karplus, Valerie J.	2014
Energy Policy	8	100	The environmental Kuznets curve in Indonesia: Exploring the potential of renewable energy	Sugiawan, Yogi Managi, Shunsuke	2016
Energy Policy	8	89	Onshore wind power development in China: Challenges behind a successful story	Han, Jingyi Mol, Arthur P.J. Lu, Yonglong Zhang, Lei	2009
Energy Policy	8	79	The driving forces of change in energy-related CO 2 emissions in Ireland: A multi-sectoral decomposition from 1990 to 2007	O' Mahony, TadhgZhou, PengSweeney, John	2012
Technological and Economic Development of Economy	16	75	Evaluation of renewable energy alternatives using MACBETH and fuzzy AHP multicriteria methods: the case of Turkey	Ertay, Tijen Kahraman, Cengiz Kaya, Ihsan	2013
Financial Innovation	19	66	The relationship between energy consumption, economic growth and carbon dioxide emissions in Pakistan	Khan, Muhammad Kamran Khan, Muhammad Imran Rehan, Muhammad	2020
Renewable and Sustainable Energy Reviews	1	58	Energy security and renewable energy policy analysis of Pakistan	Aized, Tauseef Shahid, Muhammad Bhatti, Amanat Ali Saleem, Muhammad Anandarajah, Gabrial	2018
Science of the Total Environment	9	54	An assessment of environmental sustainability corridor: The role of economic expansion and research and development in EU countries	Adedoyin, Festus Fatai Alola, Andrew Adewale Bekun, Festus Victor	2020
Science of the Total Environment	9	53	Heterogeneous impacts of renewable energy and environmental patents on CO 2 emission - Evidence from the BRIICS	Cheng, Cheng Ren, Xiaohang Wang, Zhen Yan, Cheng	2019

International Journal of Energy Economics and Policy	36	51	The role of renewable, non-renewable electricity consumption and carbon emission in development in Indonesia: Evidence from distributed lag tests	Saudi, Mohd Haizam Mohd Sinaga, Obsatar Roespinoedji, Djoko Razimi, Mohd Shahril Ahmad	2019
Latin American Economic Review	60	50	The dynamic linkage between renewable energy, tourism, CO 2 emissions, economic growth, foreign direct investment, and trade	Ben Jebli, Mehdi Ben Youssef, Slim Apergis, Nicholas	2019
Energy Policy	8	49	Hydropower, social priorities and the rural-urban development divide: The case of large dams in Cambodia	Siciliano, Giuseppina Urban, Frauke Kim, Sour Dara Lonn, Pich	2015
Emerging Markets Finance and Trade	51	47	Financing Renewable Energy Projects in Major Emerging Market Economies: Evidence in the Perspective of Sustainable Economic Development	Kutan, Ali M. Paramati, Sudharshan Reddy Ummalla, Mallesh Zakari, Abdulrasheed	2018

JR=Journal Ranking; TC=Total Citations

Source: Source: prepared by the authors with data from Scopus

The taxonomy of the publication was also aimed in this research, in this way, the studies selected through the PRISMA methodology, 199 in its entirety, were qualified in 4 subgroups by the authors, being I - Renewable and Non-Renewable Energy Consumption, Economic Growth and Economic Development; II - Transition to a low-carbon economy and energy efficiency; III – Environmental Degradation and IV - Others. Most of the articles in this sample fall into category II - Renewable Energies, Economic Growth and Economic Development, the expected result, 127 of 199 (63.819%) are in this category. Although category II relates to the keywords used in the scope, however you are not the focal point of publications; these are more related to energy efficiency and countries with the objective of reducing their carbon emissions, covers around 15.075% (30 documents) of the work. The Environmental Degradation is responsible for 8.04% or 16 documents. Finally, the other category, with less number of jobs encompasses research that relate to the subjects, but are very specific cases covers 13.065% or 26 published works on the period. When analyzing the methodologies applied in the researches that are part of this sample of this study, a prevalence of quantitative methodologies is observed, of the 199 studies, 161 or 80,904% apply quantitative methods to obtain the results of their studies. In the following paragraphs, an analysis of the studies within the given subsamples is made.

The analysis of Group I (Renewable and Non-Renewable Energy Consumption, Economic Growth, and Economic Development) shows that most of the articles published in this subsample use quantitative methodology; 89.763% of the studies employ common methodologies in economic sciences. Most studies are analyses of statistical inferences for individual countries or countries studied in isolation. Many studies cover various economies, such as Baba and Amfo (2021), Fonseca et al. (2020), Gasmi et al. (2020), Krakauer (2014), H.P. Le and Sarkodie (2020), Maneejuk et al. (2020), and N. Singh et al.

(2019). For example, Tawiah et al. (2021) conducted a study covering 123 countries, while Pereira et al. (2021) studied 146, Asafu-Adjaye et al. (2016) 53, and R. Khan and Kong (2020) 24 heterogeneous economies. However, when observing the studies that opt for groups, there is a tendency to investigate specific groups with some similarities, such as geographical, economic, or cultural. Hassan and Nosheen (2019) investigated 37 developed economies. OECD member countries have been studied from various perspectives by Al Mamun et al. (2018), Alam and Murad (2020), Balsalobre-Lorente et al. (2020), Cerqueira et al. (2020), Mujtaba and Shahzad (2021), and Soukiazis et al. (2019). Alam and Murad (2020) found that, in the long term, trade opening and technological development tend to stimulate the consumption of renewable energy in OECD countries. Emerging economies were investigated by Abdollahi (2020), Aye and Edoja (2017), Gosens (2020), Tsaurai (2020), and Yilanci et al. (2021). Further targeted studies in developing economies include Festus Fatai Adedoyin et al. (2020), Kutan et al. (2018), and Z. Yu et al. (2019). According to Kutan et al. (2018), the flow of foreign direct investment (FDI) and the development of the financial market are crucial for promoting the consumption of renewable energies, in addition to reducing emissions and promoting economic growth. The BRICS economies were also investigated in isolation: Brazil by Hdom and Fuinhas (2020), Magazzino et al. (2021), and Simas and Pacca (2013); Russia by Lisin et al. (2016); China and India by Johansson et al. (2015); and China by several researchers including Cui et al. (2021), W. Liu et al. (2021), Weiwei Liu et al. (2016), Qu et al. (2017), Samuel Asumadu Sarkodie et al. (2020), Yuan et al. (2017), and Zhao et al. (2018). There were also investigations of Chinese provinces by Qin et al. (2020) and Tseng (2019). Additionally, Brazil, China, and the USA were studied together by Muhammed and Tekbiyik-Ersoy (2020); China and the USA by W. Zhang et al. (2014); and China, the USA, France, and Japan by X. Wang et al. (2019). Continents were also targeted for research; Europe was studied by F. Adedoyin et al. (2020), F.F. Adedoyin et al. (2020), Alola et al. (2019), Alsaleh et al. (2021), Azretbergenova et al. (2021), Bilan et al. (2019), Busu (2019), Chovancová and Vavrek (2020), Madsen and Hansen (2019), Melas et al. (2017), Radmehr et al. (2021), Simionescu et al. (2017), and Xie et al. (2020). The result obtained by Alola et al. (2019) indicates a balance between environmental degradation, economic growth, trade opening, consumption of renewable and non-renewable energies, and fertility rate. It was observed that the consumption of non-renewable energies increases environmental degradation, while the consumption of renewables contributes to conservation. European countries were also studied separately: Portugal by Shahbaz et al. (2017); Portugal, Spain, Denmark, and the USA by Silva et al. (2012); Ukraine by Kravtsiv et al. (2017) and Pryshliak and Tokarchuk (2020); Turkey by Dinç and Akdoğan (2019) and Ertay et al. (2013); Romania by Safta et al. (2013); the Czech Republic and Slovakia by Štreimikienė and Mikalauskienė (2016); Wales by Bere et al. (2017); Poland by Raszkowski and Bartniczak (2019), Stadniczeńko (2020); Estonia, Latvia, and Lithuania by Miskinis et al. (2019); Scotland by Allan et al. (2008); and Russia by Tishkov et al. (2020). The American continent, specifically Latin America, was also the target of research in Koengkan et al. (2019), Ben Jebli et al. (2019), Hoang Phong Le and Bao (2020), and Zeeshan et al. (2020). Ben Jebli et al. (2019) concluded that renewable energy consumption, tourism, and FDI tend to reduce environmental degradation, while foreign trade and economic growth worsen the environment. Pansera (2013) and Pinzón (2018), as well as Robalino-López et al. (2014), analyzed Bolivia and Ecuador, respectively. Saudi Arabia was studied by Belloumi and Alshehry (2015), and Iran by Hosseini et al. (2019) in the Middle East. Research in Asia validated the Environmental Kuznets Curve, as seen in Nosheen et al. (2021); Murshed and Dao (2020) investigated South Asian economies; and Arshad et al. (2020) investigated South Asian and Southwest Asian economies, finding that both renewable and non-renewable energy consumption promotes economic growth. Belt Road countries were investigated by He et al. (2021) and A. Rauf et al. (2018); SAARC and ASEAN countries by Bakar et al. (2019); and South Korea by Baek et al. (2015). Research in Bangladesh includes Huq (2018), Malaysia by Ridzuan et al. (2020), Sinaga et al. (2019), and Sulaiman and Abdul-Rahim (2017); Indonesia by Daryono et al. (2019), Prastiyo et al. (2020), Saudi et al. (2019), Sugiawan and Managi (2016), and Surya et al. (2021); Vietnam by Nguyen et al. (2019); Taiwan by Hong and Yen (2019); Pakistan by Abbasi et al. (2020), Bano et al. (2021), Chandio et al. (2019), M.K. Khan et al. (2020), and Shabbir et al. (2020); Kazakhstan by Hasanov et al. (2019) and Zhanseitov et al. (2020); and Thailand by Ike et al. (2020). Few studies address the African continent, with Asongu et al. (2020) investigating the continent, Imasiku et al. (2020) sub-Saharan Africa, Rutebuka et al. (2018) Rwanda, Njoke et al. (2019) Cameroon, Nigeria by Riti and Shu (2016), Tenaw (2021) Ethiopia, and Ben Jebli et al. (2015) Tunisia. In Oceania, only Chambers et al. (2018) investigated Australia. OPEC member countries were studied by Sovacool and Walter (2019), which concluded that electricity production improves energy access and promotes the economy. In addition to quantitative methodologies, other methodological approaches were applied, but they were less common in this subsample (10.318%). Similar to quantitative studies, there are analyses of large groups, such as Carfora and Scandurra (2019) and Waheed et al. (2019), which analyzed a very different group of economies. Research addressing Europe includes Moraru (2015) and Marolin et al. (2020); the United Kingdom by Barrett et al. (2008); and Russia by Tishkov et al. (2020). G.C. Chen and Lees (2016) and Han et al. (2009) analyzed China, while Warner and Jones (2019) studied India and China together. Islamic countries were studied by Laila et al. (2021), and finally, Bangladesh, Indonesia, and the USA by Karim et al. (2019), Hadiwijoyo et al. (2013), and Katina et al. (2018), respectively.

The studies of subsample II (Transition to a Low-Carbon Economy/Energy Efficiency) total 30, of which 22, or 73.333%, are quantitative surveys. Quantitative studies in this sample have a broad profile, such as Gielen et al. (2019) and Rahman et al. (2016). The results of Gielen et al. (2019) highlight that renewable energy and energy efficiency technologies are central to an energy transition. Renewable energy is crucial for limiting greenhouse gas emissions and restricting the increase in global temperature to 2°C (Gielen et al., 2019). The continents were also investigated; Asia was studied by Murshed (2020), Taghizadeh-Hesary and Rasoulinezhad (2020), and Twum et al. (2021), while the African continent was covered by Van der Zwaan et al. (2018). The most localized studies focus on China, including Ou et al. (2017), Qi et al. (2014), and H. Zhang et al. (2020). Qi et al. (2014) found that electricity production targets through renewable sources in China contributed to a 1.8% increase between 2010 and 2020. Additionally, Sarangi et al. (2019) studied India and China, and India was also examined by Ortega-Ruiz et al. (2020). Within the Asian continent, Pakistan, Vietnam, Kazakhstan, and Japan were studied by Aized et al. (2018), Urban et al. (2018), Jianzhong et al. (2018), and Gao et al. (2020), respectively. In Europe, Ireland was surveyed by O'Mahony et al. (2012), Turkey by Atis et al. (2014), the Netherlands by Oteman et al. (2017), and Germany, the United Kingdom, and Norway by MacKinnon et al. (2019). For the USA, Hodson et al. (2018) found that achieving innovation targets leads to a reduction in carbon dioxide emissions. In the Middle East, Saudi Arabia was studied by Rehan et al. (2016). Monasterolo and Raberto (2019) proposed to investigate quantitatively how gradual reductions in fossil fuel consumption through government subsidies positively affect macroeconomic factors. In non-quantitative approaches, Bollino et al. (2017) investigated trends in the global energy market in the medium and long term and concluded that there is global interest in renewable and non-conventional energies and in improving energy efficiency to reduce the environmental impact of energy generation (Bollino et al., 2017). Europe was also studied by Haas et al. (2015) and Wysokińska (2013), while China was studied by Odgaard (2015) and Z. Zhang (2010). Russia was covered by Lanshina and Barinova (2017), Mexico and Vietnam by Henrysson and Hendrickson (2021), and Nigeria by Adewuyi et al. (2020).

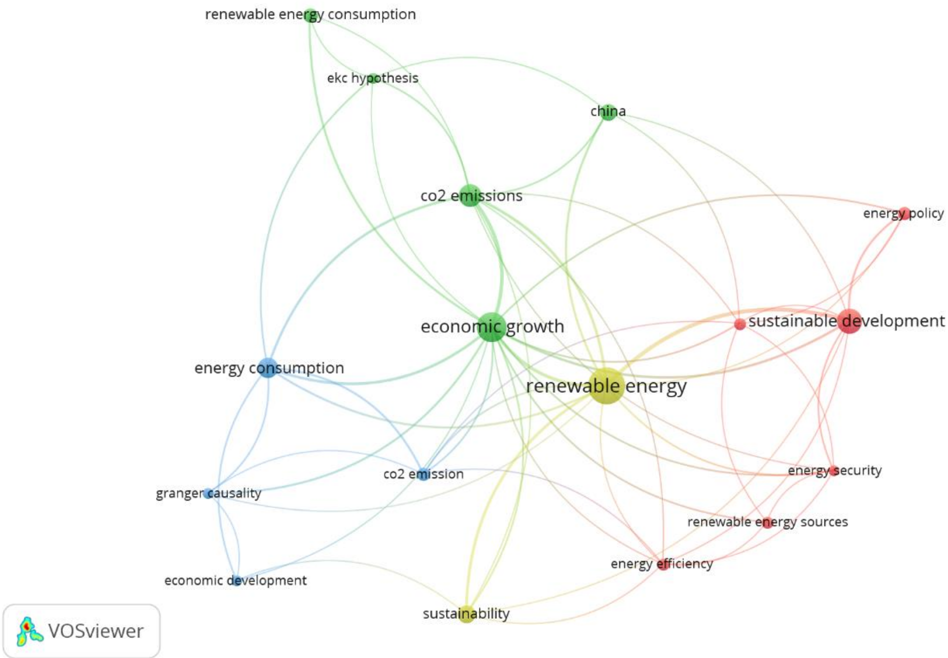
There is subsample III, in which the documents relate to the keywords used in the research, but the focus of the research is on the degradation of the environment. This group has 16 articles, 12 of which are quantitative papers, while the rest employ other methodologies. In the field of quantitative studies, Nazeer et al. (2016) studied 32 countries considered developing. Cheng et al. (2019) focused on the BRICS economies; for these economies, the consumption of renewable energies and the IDI tend to reduce carbon dioxide emissions, while the opposite relationship is observed with GDP and bank credit. An increase in these variables is accompanied by an increase in environmental degradation, as well as exports (Cheng et al., 2019). In addition to this research, South Africa was also studied by Adebayo et al. (2021) and S.A. Sarkodie (2020); and India, along with Malaysia, Indonesia, Kenya, Mexico, Colombia, and Poland, was investigated by Eyuboglu and Uzar (2020). The European Union was addressed by Pham et al. (2020), which concluded that economic factors accelerate environmental degradation. Only Turkey was analyzed in isolation in Europe by Akyol and Uçar (2021) and Yuksel (2008). ASEAN member countries were investigated by Roespinoedji et al. (2020), which showed that macroeconomic factors contribute to degradation. Still in Asia, Vietnam and Taiwan were studied by Huong et al. (2021) and C.H. Liu et al. (2012), respectively. The African continent was studied by Lawson (2020) and Ghana by Asumadu-Sarkodie and Owusu (2017). The work with non-quantitative approaches includes Van Vuuren et al. (2017), which focuses on the possibilities of development in global energy use, land exploration, emissions, and climate change to maintain constant sustainable development. The results indicate that a combination of these factors, with a focus on sustainable alternatives, can lead to a strong energy transition towards renewable sources. However, it is also necessary to apply strict climate policies to reduce the trend of rising global temperatures (Van Vuuren et al., 2017). Odeku (2017) studies how the banking sector can contribute to decarbonization. Finally, Abam et al. (2014) is the only country study that investigates Nigeria.

Finally, in category IV (Others), unlike the others, where there is a clear predominance of quantitative methodologies, there is a balance. Of the 26 papers falling into this category, 13 (50%) are quantitative, and the other half employ other approaches. This category includes comprehensive studies that do not necessarily focus on continents or countries, such as Ari and Koc (2021), Mrówczyńska et al. (2021), Režný and Bureš (2019), T. Wang et al. (2021), and Xu and Liu (2019). Additionally, Cucui et al. (2018) conducted a micro study. In studies dealing with specific territories, for the European continent, Caruso et al. (2020) concluded that renewable energy development policies improve social factors studied (government policy, general public awareness, the market, lobbying activity). In Europe, Russia was studied by Gaynanov et al. (2015), and the United Kingdom and Germany were examined together with the USA and Brazil by Bhuiyan et al. (2021). On the Asian continent, Iran, China, and Cambodia were investigated by Milad Mousavian et al. (2020), P. Wang et al. (2021), and Siciliano et al. (2015), respectively. Baumli and Jamasb (2020) studied decision-making between financing and not financing renewable energy matrices on the African continent, concluding that investor confidence in regulatory effectiveness is the main concern, in addition to local construction capacity and political instruments. In non-quantitative approaches, there are studies not directed to a specific country or continent, such as Khandekar et al. (2015), Makarov et al. (2021), Marques et al. (2020), Pretel et al. (2015), Tu et al. (2020), and Vidican (2009). Makarov et al. (2021) propose two scenarios: a conservative one in which there is no change in the current situation of energy production and a transition scenario with ambitious targets in the evolution and incentives of renewable energies. The results show that renewable sources may be responsible for providing between 35-50% of the world's electricity production by 2040, while the share of fossil fuels is expected to reduce. Liu et al. (2019) demonstrated that common law-adapted countries had better responses to renewable energy investment opportunities, suggesting that global imbalances in energy development are partly due to legal and regulatory institutions. In Europe, only Italy and Macedonia have surveys in this category, conducted by Zanuttigh et al. (2015) and Mijakovski et al. (2018), respectively. Chinese provinces were surveyed by X. Chen et al. (2020), Hao et al. (2020), and F. Zhang and Wu (2021), while at the country level in Asia, only Nepal was surveyed by R.P. Singh et al. (2020).

Due to the diverse results obtained in the studies, there is no academic consensus on the way in which energy consumption affects economic dynamics. There are economies in which the influence is positive, others negative and even economies in which the results are not statistically significant, this is likely to be the effect of specific characteristics of each sample observed in the studies. Despite this, a conclusion regarding the consumption of renewable energies was possible, they are fundamental in mitigating greenhouse gas emissions, so there is evidence that they are essential in conserving the environment.

Figure 3.4 informs us of the most used keywords, a universe of 637 keywords was obtained, however, when we limit to a minimum of 5 occurrences this number drops to 17, so, following relevance criteria previously stipulated figure 3.2 was made with the existing relationships between these 17 words that were most used by the authors as keywords.

Figure 3.4 - Keywords Occurrence Analysis

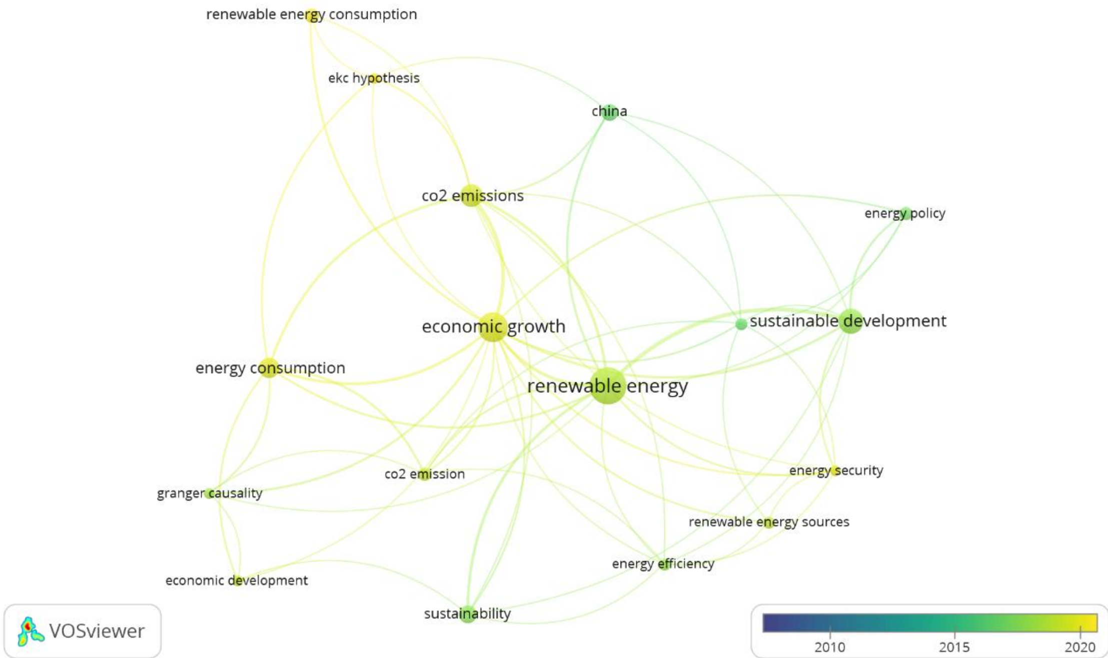


Immediately it is possible to observe that there are 4 clusters (due the different colors on the figure), all of which somehow connect with the keyword economic growth, this being the term most used by researchers, being followed by renewable energy. It is noted that of the 3 terms selected in this work 2 stand out, this may be an indication that the academy is focused on investigating the relationship between economic growth and energy consumption, a subject that is already investigated, however not saturated, since the focus is now on renewable energy matrices. With regard to the term of economic development, this subject, although extremely relevant, when related to economic growth and renewable energy appears to be marginalized, that is, there is not much targeted research, thus it is possible to conclude that there is a gap that should be explored by researchers.

It is also noted in the keywords with more occurrences a certain emphasis on Co2 in conjunction with keywords that relate to sustainability. This implies an apparent interest in studying how greenhouse gas emissions may be impacting growth and or economic development, in a way, the rise in the temperature of the planet may be one of the factors that has driven research to understand how renewable energies affect economic dynamics.

In addition, Figure 3.5 shows us that there are indications (due the yellow color) that these keywords in sets date to 2015 post surveys, again, another indication that there is still much to be explored. Finally, China is noted as one of the most cited terms, this may be one of the reasons why the country has a greater prominence in the number of publications on the subject.

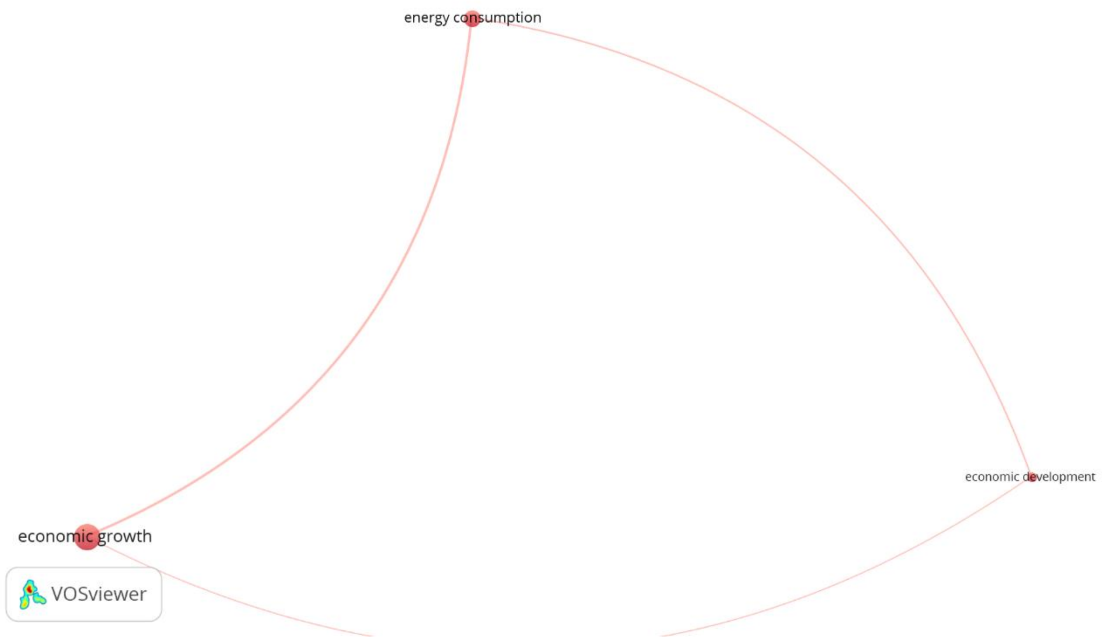
Figure 3.5 – Keywords Overlay Visualization



When the links between Renewable Energy, Economic Growth and Development Economic are observed, it is noted that there is no evidence of work relating economic development and renewable energies, as can be seen in Figure 5 below. According to Figure 3.5, it is clear the existence of two clusters, one between economic growth and renewable energies and the other between economic growth and economic development. The research gap that can be explored is even more evident, since there is no direct link between economic development and renewable energies. However, if we use energy consumption instead of renewable energies, a link is noted with economic development, as can be seen in Figure 3.6, again, this result reinforces the hypothesis of absence of studies relating the consumption of renewable energies with development.

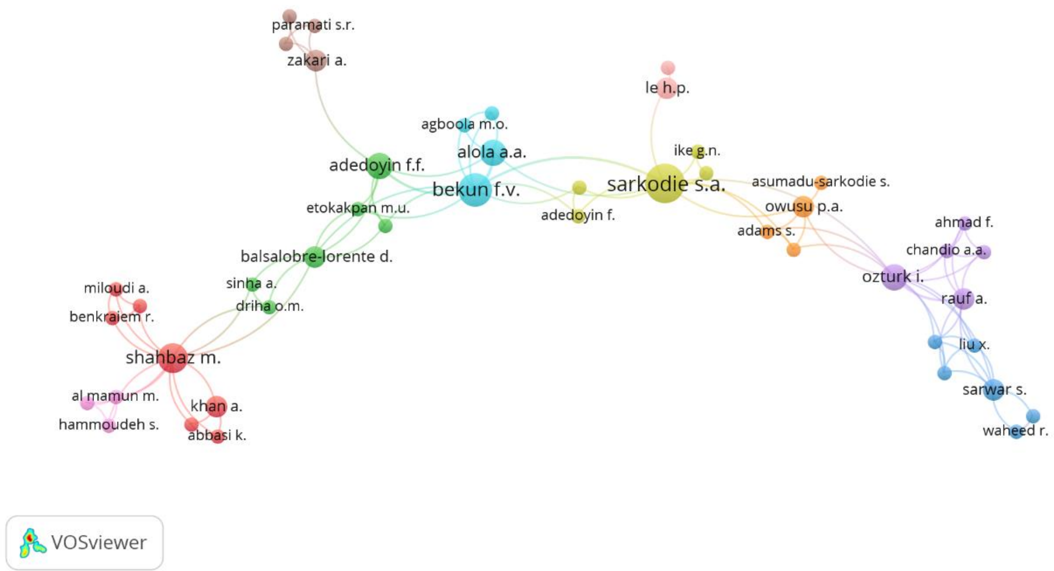
Figure 3.6 – Link Between Renewable Energy, Economic Growth and Development Economic

Figure 3.7 - Link Between Energy Consumption, Economic Growth and Development Economic



Finally, an analysis of the possible clusters and links between the researchers was also made. Having as relevance indicator the number of citations, even though it is not the accurate metric. In VOSviewer, software to perform such analysis was considered only authors with more than 5 citations, so the number of authors analyzed is 404 instead of 665 that would be the totality of researchers in this sample. Even though the number of researchers was reduced to 404, a link was found only among 46 of them, as can be seen on the Figure 3.8.

Figure 3.8 – Authors' Network Visualization



Observing the amount of colors, we see 10 clusters. However, although 10, but only 4 clusters stand out, because they have more branches, so they are connected with more researchers, they are the one led by Bekun in blue, followed by Sarkodie in yellow, then the Ozturk is in purple, and finally, the cluster formed by the Shahbaz in red. Notoriously, this relationship does not occur randomly, since they are the authors with the highest number of documents published within the stipulated criteria. Sarkodie has 7 publications in the period on the topic, Bekun has 5, Shahbaz 4, and Ozturk 3.

3.5 Conclusions

This research focused on investigating articles published in the Scopus database that studied the relationship between Renewable Energy, Economic Growth and Development Economic between 2008 and May 2021. The results of screening through the PRISMA methodology provided a sample for the study in this study of 199 articles published within a universe of 2,836. Regarding the ranking of the journals with the highest impact Renewable and Sustainable Energy Reviews was the first place, followed by Global Environmental Change and third Water Research. However, the journal with the largest number of publications was Sustainability (Switzerland).

Despite the effort to overcome the difficulty in quantitatively measuring an article, journal or author, this is the major limitation of this research, the metrics used for quantifying are susceptible to failure, so they are not accurate, because there is no defined methodology that is applicable to the type of approach used in this study. In addition to this, it is also considered the selected sampling period, since it does not consider the year 2021 as all, to be more precise, it is considered only until May 21, but the number of publications found for this year were not likely to be ignored.

The analysis of the data obtained in the Scopus database leads us to conclude that studies with respect to Renewable Energy, Economic Growth and Development Economic are just beginning, since it is possible to observe a growth trend. For, most of the studies published in the period occurred after 2015, as well as the articles considered most impacting are publications that date back to more recent years.

It is also notorious that the topic is being researched on all continents, including, in a surprising way, that China is a leader in publications, given that it is one of the countries whose economic growth had been most damaging to its environment.

This research was able to identify a research gap, studies have focused on understanding how renewable energies have affected economies around the globe, but the observed gap is precisely in one of the keywords used in this research. No studies were observed that make a relationship between renewable energies and economic development, therefore, it is suggested that it is a theme to be addressed by academia in the future.

References

Ã, I. O., Abdoli, G., Farahani, Y. G., Abosedra, S., Dah, A., Ghosh, S., Ahmed, M., Azam, M., Akadiri, S., Bekun, F. V., Taheri, E., Akadiri, A., Akinlo, A. E., Ameyaw, B., Oppong, A., Abruquah, L. A., Ashalley, E., Apergis, N., Payne, J. E., … Andrews, D. W. K. (2010). A literature survey on energy – growth nexus. Energy Policy, 38(1), 340–349. https://doi.org/10.1016/j.enpol.2009.09.024

Abam, F. I., Nwankwojike, B. N., Ohunakin, O. S., & Ojomu, S. A. (2014). Energy resource structure and on-going sustainable development policy in Nigeria: A review. International Journal of Energy and Environmental Engineering, 5(2–3), 1–16. https://doi.org/10.1007/s40095-014-0102-8

Abbasi, K., Jiao, Z., Shahbaz, M., & Khan, A. (2020). Asymmetric impact of renewable and non-renewable energy on economic growth in Pakistan: New evidence from a nonlinear analysis. Energy Exploration and Exploitation, 38(5), 1946–1967. https://doi.org/10.1177/0144598720946496

Abdollahi, H. (2020). Investigating Energy Use, Environment Pollution, and Economic Growth in Developing Countries. Environmental and Climate Technologies, 24(1), 275–293. https://doi.org/10.2478/rtuect-2020-0016

Adebayo, T. S., Kirikkaleli, D., Adeshola, I., Oluwajana, D., Akinsola, G. D., & Osemeahon, O. S. (2021). Coal consumption and environmental sustainability in South Africa: The role of financial development and globalization. International Journal of Renewable Energy Development, 10(3), 527–536. https://doi.org/10.14710/ijred.2021.34982

Adedayo, H. B., Adio, S. A., & Oboirien, B. O. (2021). Energy research in Nigeria: A bibliometric analysis. Energy Strategy Reviews, 34(June 2020), 100629. https://doi.org/10.1016/j.esr.2021.100629

Adedoyin, F., Abubakar, I., Bekun, F. V., & Sarkodie, S. A. (2020). Generation of energy and environmental-economic growth consequences: Is there any difference across transition economies? Energy Reports, 6, 1418–1427. https://doi.org/10.1016/j.egyr.2020.05.026

Adedoyin, F.F., Alola, A. A., & Bekun, F. V. (2020). An assessment of environmental sustainability corridor: The role of economic expansion and research and development in EU countries. Science of the Total Environment, 713. https://doi.org/10.1016/j.scitotenv.2020.136726

Adedoyin, Festus Fatai, Gumede, M. I., Bekun, F. V., Etokakpan, M. U., & Balsalobre-lorente, D. (2020). Modelling coal rent, economic growth and CO2 emissions: Does regulatory quality matter in BRICS economies? Science of the Total Environment, 710. https://doi.org/10.1016/j.scitotenv.2019.136284

Adewuyi, O. B., Kiptoo, M. K., Afolayan, A. F., Amara, T., Alawode, O. I., & Senjyu, T. (2020). Challenges and prospects of Nigeria's sustainable energy transition with lessons from other countries' experiences. Energy Reports, 6, 993–1009. https://doi.org/10.1016/j.egyr.2020.04.022

Ahmed, M., & Azam, M. (2016). Causal nexus between energy consumption and economic growth for high , middle and low income countries using frequency domain analysis. Renewable and Sustainable Energy Reviews, 60, 653–678. https://doi.org/10.1016/j.rser.2015.12.174

Aized, T., Shahid, M., Bhatti, A. A., Saleem, M., & Anandarajah, G. (2018). Energy security and renewable energy policy analysis of Pakistan. Renewable and Sustainable Energy Reviews, 84, 155–169. https://doi.org/10.1016/j.rser.2017.05.254

Akyol, M., & Uçar, E. (2021). Carbon footprint forecasting using time series data mining methods: the case of Turkey. Environmental Science and Pollution Research. https://doi.org/10.1007/s11356-021-13431-6

Al Mamun, M., Sohag, K., Shahbaz, M., & Hammoudeh, S. (2018). Financial markets, innovations and cleaner energy production in OECD countries. Energy Economics, 72, 236–254. https://doi.org/10.1016/j.eneco.2018.04.011

Alam, M. M., & Murad, M. W. (2020). The impacts of economic growth, trade openness and technological progress on renewable energy use in organization for economic co-operation and development countries. Renewable Energy, 145, 382–390. https://doi.org/10.1016/j.renene.2019.06.054

Allan, G. J., Bryden, I., McGregor, P. G., Stallard, T., Kim Swales, J., Turner, K., & Wallace, R. (2008). Concurrent and legacy economic and environmental impacts from establishing a marine energy sector in Scotland. Energy Policy, 36(7), 2734–2753. https://doi.org/10.1016/j.enpol.2008.02.020

Alola, A. A., Bekun, F. V., & Sarkodie, S. A. (2019). Dynamic impact of trade policy, economic growth, fertility rate, renewable and non-renewable energy consumption on ecological footprint in Europe. Science of the Total Environment, 685, 702–709. https://doi.org/10.1016/j.scitotenv.2019.05.139

Alsaleh, M., Abdulwakil, M. M., & Abdul-Rahim, A. S. (2021). Land-use change impacts from sustainable hydropower production in EU28 region: An empirical analysis. Sustainability (Switzerland), 13(9). https://doi.org/10.3390/su13094599

Ari, I., & Koc, M. (2021). Towards sustainable financing models: A proof-of-concept for a waqf-based alternative financing model for renewable energy investments. Borsa Istanbul Review. https://doi.org/10.1016/j.bir.2021.03.007

Arshad, Z., Robaina, M., & Botelho, A. (2020). Renewable and non-renewable energy, economic growth and natural resources impact on environmental quality: Empirical evidence from south and southeast asian countries with CS-ARDL modeling. International Journal of Energy Economics and Policy, 10(5), 368–383. https://doi.org/10.32479/ijeep.9956

Asafu-Adjaye, J., Byrne, D., & Alvarez, M. (2016). Economic growth, fossil fuel and non-fossil consumption: A Pooled Mean Group analysis using proxies for capital. Energy Economics, 60, 345–356. https://doi.org/10.1016/j.eneco.2016.10.016

Asongu, S. A., Agboola, M. O., Alola, A. A., & Bekun, F. V. (2020). The criticality of growth, urbanization, electricity and fossil fuel consumption to environment sustainability in Africa. Science of the Total Environment, 712. https://doi.org/10.1016/j.scitotenv.2019.136376

Asumadu-Sarkodie, S., & Owusu, P. A. (2017). The impact of energy, agriculture, macroeconomic and human-induced indicators on environmental pollution: evidence from Ghana. Environmental Science and Pollution Research, 24(7), 6622–6633. https://doi.org/10.1007/s11356-016-8321-6

Atis, S., Onat, N., & Guney, K. R. I. (2014). Assessment of the Turkey's electric power policies in terms of sustainability. Thermal Science, 18(3), 695–707. https://doi.org/10.2298/TSCI1403695A

Aye, G. C., & Edoja, P. E. (2017). Effect of economic growth on CO2 emission in developing countries: Evidence from a dynamic panel threshold model. Cogent Economics and Finance, 5(1). https://doi.org/10.1080/23322039.2017.1379239

Azretbergenova, G., Syzdykov, B., Niyazov, T., Gulzhan, T., & Yskak, N. (2021). The relationship between renewable energy production and employment in european union countries: Panel data analysis. International Journal of Energy Economics and Policy, 11(3), 20–26. https://doi.org/10.32479/ijeep.10744

Baba, E. A., & Amfo, B. (2021). Comparing the values of economic, ecological and population indicators in High- and Low-Income Economies. Economy of Region, 17(1), 72–85. https://doi.org/10.17059/ekon.reg.2021-1-6

Baek, S., Kim, H., & Chang, H. J. (2015). Optimal hybrid renewable power system for an emerging Island of South Korea: The case of Yeongjong Island. Sustainability (Switzerland), 7(10), 13985–14001. https://doi.org/10.3390/su71013985

Bakar, N. A. A., Raji, J. O., & Adeel-Farooq, R. M. (2019). Greenfield, mergers and acquisitions, energy consumption, and environmental performance in selected SAARC and ASEAN countries. International Journal of Energy Economics and Policy, 9(2), 216–224. https://doi.org/10.32479/ijeep.7512

Balsalobre-Lorente, D., Driha, O. M., Shahbaz, M., & Sinha, A. (2020). The effects of tourism and globalization over environmental degradation in developed countries. Environmental Science and Pollution Research, 27(7), 7130–7144. https://doi.org/10.1007/s11356-019-07372-4

Bano, S., Alam, M., Khan, A., & Liu, L. (2021). The nexus of tourism, renewable energy, income, and environmental quality: an empirical analysis of Pakistan. Environment, Development and Sustainability. https://doi.org/10.1007/s10668-021-01275-6

Barrett, M., Lowe, R., Oreszczyn, T., & Steadman, P. (2008). How to support growth with less energy. Energy Policy, 36(12), 4592–4599. https://doi.org/10.1016/j.enpol.2008.09.065

Bashir, M. F., Ma, B., Bashir, M. A., Bilal, & Shahzad, L. (2021). Scientific data-driven evaluation of academic publications on environmental Kuznets curve. Environmental Science and Pollution Research, 28(14), 16982–16999. https://doi.org/10.1007/s11356-021-13110-6

Baumli, K., & Jamasb, T. (2020). Assessing private investment in african renewable energy infrastructure: A multi-criteria decision analysis approach. Sustainability (Switzerland), 12(22), 1–19. https://doi.org/10.3390/su12229425

Belloumi, M., & Alshehry, A. S. (2015). Sustainable energy development in Saudi Arabia. Sustainability (Switzerland), 7(5), 5153–5170. https://doi.org/10.3390/su7055153

Ben Jebli, M., Ben Youssef, S., & Apergis, N. (2015). The dynamic interaction between combustible renewables and waste consumption and international tourism: the case of Tunisia. Environmental Science and Pollution Research, 22(16), 12050–12061. https://doi.org/10.1007/s11356-015-4483-x

Ben Jebli, M., Ben Youssef, S., & Apergis, N. (2019). The dynamic linkage between renewable energy, tourism, CO 2 emissions, economic growth, foreign direct investment, and trade. Latin American Economic Review, 28(1). https://doi.org/10.1186/s40503-019-0063-7

Bere, J., Jones, C., Jones, S., & Munday, M. (2017). Energy and development in the periphery: A regional perspective on small hydropower projects. Environment and Planning C: Government and Policy, 35(2), 355–375. https://doi.org/10.1177/0263774X16662029

Bhuiyan, M. A., An, J., Mikhaylov, A., Moiseev, N., & Danish, M. S. S. (2021). Renewable energy deployment and covid-19 measures for sustainable development. Sustainability (Switzerland), 13(8). https://doi.org/10.3390/su13084418

Bilan, Y., Streimikiene, D., Vasylieva, T., Lyulyov, O., Pimonenko, T., & Pavlyk, A. (2019). Linking between renewable energy, CO2 emissions, and economic growth: Challenges for candidates and potential candidates for the EU membership. Sustainability (Switzerland), 11(6). https://doi.org/10.3390/su11061528

Bollino1, C. A., Asdrubali, F., Polinori, P., Bigerna, S., Micheli, S., Guattari, C., & Rotili, A. (2017). A note on medium- and long-term global energy prospects and scenarios. Sustainability (Switzerland), 9(5). https://doi.org/10.3390/su9050833

Borri, E., Zsembinszki, G., & Cabeza, L. F. (2021). Recent developments of thermal energy storage applications in the built environment: A bibliometric analysis and systematic review. Applied Thermal Engineering, 189(September 2020). https://doi.org/10.1016/j.applthermaleng.2021.116666

Bortoluzzi, M., Correia de Souza, C., & Furlan, M. (2021). Bibliometric analysis of renewable energy types using key performance indicators and multicriteria decision models. Renewable and Sustainable Energy Reviews, 143(July 2020), 110958. https://doi.org/10.1016/j.rser.2021.110958

Busu, M. (2019). Adopting circular economy at the European Union level and its impact on economic growth. Social Sciences, 8(5). https://doi.org/10.3390/socsci8050159

Carfora, A., & Scandurra, G. (2019). The impact of climate funds on economic growth and their role in substituting fossil energy sources. Energy Policy, 129, 182–192. https://doi.org/10.1016/j.enpol.2019.02.023

Caruso, G., Colantonio, E., & Gattone, S. A. (2020). Relationships between renewable energy consumption, social factors, and health: A panel vector auto regression analysis of a cluster of 12 EU countries. Sustainability (Switzerland), 12(7). https://doi.org/10.3390/su12072915

Cavalcante, W. Q. de F., Coelho, A., & Bairrada, C. M. (2021). Sustainability and tourism marketing: A bibliometric analysis of publications between 1997 and 2020 using vosviewer software. Sustainability (Switzerland), 13(9). https://doi.org/10.3390/su13094987

Cerqueira, P. A., Soukiazis, E., & Proença, S. (2020). Assessing the linkages between recycling, renewable energy and sustainable development: evidence from the OECD countries. Environment, Development and Sustainability. https://doi.org/10.1007/s10668-020-00780-4

Chambers, I., Russell-Smith, J., Costanza, R., Cribb, J., Kerins, S., George, M., James, G., Pedersen, H., Lane, P., Christopherson, P., Ansell, J., & Sangha, K. (2018). Australia's north, Australia's future: A vision and strategies for sustainable economic, ecological and social prosperity in northern Australia. Asia and the Pacific Policy Studies, 5(3), 615–640. https://doi.org/10.1002/app5.259

Chandio, A. A., Rauf, A., Jiang, Y., Ozturk, I., & Ahmad, F. (2019). Cointegration and causality analysis of dynamic linkage between industrial energy consumption and economic growth in Pakistan. Sustainability (Switzerland), 11(17). https://doi.org/10.3390/su11174546

Chen, G. C., & Lees, C. (2016). Growing China's renewables sector: a developmental state approach. New Political Economy, 21(6), 574–586. https://doi.org/10.1080/13563467.2016.1183113

Chen, X., Foley, A., Zhang, Z., Wang, K., & O'Driscoll, K. (2020). An assessment of wind energy potential in the Beibu Gulf considering the energy demands of the Beibu Gulf Economic Rim. Renewable and Sustainable Energy Reviews, 119. https://doi.org/10.1016/j.rser.2019.109605

Cheng, C., Ren, X., Wang, Z., & Yan, C. (2019). Heterogeneous impacts of renewable energy and environmental patents on CO 2 emission - Evidence from the BRIICS. Science of the Total Environment, 668, 1328–1338. https://doi.org/10.1016/j.scitotenv.2019.02.063

Chovancová, J., & Vavrek, R. (2020). (De)coupling analysis with focus on energy consumption in EU countries and its spatial evaluation. Polish Journal of Environmental Studies, 29(3), 2091–2100. https://doi.org/10.15244/pjoes/110613

Cucui, G., Ionescu, C. A., Goldbach, I. R., Coman, M. D., & Marin, E. L. M. (2018). Quantifying the economic effects of biogas installations for organicwaste from agro-industrial sector. Sustainability (Switzerland), 10(7). https://doi.org/10.3390/su10072582

Cui, H., Wu, X., & Fang, T. (2021). An empirical research on the relationship between renewable energy investment and low carbon growth in china. Polish Journal of Environmental Studies, 30(2), 1095–1104. https://doi.org/10.15244/pjoes/123198

Daryono, Wahyudi, S., & Suharnomo, S. (2019). The development of green energy policy planning model to improve economic growth in Indonesia. International Journal of Energy Economics and Policy, 9(5), 216–223. https://doi.org/10.32479/ijeep.7779

De las Heras, A., Relinque-Medina, F., Zamora-Polo, F., & Luque-Sendra, A. (2021). Analysis of the evolution of the sharing economy towards sustainability. Trends and transformations of the concept. Journal of Cleaner Production, 291, 125227. https://doi.org/10.1016/j.jclepro.2020.125227

Dinç, D. T., & Akdoğan, E. C. (2019). Renewable energy production, energy consumption and sustainable economic growth in Turkey: A VECM approach. Sustainability (Switzerland), 11(5). https://doi.org/10.3390/su11051273

Ding, Z., Wu, W., & Leung, M. (2021). Advanced/hybrid thermal energy storage technology: material, cycle, system and perspective. Renewable and Sustainable Energy Reviews, 145(April), 111088. https://doi.org/10.1016/j.rser.2021.111088

Dogan, B., & Deger, O. (2018). The Energy Consumption and Economic Growth In The E7 Countries: Cointegration In Panel Data With Structural Breaks. Romanian Journal of Economic Forecasting, 1, 63–75.

Ertay, T., Kahraman, C., & Kaya, I. (2013). Evaluation of renewable energy alternatives using MACBETH and fuzzy AHP multicriteria methods: the case of Turkey. Technological and Economic Development of Economy, 19(1), 38–62. https://doi.org/10.3846/20294913.2012.762950

Esen, Ö., & Bayrak, M. (2017). Does more energy consumption support economic growth in net energy-importing countries? Journal of Economics, Finance and Administrative Science, 22(42), 75–98. https://doi.org/10.1108/JEFAS-01-2017-0015

Eyuboglu, K., & Uzar, U. (2020). Examining the roles of renewable energy consumption and agriculture on CO2 emission in lucky-seven countries. Environmental Science and Pollution Research, 27(36), 45031–45040. https://doi.org/10.1007/s11356-020-10374-2

Fang, Z., Chang, Y., & Hamori, S. (2017). Human Capital and Energy: a Driver or Drag for Economic Growth. Singapore Economic Review, 63(1), 1–32. https://doi.org/10.1142/S0217590817500163

Fonseca, L. M., Domingues, P., & Dima, A. M. (2020). Mapping the sustainable development goals relationships. Sustainability (Switzerland), 12(8). https://doi.org/10.3390/SU12083359

Gao, L., Hiruta, Y., & Ashina, S. (2020). Promoting renewable energy through willingness to pay for transition to a low carbon society in Japan. Renewable Energy, 162, 818–830. https://doi.org/10.1016/j.renene.2020.08.049

Gasmi, F., Recuero Virto, L., & Couvet, D. (2020). The Impact of Renewable Versus Non-renewable Natural Capital on Economic Growth. Environmental and Resource Economics, 77(2), 271–333. https://doi.org/10.1007/s10640-020-00495-0

Gaynanov, D. A., Kantor, O. G., & Kashirina, E. S. (2015). Synergetic modelling of the Russian Federation's energy system parameters. Economy of Region, 1(4), 618–628. https://doi.org/10.15826/recon.2015.4.024

Ghobakhloo, M., Fathi, M., Iranmanesh, M., Maroufkhani, P., & Morales, M. E. (2021). Industry 4.0 ten years on: A bibliometric and systematic review of concepts, sustainability value drivers, and success determinants. Journal of Cleaner Production, 302, 127052. https://doi.org/10.1016/j.jclepro.2021.127052

Gielen, D., Boshell, F., Saygin, D., Bazilian, M. D., Wagner, N., & Gorini, R. (2019). The role of renewable energy in the global energy transformation. Energy Strategy Reviews, 24, 38–50. https://doi.org/10.1016/j.esr.2019.01.006

Gosens, J. (2020). The greening of South-South trade: Levels, growth, and specialization of trade in clean energy technologies between countries in the global South. Renewable Energy, 160, 931–943. https://doi.org/10.1016/j.renene.2020.06.014

Haas, W., Krausmann, F., Wiedenhofer, D., & Heinz, M. (2015). How circular is the global economy?: An assessment of material flows, waste production, and recycling in the European union and the world in 2005. Journal of Industrial Ecology, 19(5), 765–777. https://doi.org/10.1111/jiec.12244

Hadiwijoyo, R., Purwanto, P., & Hadi, S. P. (2013). Innovative green technology for sustainable industrial estate development. International Journal of Renewable Energy Development, 2(1), 53–58. https://doi.org/10.14710/ijred.2.1.53-58

Han, J., Mol, A. P. J., Lu, Y., & Zhang, L. (2009). Onshore wind power development in China: Challenges behind a successful story. Energy Policy, 37(8), 2941–2951. https://doi.org/10.1016/j.enpol.2009.03.021

Hao, Y.-L., Li, S., & Xia, Q. (2020). Strategic Research on the Urban Natural Gas Energy System Under the Path to Ecological Civilization: Fuyang City Case Study. Frontiers in Energy Research, 7. https://doi.org/10.3389/fenrg.2019.00147

Hasanov, F. J., Mikayilov, J. I., Mukhtarov, S., & Suleymanov, E. (2019). Does CO2 emissions–economic growth relationship reveal EKC in developing countries? Evidence from Kazakhstan. Environmental Science and Pollution Research, 26(29), 30229–30241. https://doi.org/10.1007/s11356-019-06166-y

Hassan, S. A., & Nosheen, M. (2019). Estimating the Railways Kuznets Curve for high income nations—A GMM approach for three pollution indicators. Energy Reports, 5, 170–186. https://doi.org/10.1016/j.egyr.2019.01.001

Hdom, H. A. D., & Fuinhas, J. A. (2020). Energy production and trade openness: Assessing economic growth, CO2 emissions and the applicability of the cointegration analysis. Energy Strategy Reviews, 30. https://doi.org/10.1016/j.esr.2020.100488

He, J., Chen, J., Peng, H., & Duan, H. L. (2021). Exploring the effect of renewable energy on low-carbon sustainable development in the Belt and Road Initiative countries: evidence from the spatial-temporal perspective. Environmental Science and Pollution Research. https://doi.org/10.1007/s11356-021-13611-4

Henrysson, M., & Hendrickson, C. Y. (2021). Transforming the governance of energy systems: the politics of ideas in low-carbon infrastructure development in Mexico and Vietnam. Climate and Development, 13(1), 49–60. https://doi.org/10.1080/17565529.2020.1723469

Hirsch, J. E. (2005). An index to quantify an individual's scientific research output. Proceedings of the National Academy of Sciences of the United States of America, 102(46), 16569–16572. https://doi.org/10.1073/pnas.0507655102

Hodson, E. L., Brown, M., Cohen, S., Showalter, S., Wise, M., Wood, F., Caron, J., Feijoo, F., Iyer, G., & Cleary, K. (2018). U.S. energy sector impacts of technology innovation, fuel price, and electric sector CO2 policy: Results from the EMF 32 model intercomparison study. Energy Economics, 73, 352–370. https://doi.org/10.1016/j.eneco.2018.03.027

Hong, C.-Y., & Yen, Y.-S. (2019). A way from renewable energy sources to urban sustainable development: Empirical evidences from taichung city. International Journal of Energy Economics and Policy, 9(2), 83–88. https://doi.org/10.32479/ijeep.7225

Hosseini, S. M., Saifoddin, A., Shirmohammadi, R., & Aslani, A. (2019). Forecasting of CO2 emissions in Iran based on time series and regression analysis. Energy Reports, 5, 619–631. https://doi.org/10.1016/j.egyr.2019.05.004

Huong, T. T., Shah, I. H., & Park, H. S. (2021). Decarbonization of Vietnam's economy: decomposing the drivers for a low-carbon growth. Environmental Science and Pollution Research, 28(1), 518–529. https://doi.org/10.1007/s11356-020-10481-0

Huq, H. (2018). Solar energy fuels for sustainable livelihoods: Case study of southwest coastal region of Bangladesh. Geography, Environment, Sustainability, 11(4), 132–143. https://doi.org/10.24057/2071-9388-2018-11-4-132-143

Ike, G. N., Usman, O., & Sarkodie, S. A. (2020). Fiscal policy and CO2 emissions from heterogeneous fuel sources in Thailand: Evidence from multiple structural breaks cointegration test. Science of the Total Environment, 702. https://doi.org/10.1016/j.scitotenv.2019.134711

Imasiku, K., Thomas, V. M., & Ntagwirumugara, E. (2020). Unpacking ecological stress from economic activities for sustainability and resource optimization in Sub-Saharan Africa. Sustainability (Switzerland), 12(9). https://doi.org/10.3390/SU12093538

Jamel, L., & Abdelkader, D. (2016). Do energy consumption and economic growth lead to environmental degradation? Evidence from Asian economies. Cogent Economics and Finance, 4(1). https://doi.org/10.1080/23322039.2016.1170653

Jianzhong, X. U., Assenova, A., & Erokhin, V. (2018). Renewable energy and sustainable development in a resource-abundant country: Challenges of wind power generation in Kazakhstan. Sustainability (Switzerland), 10(9). https://doi.org/10.3390/su10093315

Johansson, D. J. A., Lucas, P. L., Weitzel, M., Ahlgren, E. O., Bazaz, A. B., Chen, W., den Elzen, M. G. J., Ghosh, J., Grahn, M., Liang, Q.-M., van Vuuren, D. P., & Wei, Y.-M. (2015). Multi-model comparison of the economic and energy implications for China and India in an international climate regime. Mitigation and Adaptation Strategies for Global Change, 20(8), 1335–1359. https://doi.org/10.1007/s11027-014-9549-4

Kablamaci, B. (2017). A re-examination of causal relation between economic growth and energy consumption: Evidence from 91 countries. Economics Bulletin, 37(2), 790–805.

Karim, M. E., Karim, R., Islam, M. T., Muhammad-Sukki, F., Bani, N. A., & Muhtazaruddin, M. N. (2019). Renewable energy for sustainable growth and development: An evaluation of law and policy of Bangladesh. Sustainability (Switzerland), 11(20). https://doi.org/10.3390/su11205774

Katina, J., Sansyzbayeva, G. N., Guliyeva, A., & Rzayeva, U. (2018). Threats to the country's sustainable economic development: A case study. Journal of Security and Sustainability Issues, 8(1), 113-122. https://doi.org/10.9770/jssi.2018.8.1(10)

Khan, M. K., Khan, M. I., & Rehan, M. (2020). The relationship between energy consumption, economic growth and carbon dioxide emissions in Pakistan. Financial Innovation, 6(1). https://doi.org/10.1186/s40854-019-0162-0

Khan, R., & Kong, Y. (2020). Effects of Energy Consumption on GDP: New Evidence of 24 Countries on Their Natural Resources and Production of Electricity. Ekonomika Vilniaus Universitetas, 99(1), 26–49. https://doi.org/10.15388/ekon.2020.1.2

Khandekar, A. V., Antuchevičienė, J., & Chakraborty, S. (2015). Small hydro-power plant project selection using fuzzy axiomatic design principles. Technological and Economic Development of Economy, 21(5), 756–772. https://doi.org/10.3846/20294913.2015.1056282

Koengkan, M., Santiago, R., Fuinhas, J. A., & Marques, A. C. (2019). Does financial openness cause the intensification of environmental degradation? New evidence from Latin American and Caribbean countries. Environmental Economics and Policy Studies, 21(4), 507–532. https://doi.org/10.1007/s10018-019-00240-y

Koondhar, M. A., Shahbaz, M., Memon, K. A., Ozturk, I., & Kong, R. (2021). A visualization review analysis of the last two decades for environmental Kuznets curve “EKC” based on co-citation analysis theory and pathfinder network scaling algorithms. Environmental Science and Pollution Research, 28(13), 16690–16706. https://doi.org/10.1007/s11356-020-12199-5

Krakauer, N. Y. (2014). Economic growth assumptions in climate and energy policy. Sustainability (Switzerland), 6(3), 1448–1461. https://doi.org/10.3390/su6031448

Kravtsiv, V., Zhuk, P., & Bashynska, Y. (2017). Development capacity and perspectives of the renewable energy in the Carpathian region of Ukraine. Economic Annals-XXI, 168(11–12), 73–77. https://doi.org/10.21003/ea.V168-15

Kutan, A. M., Paramati, S. R., Ummalla, M., & Zakari, A. (2018). Financing Renewable Energy Projects in Major Emerging Market Economies: Evidence in the Perspective of Sustainable Economic Development. Emerging Markets Finance and Trade, 54(8), 1762–1778. https://doi.org/10.1080/1540496X.2017.1363036

Laila, N., Rusydiana, A. S., Irfany, M. I., Imron, H. R., Srisusilawati, P., & Taqi, M. (2021). Energy economics in Islamic countries: A bibliometric review. International Journal of Energy Economics and Policy, 11(2), 88–95. https://doi.org/10.32479/ijeep.10763

Lanshina, T., & Barinova, V. (2017). The Global Governance of Renewable Energy: International trends and Russia. International Organisations Research Journal, 12(1), 110–126. https://doi.org/10.17323/1996-7845-2017-01-110

Lawson, L. A. (2020). GHG emissions and fossil energy use as consequences of efforts of improving human well-being in Africa. Journal of Environmental Management, 273. https://doi.org/10.1016/j.jenvman.2020.111136

Le, H.P., & Sarkodie, S. A. (2020). Dynamic linkage between renewable and conventional energy use, environmental quality and economic growth: Evidence from Emerging Market and Developing Economies. Energy Reports, 6, 965–973. https://doi.org/10.1016/j.egyr.2020.04.020

Le, Hoang Phong, & Bao, H. H. G. (2020). Renewable and nonrenewable energy consumption, government expenditure, institution quality, financial development, trade openness, and sustainable development in Latin America and Caribbean emerging market and developing economies. International Journal of Energy Economics and Policy, 10(1), 242–248. https://doi.org/10.32479/ijeep.8506

Lisin, E., Kurdiukova, G., & Strielkowski, W. (2016). Economic prospects of the power-plant industry development in russia. Journal of International Studies, 9(3), 178–190. https://doi.org/10.14254/2071-8330.2016/9-3/14

Liu, C. H., Lin, S. J., & Lewis, C. (2012). Environmental impacts of electricity sector in Taiwan by using input-output life cycle assessment: The role of carbon dioxide emissions. Aerosol and Air Quality Research, 12(5), 733–744. https://doi.org/10.4209/aaqr.2012.04.0090

Liu, J., Zhang, D., Cai, J., & Davenport, J. (2019). Legal Systems, National Governance and Renewable Energy Investment: Evidence from Around the World. British Journal of Management. https://doi.org/10.1111/1467-8551.12377

Liu, W., Fan, W., Hong, Y., & Chen, C. (2021). A Study on the Comprehensive Evaluation and Analysis of China's Renewable Energy Development and Regional Energy Development. Frontiers in Energy Research, 9. https://doi.org/10.3389/fenrg.2021.635570

Liu, Weiwei, Xu, X., Yang, Z., Zhao, J., & Xing, J. (2016). Impacts of FDI renewable energy technology spillover on China's energy industry performance. Sustainability (Switzerland), 8(9). https://doi.org/10.3390/su8090846

MacKinnon, D., Dawley, S., Steen, M., Menzel, M.-P., Karlsen, A., Sommer, P., Hansen, G. H., & Normann, H. E. (2019). Path creation, global production networks and regional development: A comparative international analysis of the offshore wind sector. Progress in Planning, 130, 1–32. https://doi.org/10.1016/j.progress.2018.01.001

Madsen, D. N., & Hansen, J. P. (2019). Outlook of solar energy in Europe based on economic growth characteristics. Renewable and Sustainable Energy Reviews, 114. https://doi.org/10.1016/j.rser.2019.109306

Magazzino, C., Mele, M., & Morelli, G. (2021). The relationship between renewable energy and economic growth in a time of COVID-19: A machine learning experiment on the Brazilian economy. Sustainability (Switzerland), 13(3), 1–24. https://doi.org/10.3390/su13031285

Makarov, A. A., Mitrova, T. A., & Kulagin, V. A. (2021). Long-term development of the global energy sector under the influence of energy policies and technological progress. Russian Journal of Economics, 6(4), 347–357. https://doi.org/10.32609/J.RUJE.6.55196

Maneejuk, N., Ratchakom, S., Maneejuk, P., & Yamaka, W. (2020). Does the environmental Kuznets curve exist? An international study. Sustainability (Switzerland), 12(21), 1–22. https://doi.org/10.3390/su12219117

Mardani, A., Streimikiene, D., Cavallaro, F., Loganathan, N., & Khoshnoudi, M. (2019). Carbon dioxide (CO2) emissions and economic growth: A systematic review of two decades of research from 1995 to 2017. Science of the Total Environment, 649, 31–49. https://doi.org/10.1016/j.scitotenv.2018.08.229

Marolin, M., Drvenkar, N., & Unukić, I. (2020). The potential of solar energy as a driver of regional development - Challenges and opportunities. International Journal of Energy Economics and Policy, 10(6), 411–420. https://doi.org/10.32479/ijeep.10068

Marques, R. S., Silva Martins, L. O., Fernandes, F. M., Silva, M. S., & Freires, F. G. M. (2020). Wind power and competitiveness: A bibliometric analysis | Energia eólica e competitividade: Uma análise bibliométrica. Informacao e Sociedade, 30(2). https://doi.org/10.22478/ufpb.1809-4783.2020v30n2.52282

Melas, V., Lisin, E., Tvaronavičiene, M., Peresadko, G., & Radwański, R. (2017). Energy security and economic development: Renewables and the integration of energy systems. Journal of Security and Sustainability Issues, 7(1), 133–140. https://doi.org/10.9770/jssi.2017.7.1(11)

Merigó, J. M., & Yang, J. B. (2017). Accounting Research: A Bibliometric Analysis. Australian Accounting Review, 27(1), 71–100. https://doi.org/10.1111/auar.12109

Mijakovski, V., Lutovska, M., & Trajkovski, Z. (2018). Techno-economic analysis of the wind park bogdanci in the republic of Macedonia. Thermal Science, 22, S1449–S1458. https://doi.org/10.2298/TSCI18S5449M

Milad Mousavian, H., Hamed Shakouri, G., Mashayekhi, A. N., & Kazemi, A. (2020). Does the short-term boost of renewable energies guarantee their stable long-term growth? Assessment of the dynamics of feed-in tariff policy. Renewable Energy, 159, 1252–1268. https://doi.org/10.1016/j.renene.2020.06.068

Miskinis, V., Galinis, A., Konstantinaviciute, I., Lekavicius, V., & Neniskis, E. (2019). Comparative analysis of the energy sector development trends and forecast of final energy demand in the Baltic States. Sustainability (Switzerland), 11(2). https://doi.org/10.3390/su11020521

Monasterolo, I., & Raberto, M. (2019). The impact of phasing out fossil fuel subsidies on the low-carbon transition. Energy Policy, 124, 355–370. https://doi.org/10.1016/j.enpol.2018.08.051

Moraru, D. (2015). The need of a win-win regulation regarding the harmonization of advantages for the renewable energy sector and the concerns about the environment. Management and Marketing, 10(1), 61–71. https://doi.org/10.1515/mmcks-2015-0005

Mrówczyńska, M., Skiba, M., Sztubecka, M., Bazan-Krzywoszańska, A., Kazak, J. K., & Gajownik, P. (2021). Scenarios as a tool supporting decisions in urban energy policy: The analysis using fuzzy logic, multi-criteria analysis and GIS tools. Renewable and Sustainable Energy Reviews, 137. https://doi.org/10.1016/j.rser.2020.110598

Muhammed, G., & Tekbiyik-Ersoy, N. (2020). Development of renewable energy in china, usa, and brazil: A comparative study on renewable energy policies. Sustainability (Switzerland), 12(21), 1–30. https://doi.org/10.3390/su12219136

Mujtaba, G., & Shahzad, S. J. H. (2021). Air pollutants, economic growth and public health: implications for sustainable development in OECD countries. Environmental Science and Pollution Research, 28(10), 12686–12698. https://doi.org/10.1007/s11356-020-11212-1

Murshed, M. (2020). An empirical analysis of the non-linear impacts of ICT-trade openness on renewable energy transition, energy efficiency, clean cooking fuel access and environmental sustainability in South Asia. Environmental Science and Pollution Research, 27(29), 36254–36281. https://doi.org/10.1007/s11356-020-09497-3

Murshed, M., & Dao, N. T. T. (2020). Revisiting the CO2 emission-induced EKC hypothesis in South Asia: the role of Export Quality Improvement. GeoJournal. https://doi.org/10.1007/s10708-020-10270-9

Nazeer, M., Tabassum, U., & Alam, S. (2016). Environmental pollution and sustainable development in developing countries. Pakistan Development Review, 55(4), 589–604. https://doi.org/10.30541/v55i4i-iipp.589-604

Nguyen, H. M., Bui, N. H., Vo, D. H., & McAleer, M. (2019). Energy consumption and economic growth: Evidence from Vietnam. Journal of Reviews on Global Economics, 8, 350–361. https://doi.org/10.6000/1929-7092.2019.08.30

Njoke, M. L., Wu, Z., & Tamba, J. G. (2019). Empirical analysis of electricity consumption, CO2 emissions and economic growth: Evidence from Cameroon. International Journal of Energy Economics and Policy, 9(5), 63–73. https://doi.org/10.32479/ijeep.7915

Nosheen, M., Iqbal, J., & Khan, H. U. (2021). Analyzing the linkage among CO2 emissions, economic growth, tourism, and energy consumption in the Asian economies. Environmental Science and Pollution Research, 28(13), 16707–16719. https://doi.org/10.1007/s11356-020-11759-z

O' Mahony, T., Zhou, P., & Sweeney, J. (2012). The driving forces of change in energy-related CO 2 emissions in Ireland: A multi-sectoral decomposition from 1990 to 2007. Energy Policy, 44, 256–267. https://doi.org/10.1016/j.enpol.2012.01.049

Odeku, K. O. (2017). The intrinsic role of the banks in decarbonizing the economy. Banks and Bank Systems, 12(4), 44–55. https://doi.org/10.21511/bbs.12(4).2017.04

Odgaard, O. (2015). China's low carbon energy policy: National dilemmas and global perspectives. Copenhagen Journal of Asian Studies, 33(1), 13–39. https://doi.org/10.22439/cjas.v33i1.4810

Ortega-Ruiz, G., Mena-Nieto, A., & García-Ramos, J. E. (2020). Is India on the right pathway to reduce CO2 emissions? Decomposing an enlarged Kaya identity using the LMDI method for the period 1990–2016. Science of the Total Environment, 737. https://doi.org/10.1016/j.scitotenv.2020.139638

Oteman, M., Kooij, H. J., & Wiering, M. A. (2017). Pioneering renewable energy in an economic energy policy system: The history and development of dutch grassroots initiatives. Sustainability (Switzerland), 9(4). https://doi.org/10.3390/su9040550

Ou, X., Yuan, Z., Peng, T., Sun, Z., & Zhou, S. (2017). The low-carbon transition toward sustainability of regional coal-dominated energy consumption structure: A case of Hebei province in china. Sustainability (Switzerland), 9(7). https://doi.org/10.3390/su9071184

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. PLoS Medicine, 18(3), e1003583. https://doi.org/10.1371/journal.pmed.1003583

Pansera, M. (2013). Innovation system for sustainability in developing countries: The renewable energy sector in Bolivia. International Journal of Innovation and Sustainable Development, 7(1), 27–45. https://doi.org/10.1504/IJISD.2013.052119

Pastén, R., Saens, R., & Contreras Marín, R. (2015). Does energy use cause economic growth in Latin America? Applied Economics Letters, 22(17), 1399–1403. https://doi.org/10.1080/13504851.2015.1034834

Pereira, R., Sequeira, T., & Cerqueira, P. (2021). Renewable energy consumption and economic growth: a note reassessing panel data results. Environmental Science and Pollution Research, 28(15), 19511–19520. https://doi.org/10.1007/s11356-021-12961-3

Pham, N. M., Huynh, T. L. D., & Nasir, M. A. (2020). Environmental consequences of population, affluence and technological progress for European countries: A Malthusian view. Journal of Environmental Management, 260. https://doi.org/10.1016/j.jenvman.2020.110143

Pinzón, K. (2018). Dynamics between energy consumption and economic growth in Ecuador: A granger causality analysis. Economic Analysis and Policy, 57, 88–101. https://doi.org/10.1016/j.eap.2017.09.004

Prastiyo, S. E., Irham, Hardyastuti, S., & Jamhari. (2020). How agriculture, manufacture, and urbanization induced carbon emission? The case of Indonesia. Environmental Science and Pollution Research, 27(33), 42092–42103. https://doi.org/10.1007/s11356-020-10148-w

Pretel, R., Shoener, B. D., Ferrer, J., & Guest, J. S. (2015). Navigating environmental, economic, and technological trade-offs in the design and operation of submerged anaerobic membrane bioreactors (AnMBRs). Water Research, 87, 531–541. https://doi.org/10.1016/j.watres.2015.07.002

Pryshliak, N., & Tokarchuk, D. (2020). Socio-economic and environmental benefits of biofuel production development from agricultural waste in Ukraine. Environmental and Socio-Economic Studies, 8(1), 18–27. https://doi.org/10.2478/environ-2020-0003

Qi, T., Zhang, X., & Karplus, V. J. (2014). The energy and CO2 emissions impact of renewable energy development in China. Energy Policy, 68, 60–69. https://doi.org/10.1016/j.enpol.2013.12.035

Qin, J., Tao, H., Cheng, C., Brindha, K., Zhan, M., Ding, J., & Mu, G. (2020). Analysis of factors influencing carbon emissions in the energy base, Xinjiang autonomous region, China. Sustainability (Switzerland), 12(3). https://doi.org/10.3390/su12031089

Qu, L., Shi, X., Liu, C., & Yuan, Y. (2017). An emergy-based hybrid method for assessing sustainability of the resource-dependent region. Sustainability (Switzerland), 9(1). https://doi.org/10.3390/su9010153

Radmehr, R., Henneberry, S. R., & Shayanmehr, S. (2021). Renewable Energy Consumption, CO2 Emissions, and Economic Growth Nexus: A Simultaneity Spatial Modeling Analysis of EU Countries. Structural Change and Economic Dynamics, 57, 13–27. https://doi.org/10.1016/j.strueco.2021.01.006

Rahman, S. M., Dinar, A., & Larson, D. F. (2016). The incidence and extent of the CDM across developing countries. Environment and Development Economics, 21(4), 415–438. https://doi.org/10.1017/S1355770X15000388

Raszkowski, A., & Bartniczak, B. (2019). On the road to sustainability: Implementation of the 2030 Agenda sustainable development goals (SDG) in Poland. Sustainability (Switzerland), 11(2). https://doi.org/10.3390/su11020366

Rauf, A., Liu, X., Amin, W., Ozturk, I., Rehman, O. U., & Sarwar, S. (2018). Energy and ecological sustainability: Challenges and panoramas in belt and road initiative countries. Sustainability (Switzerland), 10(8). https://doi.org/10.3390/su10082743

Rauf, Abdul, Zhang, J., Li, J., & Amin, W. (2018). Structural changes, energy consumption and carbon emissions in China: Empirical evidence from ARDL bound testing model. Structural Change and Economic Dynamics, 47, 194–206. https://doi.org/10.1016/j.strueco.2018.08.010

Rehan, M., Nizami, A. S., Shahzad, K., Ouda, O. K. M., Ismail, I. M. I., Almeelbi, T., Iqbal, T., & Demirbas, A. (2016). Pyrolytic liquid fuel: A source of renewable electricity generation in Makkah. Energy Sources, Part A: Recovery, Utilization and Environmental Effects, 38(17), 2598–2603. https://doi.org/10.1080/15567036.2016.1153753

Režný, L., & Bureš, V. (2019). Energy transition scenarios and their economic impacts in the extended neoclassical model of economic growth. Sustainability (Switzerland), 11(13). https://doi.org/10.3390/su11133644

Ridzuan, A. R., Kamaludin, M., Ismail, N. A., Razak, M. I. M., & Haron, N. F. (2020). Macroeconomic indicators for electrical consumption demand model in malaysia. International Journal of Energy Economics and Policy, 10(1), 16–22. https://doi.org/10.32479/ijeep.8139

Riti, J. S., & Shu, Y. (2016). Renewable energy, energy efficiency, and eco-friendly environment (R-E5) in Nigeria. Energy, Sustainability and Society, 6(1). https://doi.org/10.1186/s13705-016-0072-1

Robalino-López, A., García-Ramos, J.-E., Golpe, A. A., & Mena-Nieto, T. (2014). System dynamics modelling and the environmental Kuznets curve in Ecuador (1980-2025). Energy Policy, 67, 923–931. https://doi.org/10.1016/j.enpol.2013.12.003

Roespinoedji, D., Juniati, S., Hasan, H., Jalil, N. A., & Shamsudin, M. F. (2019). Experimenting the long-haul association between components of consuming renewable energy: ARDL method with special reference to Malaysia. International Journal of Energy Economics and Policy, 9(6), 453–460. https://doi.org/10.32479/ijeep.8694

Roespinoedji, R., Juniati, S., & Ali, A. (2020). Macroeconomic Indicators And Co2 Emission: Are Asean Countries Doing A Wrong Trade-Off? Journal of Security and Sustainability Issues, 10(Oct), 279–290. https://doi.org/10.9770/jssi.2020.10.Oct(21)

Rutebuka, E., Zhang, L., Asamoah, E. F., Pang, M., & Rukundo, E. (2018). Resource dynamism of the Rwandan economy: An emergy approach. Sustainability (Switzerland), 10(6). https://doi.org/10.3390/su10061791

Safta, C. A., Marinov, A. M., Dumitran, G. E., & Popa, B. (2013). Clean and sustainable electric energy in Romania. WIT Transactions on Ecology and the Environment, 176, 3–15. https://doi.org/10.2495/ESUS130011

Sarangi, G. K., Mishra, A., Chang, Y., & Taghizadeh-Hesary, F. (2019). Indian electricity sector, energy security and sustainability: An empirical assessment. Energy Policy, 135. https://doi.org/10.1016/j.enpol.2019.110964

Sarkodie, S.A. (2020). Causal effect of environmental factors, economic indicators and domestic material consumption using frequency domain causality test. Science of the Total Environment, 736. https://doi.org/10.1016/j.scitotenv.2020.139602

Sarkodie, Samuel Asumadu, Adams, S., Owusu, P. A., Leirvik, T., & Ozturk, I. (2020). Mitigating degradation and emissions in China: The role of environmental sustainability, human capital and renewable energy. Science of the Total Environment, 719. https://doi.org/10.1016/j.scitotenv.2020.137530

Saudi, M. H. M., Sinaga, O., Roespinoedji, D., & Razimi, M. S. A. (2019). The role of renewable, non-renewable electricity consumption and carbon emission in development in Indonesia: Evidence from distributed lag tests. International Journal of Energy Economics and Policy, 9(3), 46–52. https://doi.org/10.32479/ijeep.7730

Sekrafi, H., & Sghaier, A. (2018). Examining the Relationship Between Corruption, Economic Growth, Environmental Degradation, and Energy Consumption: a Panel Analysis in MENA Region. Journal of the Knowledge Economy, 9(3), 963–979. https://doi.org/10.1007/s13132-016-0384-6

Shabbir, A., Kousar, S., & Kousar, F. (2020). The role of natural resources in economic growth: new evidence from Pakistan. Journal of Economics, Finance and Administrative Science, 25(50), 221–238. https://doi.org/10.1108/JEFAS-03-2019-0044

Shahbaz, M., Benkraiem, R., Miloudi, A., & Lahiani, A. (2017). Production function with electricity consumption and policy implications in Portugal. Energy Policy, 110, 588–599. https://doi.org/10.1016/j.enpol.2017.08.056

Shi, S., & Yin, J. (2021). Global research on carbon footprint: A scientometric review. Environmental Impact Assessment Review, 89(February). https://doi.org/10.1016/j.eiar.2021.106571

Siciliano, G., Urban, F., Kim, S., & Dara Lonn, P. (2015). Hydropower, social priorities and the rural-urban development divide: The case of large dams in Cambodia. Energy Policy, 86, 273–285. https://doi.org/10.1016/j.enpol.2015.07.009

Silva, S., Soares, I., & Pinho, C. (2012). The impact of renewable energy sources on economic growth and co 2 emissions - A svar approach. European Research Studies Journal, 15(SPECIAL ISSUE), 133–144. https://doi.org/10.35808/ersj/374

Simas, M., & Pacca, S. (2013). Socio-economic benefits of wind power in Brazil. Journal of Sustainable Development of Energy, Water and Environment Systems, 1(1), 27–40. https://doi.org/10.13044/j.sdewes.2013.01.0003

Simionescu, M., Albu, L.-L., Raileanu Szeles, M., & Bilan, Y. (2017). The impact of biofuels utilisation in transport on the sustainable development in the European Union. Technological and Economic Development of Economy, 23(4), 667–686. https://doi.org/10.3846/20294913.2017.1323318

Sinaga, O., Alaeddin, O., & Jabarullah, N. H. (2019). The impact of hydropower energy on the environmental kuznets curve in Malaysia. International Journal of Energy Economics and Policy, 9(1), 308–315. https://doi.org/10.32479/ijeep.7328

Singh, N., Nyuur, R., & Richmond, B. (2019). Renewable energy development as a driver of economic growth: Evidence from multivariate panel data analysis. Sustainability (Switzerland), 11(8). https://doi.org/10.3390/su11082418

Singh, R. P., Nachtnebel, H. P., & Komendantova, N. (2020). Deployment of hydropower in Nepal: Multiple stakeholders' perspectives. Sustainability (Switzerland), 12(16). https://doi.org/10.3390/SU12166312

Soukiazis, E., Proença, S., & Cerqueira, P. A. (2019). The interconnections between renewable energy, economic development and environmental pollution: A simultaneous equation system approach. Energy Journal, 40(4), 1–23. https://doi.org/10.5547/01956574.40.4.esou

Sovacool, B. K., & Walter, G. (2019). Internationalizing the political economy of hydroelectricity: security, development and sustainability in hydropower states. Review of International Political Economy, 26(1), 49–79. https://doi.org/10.1080/09692290.2018.1511449

Stadniczeńko, D. (2020). Development and challenges for the functioning of the renewable energy prosumer in Poland: A legal perspective. International Journal of Energy Economics and Policy, 10(5), 623–630. https://doi.org/10.32479/ijeep.10225

Štreimikienė, D., & Mikalauskienė, A. (2016). Green growth and use of EU structural funds in baltic states, Czech Republic and Slovakia. E a M: Ekonomie a Management, 19(2), 55–72. https://doi.org/10.15240/tul/001/2016-2-004

Sugiawan, Y., & Managi, S. (2016). The environmental Kuznets curve in Indonesia: Exploring the potential of renewable energy. Energy Policy, 98, 187–198. https://doi.org/10.1016/j.enpol.2016.08.029

Sulaiman, C., & Abdul-Rahim, A. S. (2017). The relationship between CO2 emission, energy consumption and economic growth in Malaysia: a three-way linkage approach. Environmental Science and Pollution Research, 24(32), 25204–25220. https://doi.org/10.1007/s11356-017-0092-1

Surya, B., Muhibuddin, A., Suriani, S., Rasyidi, E. S., Baharuddin, B., Fitriyah, A. T., & Abubakar, H. (2021). Economic evaluation, use of renewable energy, and sustainable urban development mamminasata metropolitan, Indonesia. Sustainability (Switzerland), 13(3), 1–45. https://doi.org/10.3390/su13031165

Taghizadeh-Hesary, F., & Rasoulinezhad, E. (2020). Analyzing Energy Transition Patterns in Asia: Evidence From Countries With Different Income Levels. Frontiers in Energy Research, 8. https://doi.org/10.3389/fenrg.2020.00162

Tang, Xu;Deng, Hongmei; Zhang, Baosheng; Snowden, Simon;Höök, M. (2016). Nexus Between Energy Consumption and Economic Growth in China: From the Perspective of Embodied Energy Imports and Exports. Emerging Markets Finance and Trade, 52(6), 1298–1304. https://doi.org/10.1080/1540496X.2016.1152791

Tawiah, V., Zakari, A., & Adedoyin, F. F. (2021). Determinants of green growth in developed and developing countries. Environmental Science and Pollution Research. https://doi.org/10.1007/s11356-021-13429-0

Tenaw, D. (2021). Decomposition and macroeconomic drivers of energy intensity: The case of Ethiopia. Energy Strategy Reviews, 35. https://doi.org/10.1016/j.esr.2021.100641

Tishkov, S., Shcherbak, A., Karginova-Gubinova, V., Volkov, A., Tleppayev, A., & Pakhomova, A. (2020). Assessment the role of renewable energy in socio-economic development of rural and arctic regions. Entrepreneurship and Sustainability Issues, 7(4), 3354–3368. https://doi.org/10.9770/jesi.2020.7.4(51)

Tsaurai, K. (2020). Exploring the macroeconomic determinants of carbon emissions in transitional economies: A panel data analysis approach. International Journal of Energy Economics and Policy, 10(6), 536–544. https://doi.org/10.32479/ijeep.9362

Tseng, S. W. (2019). Analysis of Energy-Related Carbon Emissions in Inner Mongolia, China. Sustainability (Switzerland), 11(24). https://doi.org/10.3390/su11247008

Tu, J. C., Chan, H. C., & Chen, C. H. (2020). Establishing circular model and management benefits of enterprise from the circular economy standpoint: A case study of Chyhjiun Jewelry in Taiwan. Sustainability (Switzerland), 12(10). https://doi.org/10.3390/su12104146

Twum, F. A., Long, X., Salman, M., Mensah, C. N., Kankam, W. A., & Tachie, A. K. (2021). The influence of technological innovation and human capital on environmental efficiency among different regions in Asia-Pacific. Environmental Science and Pollution Research, 28(14), 17119–17131. https://doi.org/10.1007/s11356-020-12130-y

Urban, F., Siciliano, G., Wallbott, L., Lederer, M., & Dang Nguyen, A. (2018). Green transformations in Vietnam's energy sector. Asia and the Pacific Policy Studies, 5(3), 558–582. https://doi.org/10.1002/app5.251

van der Zwaan, B., Kober, T., Longa, F. D., van der Laan, A., & Jan Kramer, G. (2018). An integrated assessment of pathways for low-carbon development in Africa. Energy Policy, 117, 387–395. https://doi.org/10.1016/j.enpol.2018.03.017

van Vuuren, D. P., Stehfest, E., Gernaat, D. E. H. J., Doelman, J. C., van den Berg, M., Harmsen, M., de Boer, H. S., Bouwman, L. F., Daioglou, V., Edelenbosch, O. Y., Girod, B., Kram, T., Lassaletta, L., Lucas, P. L., van Meijl, H., Müller, C., van Ruijven, B. J., van der Sluis, S., & Tabeau, A. (2017). Energy, land-use and greenhouse gas emissions trajectories under a green growth paradigm. Global Environmental Change, 42, 237–250. https://doi.org/10.1016/j.gloenvcha.2016.05.008

Vidican, G. (2009). The role of universities in innovation and sustainable development. WIT Transactions on Ecology and the Environment, 120, 131–139. https://doi.org/10.2495/SDP090131

Waheed, R., Sarwar, S., & Wei, C. (2019). The survey of economic growth, energy consumption and carbon emission. Energy Reports, 5, 1103–1115. https://doi.org/10.1016/j.egyr.2019.07.006

Wang, P., Zhang, Z., Zeng, Y., Yang, S., & Tang, X. (2021). The Effect of Technology Innovation on Corporate Sustainability in Chinese Renewable Energy Companies. Frontiers in Energy Research, 9. https://doi.org/10.3389/fenrg.2021.638459

Wang, T., Wang, Q., & Zhang, C. (2021). Research on the optimal operation of a novel renewable multi-energy complementary system in rural areas. Sustainability (Switzerland), 13(4), 1–16. https://doi.org/10.3390/su13042196

Wang, X., Yu, J., Zhang, M., & Qin, X. (2019). Nuclear, renewables and low carbon growth: A comparative study on China, U.S., France and Japan. Polish Journal of Environmental Studies, 28(4), 2889–2899. https://doi.org/10.15244/pjoes/94059

Warner, K. J., & Jones, G. A. (2019). The 21st century coal question: China, India, development, and climate change. Atmosphere, 10(8). https://doi.org/10.3390/atmos10080476

Wu, L., Huang, K., Ridoutt, B. G., Yu, Y., & Chen, Y. (2021). A planetary boundary-based environmental footprint family: From impacts to boundaries. Science of the Total Environment, 785, 147383. https://doi.org/10.1016/j.scitotenv.2021.147383

Wysokińska, Z. (2013). Transition To A Green Economy In The Context Of Selected European And Global Requirements For Sustainable Development. Comparative Economic Research, 16(4), 203–226. https://doi.org/10.2478/cer-2013-0034

Xiao, Y., Wu, H., Wang, G., & Mei, H. (2021). Mapping the worldwide trends on energy poverty research: A bibliometric analysis (1999–2019). International Journal of Environmental Research and Public Health, 18(4), 1–22. https://doi.org/10.3390/ijerph18041764

Xie, F., Liu, Y., Guan, F., & Wang, N. (2020). How to coordinate the relationship between renewable energy consumption and green economic development: from the perspective of technological advancement. Environmental Sciences Europe, 32(1). https://doi.org/10.1186/s12302-020-00350-5

Xu, X.-L., & Liu, C. K. (2019). How to keep renewable energy enterprises to reach economic sustainable performance: From the views of intellectual capital and life cycle. Energy, Sustainability and Society, 9(1). https://doi.org/10.1186/s13705-019-0187-2

Yilanci, V., Haouas, I., Ozgur, O., & Sarkodie, S. A. (2021). Energy Diversification and Economic Development in Emergent Countries: Evidence From Fourier Function-Driven Bootstrap Panel Causality Test. Frontiers in Energy Research, 9. https://doi.org/10.3389/fenrg.2021.632712

Yu, Tiffany Hui Kuang; Huang, Meng Chen; Huarng, K. H. (2016). Causal complexity of economic development by energy consumption. Journal of Business Research, 69(6), 2271–2276. https://doi.org/10.1016/j.jbusres.2015.12.041

Yu, B., Zhao, Q., & Wei, Y. M. (2021). Review of carbon leakage under regionally differentiated climate policies. Science of the Total Environment, 782(5), 146765. https://doi.org/10.1016/j.scitotenv.2021.146765

Yu, Z., Liu, W., Chen, L., Eti, S., Dinçer, H., & Yüksel, S. (2019). The effects of electricity production on industrial development and sustainable economic growth: A VAR analysis for BRICS countries. Sustainability (Switzerland), 11(21). https://doi.org/10.3390/su11215895

Yuan, X. C., Sun, X., Zhao, W., Mi, Z., Wang, B., & Wei, Y. M. (2017). Forecasting China's regional energy demand by 2030: A Bayesian approach. Resources, Conservation and Recycling, 127, 85–95. https://doi.org/10.1016/j.resconrec.2017.08.016

Yuksel, I. (2008). Energy utilization, renewables and climate change mitigation in Turkey. Energy Exploration and Exploitation, 26(1), 35–52. https://doi.org/10.1260/014459808784305798

Zanuttigh, B., Angelelli, E., Bellotti, G., Romano, A., Krontira, Y., Troianos, D., Suffredini, R., Franceschi, G., Cantù, M., Airoldi, L., Evriviadou, M., & Broszeit, S. (2015). Boosting blue growth in a mild sea: Analysis of the synergies produced by a multi-purpose offshore installation in the Northern Adriatic, Italy. Sustainability (Switzerland), 7(6), 6804–6853. https://doi.org/10.3390/su7066804

Zeeshan, M., Han, J., Rehman, A., Bilal, H., Farooq, N., Waseem, M., Hussain, A., Khan, M., & Ahmad, I. (2020). Nexus between foreign direct investment, energy consumption, natural resource, and economic growth in latin american countries. International Journal of Energy Economics and Policy, 11(1), 407–416. https://doi.org/10.32479/ijeep.10255

Zhang, F., & Wu, F. (2021). Performing the ecological fix under state entrepreneurialism: A case study of Taihu New Town, China. Urban Studies. https://doi.org/10.1177/0042098021997034

Zhang, H., Shen, L., Zhong, S., & Elshkaki, A. (2020). Economic structure transformation and low-carbon development in energy-rich cities: The case of the contiguous area of Shanxi and Shaanxi Provinces, and inner mongolia autonomous region of China. Sustainability (Switzerland), 12(6). https://doi.org/10.3390/su12051875

Zhang, W., Yang, J., Sheng, P., Li, X., & Wang, X. (2014). Potential cooperation in renewable energy between China and the United States of America. Energy Policy, 75, 403–409. https://doi.org/10.1016/j.enpol.2014.09.016

Zhang, Z. (2010). China in the transition to a low-carbon economy. Energy Policy, 38(11), 6638–6653. https://doi.org/10.1016/j.enpol.2010.06.034

Zhanseitov, A., Raikhanova, G., Mambetova, S., Daribekov, S., & Akbayev, Y. (2020). The influence of fiscal progress on energy consumption in Kazakhstan. International Journal of Energy Economics and Policy, 10(5), 344–347. https://doi.org/10.32479/ijeep.9784

Zhao, X., Zhang, Y., Liang, J., Li, Y., Jia, R., & Wang, L. (2018). The sustainable development of the economic-energy-environment (3E) system under the carbon trading (CT) mechanism: A Chinese case. Sustainability (Switzerland), 10(1). https://doi.org/10.3390/su10010098

Chapter 4 – Exploring the Relationship Between Technological Progress, Human Capital, Political Uncertain, Energy Consumption, and Economic Growth: Evidence from a Panel-Dynamic Analysis[2]

4.1. Introduction

Since the industrial revolution, society has experienced a scenario of economic expansion and economic development. Due to this phenomenon, the understanding of economic growth has been addressed. In this context, Solow, in 1956, with his endogenous economic growth model, demonstrated that economic growth is partly related to technical progress, workforce and capital. These elements tend to increase productivity. Thus, the most used metric to measure is the Gross Domestic Product (GDP), which comes from this study. GDP is output by production optics, defined by the final amount of the products and services made in a given period (Mankiw, 2009).

It can be said that GDP is given by household and company consumption, government spending, investments, and trade balance results (net exports) (Mankiw, 2009). That said, the present work aims to study economic growth through GDP, but taking into account variables that affect economic activity indirectly or directly, these variables being technological progress, gross capital formation, human capital or the workforce, disaggregated energy consumption, political stability, and finally, economic development.

The endogenous growth models applied in the context of this research are that of Lucas and Romer. Lucas's model deals with the possibility that different technologies produce human capital and physical capital. Human capital is the only input in the educational sector. Human capital is the skills, the educational or individual talent of each individual. In contrast, Romer's model considered knowledge creation a side effect of the investment (Barro & Sala-i-Martin, 2000). As a company increases its physical capital, it becomes more efficient in production, a phenomenon that Romer terms "learning by doing." (Barro & Sala-i-Martin, 2000). However, Lucas's model differs from Romer's regarding how knowledge is created and transmitted. Lucas argues that knowledge spillover occurs through human capital, while Romer suggests that it is linked to the involvement of intelligent individuals (Romer,

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1990). Human capital is a cumulative result of knowledge acquired through formal education or skill enhancement through practice.

The relationship between energy consumption and economic activity has been studied for several decades. This ratio is divided into four categories, which are essential for policy formulation: causality (hypothesis neutrality), unidirectional causality from economic expansion to energy use (conservation hypothesis), unidirectional causality from energy use to economic expansion (growth hypothesis), and bidirectional relationship (feedback hypothesis) (I. O. Ã et al., 2010). Therefore, by analyzing the disaggregated consumption of gas, oil, coal, and renewable energy in energy matrices, as proposed in this study, it is possible to observe the impact of each energy matrix on GDP and develop public policies more effectively to optimize this relationship.

Political stability, facilitated by a stable democratic regime, can promote economic growth. According to Acemoglu et al., (2019), democracy has a positive impact on economic growth by encouraging investment, promoting economic reforms, reducing civil disobedience, increasing education levels, and improving the provision of public goods. Thus, it is important to examine how the variable of Economic Policy Uncertainty Index (EPU) interacts with GDP.

The Human Development Index (HDI) is a composite measure that assesses human development, consisting of three dimensions: health, education, and standard of living (Roser, 2014). The incorporation of this metric in the current study is justified by the fact that economic growth should ultimately lead to social and economic development for the population. Hence, examining the interplay between HDI and GDP is crucial to devise effective public policies promoting human development.

In this study, we aim to investigate the impact of various variables on the Gross Domestic Product (GDP) from 2009 to 2019. This time frame is significant as it covers a period between the post-crisis subprime and the pre-crisis of the COVID pandemic. We selected 21 economies, including Australia, Brazil, Canada, Chile, Colombia, France, Germany, Greece, Ireland, Italy, Korea, Netherlands, Russia, Spain, United Kingdom, and the USA, and used the Bias-Corrected Estimation (BC) and Generalized Method of Moments (GMM) approaches to estimate the models.

Section 2 concisely reviews the relevant literature on the subject, while Section 3 outlines the theoretical framework and model specifications used in this study. Section 4 provides details on the data and approach used in the investigation. Section 5 presents the study's results, findings, and analysis based on the research objectives. Finally, Section 6 concludes with some closing remarks, limitations of this study, and suggestions for future research.

4.2. Literature Review

The relationship between economic growth and human capital has been extensively investigated through theoretical and empirical studies, examining various economies and the impact of human capital on their economic activity. A brief literature review of the subject is provided in this section. Matousek & Tzeremes (2021) investigated the effect of human capital on economic expansion using a comprehensive sample of 100 countries and 35 years of observations. They employed a methodology for non-parametric and semiparametric analysis, and their findings indicated that human capital significantly contributes to economic growth in most cases. Moreover, the study demonstrates that the quality of human capital may account for the differences in growth between countries (Matousek & Tzeremes, 2021). Shidong et al.(2022) also observed a positive impact of human capital on the G10 economies. In addition, they included the variable of renewable energies in their analysis, and the study demonstrated that human capital also has a positive effect on this variable. The findings suggest that the joint consideration of renewable energies and human capital has a greater impact on economic activity than when analyzed separately (Shidong et al., 2022).

The impact of human capital on environmental quality and sustainability was investigated in the context of BRICS countries (Brazil, Russia, India, China, and South Africa). Ganda(2022)'s study aimed to understand the relationship between human capital, environmental quality, and sustainability in these economies. The author concluded that human capital significantly impacts environmental quality and sustainability, both in the short and long term. These findings align with those of Zafar et al. (2019) on the American economy, which demonstrated that increased energy consumption and economic activity contribute to environmental degradation, while increased human capital is associated with environmental preservation. The results found by Shidong et al. (2022), Ganda (2022), and Zafar et al. (2019) are noteworthy, as they provide evidence that human capital can play a crucial role in promoting sustainable growth.

Agasisti and Bertoletti (2022) approached the study of human capital from a unique perspective by investigating the impact of regional higher education systems (HESs) on the economic growth of 284 European regions over 18 years (2000-2017). Their research aimed to answer the question: "What is the impact of the characteristics of regional higher education systems on the economic growth of European regions?" The findings revealed a beneficial effect of universities on the local economy, with an increase in the GDP per capita of the regions. Furthermore, the results indicated that an improvement in the quality of research production has a positive effect on the economic growth of the regions (Agasisti & Bertoletti, 2022).

The relationship between trade, human capital, and economic growth has been studied in Asia. Majidi (2017) employed Ordinary Least Square (OLS) estimates to examine this relationship from 1990-2014 and found that both foreign trade and human capital had a significant positive impact on economic development in Asia. Similarly, Fatimah et al. (2021) investigated the effects of human capital and innovation capacity on economic activity in Malaysia, Thailand, and Indonesia. The findings indicated that human capital positively influences the economy, while innovation capacity was not statistically significant. This pattern was also observed in other studies examining the Indonesian economy (Fatimah et al., 2021; Prasetyo & Kistanti, 2020; Widarni & Bawono, 2021). Furthermore, Maitra (2016) explored the contribution of investment in human capital and employment to Singapore's economic growth from 1981-2010. The findings suggested a positive relationship between human capital, the labor force, and economic activity. However, unlike the labor force, human capital did not contribute to economic growth immediately (Maitra, 2016).

Adeleye et al. (2022) conducted a study to examine the relationship between human capital and economic growth in the Middle East and North African (MENA) member countries between 1980 and 2020. The study's findings support the hypothesis that human capital is a critical driver of economic expansion. Turna and Ceylan (2022) investigated the relationships among physical and human capital, energy consumption, and their effects on GDP in Turkey from 1965 to 2014 using a Nonlinear Autoregressive Distributed Lags (NARDL) methodology. The study's estimates revealed an asymmetric relationship between physical capital and GDP in both the short and long run, whereas energy consumption directly impacted economic activity. Specifically, increased energy consumption led to increased GDP, and the same relationship was observed for human capital (Turna & Ceylan, 2022).

Several studies have focused on the American economy; among them, Faggian et al. (2017) analyzed the human capital ratio in the United States from 2000 to 2007, using a broader definition of human capital that included creativity, entrepreneurship, and education. The study's findings suggest that education has the most significant impact on economic growth of the three variables used for human capital. The authors concluded that the best strategies for economic development involve retaining a highly educated workforce. A similar relationship between education and economic growth was observed in previous studies, including those by Baldwin and Borrelli (2008) and Fan et al. (2016). The study conducted by Jorgenson and Fraumeni (1992) investigated the effect of investing in education on the American economy from 1948 to 1986. The results revealed that investment in human and non-human capital accounted for a substantial proportion of economic growth in the United States during the period examined (Jorgenson & Fraumeni, 1992). Another study by Bowen and Qian (2017) extended the scope of research on human capital in the United States by examining the impact of investment in higher education across U.S. states. The results showed that while state spending on higher education did not lead to an increase in economic activity, it did lead to an improvement in economic performance, suggesting that higher education is a normal good (Bowen & Qian, 2017).

Furthermore, the study concluded that investment in human capital promoted increased economic activity, a finding that aligns with the results of Faggian et al. (2017) and Jorgenson and Fraumeni (1992). The results found by Baldwin et al. (2011) indicate that state investment in education promotes an increase in state GDP. The state of Georgia was analyzed in isolation between 2006 and 2008 by Clarke et al. (2015). The analysis showed that Georgia's low-education municipalities tended to have difficulties growing economically. However, the results also indicated that responding to the low quality of the workforce only with investment in education will not promote economic growth directly since the relationship between unemployment and the effect of poverty impedes local economic growth. Thus, the authors determined that economic growth is linked to a skilled and uneducated workforce (Clarke et al., 2015). A result different from that was obtained by Baldwin et al. (2011). The sample used in their research was different, but this demonstrates that there is no total agreement in the academy on human capital and its effects.

In a study conducted by Ben Jebli et al. (2019) on South and Central American countries, the causal relationships among renewable energy consumption, tourist visits, commercial opening index, economic growth, and carbon gas emissions were explored. The findings revealed that economic growth and trade between countries were the main contributors to increasing emissions, while other variables had a mitigating effect. In the long term, a feedback loop was observed among all variables, while in the short term, a one-way causal relationship was observed between commercial opening and renewable energy utilization. Similarly, there was a two-way short-term causality between direct foreign investment (FDI) and GDP and between FDI and commercial opening.

In another study by Balsalobre-Lorente et al. (2018) on the EU-5 countries, the links among economic activity, commercial openness, renewable electricity use, energy innovation, natural reserves, and CO_2 emissions were analyzed. The results indicated that renewable electricity had an adverse effect on CO_2 emissions, while economic activity had a diminishing effect on renewable electricity output. Furthermore, the study supported the growth hypothesis that abundant energy sources reduce CO_2 emissions per capita in EU-5 countries. Çakar et al. (2021) investigated the relationship between human capital and environmental deterioration in 21 European economies at different levels of financial development. The findings suggested that human capital positively reduces environmental deterioration in scenarios of high financial development but has the opposite effect in less developed scenarios.

In a study by Oliveira & Moutinho (2021) on the BRICS economies from 1990-2018, an inverse relationship was observed between renewable energy consumption and GDP. In contrast, in Tunisia, Ben Mbarek et al. (2018) found a bidirectional link between economic activity and renewable energies. Furthermore, Ouedraogo (2013) examined the relationship between energy consumption and human development in 15 developing economies from 1988-2008. The results indicated that while there was a neutral relationship between total energy and electricity consumption and the Human Development Index (HDI) in the short term, a long-term inverse relationship was observed between HDI and total energy consumption, but a direct relationship with electricity consumption. Finally, Huang et al. (2022) found that higher economic activity was associated with higher emissions for selected emerging economies (Brazil, China, India, Indonesia, Mexico, Russia, and Turkey). However, the study also found that the green economy and human capital were essential in reducing emissions and promoting sustainable growth.

Similarly, Hong Vo et al. (2021) found that financial development positively affects human capital in emerging Asian countries and that increased GDP contributes to a greater accumulation of human capital. According to Aydin (2022) research, political security and the utilization of renewable energy positively impact economic activity in Turkey. Additionally, a unidirectional relationship has been observed between political security, renewable energy use, and tourism, as well as between tourism and economic activity.

Meanwhile, Khan et al. (2022) have examined the consequences of political stability, economic growth, carbon emissions, and financial development on inequality in countries belonging to the Belt Road Initiative (BRI), developing countries, and high-income countries. The study found that an increase in the gross domestic product (GDP) reduces inequality in developing economies, while emissions, political stability, and financial development tend to increase it. In high-income countries, financial development reduces inequality, while emissions and political stability have the opposite effect. Lastly, BRI countries have reduced inequality by expanding their economies, ensuring political stability, and controlling carbon emissions (Khan et al., 2022).

Several studies have investigated the causal relationship between energy usage and economic activity in various countries. Pinzón (2018) found a unidirectional causal relationship between energy usage and GDP in Ecuador, while Shahbaz et al. (2018) identified a feedback relationship between energy use and GDP in Pakistan. In Malaysia, Nguyen et al. (2019) and Tang et al. (2016) found a unidirectional influence from energy consumption to economic activity, and Xuan et al. (2018) observed a one-way relationship between energy usage and GDP. Ameyaw et al. (2017) found that economic activity was causally linked to energy consumption in Ghana, while in Turkey, the neutrality hypothesis was valid in the short term, but bidirectional Granger causality between energy usage and GDP was observed in the long term (Aslan, 2013; Nazlioglu et al., 2014). In Switzerland, Baranzini et al. (2013) found a one-way causality from GDP to different types of energy consumption. Abderrahmani and Be (2013) observed a short-term feedback relationship in Algeria, while Belloumi and Alshehry (2016) found evidence of the long-term conservation hypothesis in Saudi Arabia. Elfaki et al. (2018) observed a long-term causal link between energy use and GDP in Sudan, while Emir and Bekun (2019) found a feedback relationship in Romania. The growth hypothesis was found for Bahrain (Hamdi et al., 2014) and Hong Kong (C. H. Ã & Siu, 2007). Abosedra et al. (2009) found no long-term balance link between electricity usage and GDP in Lebanon but suggested a unidirectional causal relationship of electrical consumption to GDP. In Nigeria, there was a causal flow of electricity consumption for GDP, both in the short and long term (Iyke, 2015; Solarin & Opeyemi, 2011), and for Mozambique, the growth hypothesis was observed (Nindi & Odhiambo, 2014).

The hypothesis has been posited that a reciprocal relationship exists between financial development, serving as a proxy for technological development, and green growth (Ngo et al., 2022). Furthermore, the study investigates the impact of human capital and the Human Development Index (HDI) on sustainable growth. The econometric estimates of the study provide empirical evidence supporting the proposed hypothesis, demonstrating that both human capital and HDI positively influence green growth. Hence, the findings suggest sustainable growth is contingent upon a nation's empowerment and social development.

Adewale Alola et al. (2021) have developed a model wherein the Human Development Index (HDI) is the dependent variable. The study examines how Gross Domestic Product (GDP), access to clean energy, and access to technological innovations impact this index in twelve Sub-Saharan countries. The empirical estimates suggest that an increase in economic activity has a positive effect on HDI in both the short and long term, while technological advancements also contribute to sustainable development, thus supporting the assertions of Romer's growth model. However, access to clean energy sources does not affect sustainable development significantly (Adewale Alola et al., 2021). Meanwhile, Kaewnern et al. (2023) conducted a study on the top ten HDI countries, analyzing the impact of GDP, renewable energy utilization, research and development expenses, and total natural resource rent on HDI. The results indicate a positive relationship between all the variables and HDI in the countries studied. The study further reveals a unidirectional causality from HDI to renewable energy utilization and research and development expenses (Kaewnern et al., 2023).

In Latin America, Ponce et al. (2021) have examined sustainable growth from the perspective of clean energy, financial development, and human capital. The empirical estimates indicate a positive and long-term relationship between renewable and non-renewable energy usage, financial development, and human capital with economic growth. The study further identifies a two-way causality between financial development and human capital with economic expansion and unidirectional causality from GDP to the consumption of renewables and non-renewables (Ponce et al., 2021).

Feng (1997) investigated the interplay between democracy, political stability, and economic growth across 96 economies from 1960 to 1980. The findings suggest that a change in the political regime negatively impacts the economy, reinforcing the notion that a growing economy enhances the likelihood of political continuity. The impact of democracy on economic growth remains equivocal, as evidenced by the findings of Feng (1997). Although a change in leadership in the short-term may potentially impede economic progress, in the long-term, democracy has the potential to stimulate growth by fostering political stability and a dynamic environment that encourages change. Uddin et al. (2017) examined the relationship between GDP and political stability across 120 economies from 1990 to 2014. The study highlights the critical role of stability in promoting economic growth, as political instability harms human capital and GDP.

Evidence suggests that financial markets play a direct or indirect role in the development of an economy. However, political and economic stability may also influence investment decision-making in an economy. Within this context, Sayar et al. (2020) investigated the impact of economic expansion, democracy, human capital, and financial development on economic inequality in 23 developing economies. The empirical analyses revealed that increased income, democracy, and human capital contribute to reducing inequality. However, the authors' proposed hypothesis, the Financial Kuznets Curve, was not validated regarding the relationship between financial development and inequality. Asafo-Adjei et al. (2021) examined the link between the financial sector and economic expansion, using the Global Economy Policy Uncertainty Index (GEPU) to analyze their impact on these variables in China's economy. The estimates indicated a two-way causality between GDP and financial markets, suggesting a positive interdependence in the medium and long term for most of the countries studied. The authors also observed that South Africa's economy is more vulnerable to shocks caused by GEPU. Chen et al. (2019) demonstrated that GEPU has a negative effect on the Chinese economy, while oil price shocks tend to have a positive impact on industrial economic growth.

4.3. Theoretical Framework

4.3.1 The AK model

In 1956, Solow introduced a neoclassical economic growth model that is widely recognized. This model considers three primary factors influencing economic growth, specifically physical capital ($K_{(t)}$), the labor force ($L_{(t)}$), and knowledge ($A_{(t)}$). As a result, the output function ($Y_{(t)}$) can be articulated as follows.

$$Y_{(t)} = F[K_t, L_t, A_t] \ (1)$$

In this context, $K_{(t)}$, symbolizes durable production goods, including machinery. $L_{(t)}$ represents the aggregate contribution of the human workforce to economic growth, a variable subject to temporal fluctuations influenced by the population growth rate. Lastly, $A_{(t)}$ signifies knowledge, alternatively referred to as technology (Barro & Sala-i-Martin, 2000).

Nevertheless, the Solow neoclassical economic growth model proved inadequate in elucidating long-term growth dynamics. As posited by Barro & Sala-i-Martin (2000), the model's assumption of constant technological progress results in the economy reaching a steady state. In this state, alterations in variables cease to translate into changes in the overall economic landscape. Moreover, the model assumes constant knowledge (A), leading to diminishing returns on capital over time. This, in turn, dissuades new investments and acts as a deterrent to sustained economic growth. In response to these limitations, the AK model emerged as a modified version of the Solow model. A notable characteristic of the AK model is the absence of diminishing returns on capital (Barro & Sala-i-Martin, 2000). The AK function can be expressed as follows.

$$Y = AK \ (2)$$

According to the model proposed by Barro & Sala-i-Martin (2000), a positive constant denoted as A signifies the level of technology, with the variable K having a broader interpretation that encompasses human capital. In this framework, the constancy of the return on capital is maintained, contingent upon A being greater than zero.

The AK model posits that a single equation can describe both short-term and long-term economic growth and that model parameter changes can affect variable levels and growth rates (Barro & Sala-i-Martin, 2000). Technological progress, represented by the variable A, is a key factor in economic growth, as it raises the marginal and ordinary products of capital, leading to increased economic expansion and alterations in the savings rate (Barro & Sala-i-Martin, 2000). It is worth noting that technological progress can vary over time and may differ between countries, which could help to explain the differences observed between economies. In this way, technological progress has been identified as a means for economies to avoid the return of decreasing capital in the long run (Barro & Sala-i-Martin, 2000).

Solow-Swan (1956) introduced a simplified growth model that incorporates only three variables. The ensuing equation encapsulates the essence of the model.

$$Y = A \times L^{(1-\alpha)} \times K^{\alpha} \ (3)$$

All variables constituting the model are deemed endogenous, leading to the nomenclature of an endogenous growth model. The contributions of physical capital (K) and labor (L) to economic growth (Y) exhibit diminishing returns, whereas technology (A) is held constant (Kasim, 2017). However, according to the innovation model proposed by Barro & Sala-i-Martin (2000), technological advancements stand as the singular avenue through which an economy can avert a decline in returns in the long run.

4.3.2. The Lucas Model

Lucas' model explores the possibility that human and physical capital production relies on different technologies. In this model, only human capital serves as an input in the educational sector, creating an imbalance in the economic expansion rate between human capital and physical capital due to an asymmetry resulting from the positive relationship between the two factors (Barro & Sala-i-Martin, 2000). This asymmetry can be observed in the real wage per unit of human capital, leading to an opportunity cost of dedicating human capital to education (Barro & Sala-i-Martin, 2000).

However, this asymmetry also leads to the relaxation of the restriction of decreasing scale returns, creating opportunities for long-term economic expansion even in the absence of exogenous technological advancement. Human capital is considered a potential technological improvement for long-term economic growth (Barro & Sala-i-Martin, 2000).

Human capital is defined as individuals' individual skills, talents, and education and is considered a rival commodity - meaning that it cannot be used simultaneously by multiple firms. This contrasts with Romer's proposal that knowledge is a non-rival good. Nevertheless, the concept of spillover remains relevant to this assumption.

Mathematically, the model can be described as follows.

$$Y = AK^{\alpha}H^{1-\alpha} \ (4)$$

In this particular model, denoted by $0 \leq \alpha \leq 1$, the variable H represents the product of the number of workers, commonly referred to as L in other models, and the quality of labour, denoted by h. The inclusion of this specification in the model ensures that treating L as a constant will not lead to decreasing returns of scale. This is due to the dual effect on output resulting from h and K, with the growth in productivity of H being driven by h, which represents the increased capacitation of workers. As such, the model accounts for the cumulative effect of education workers receive, which is treated as a multiplier of labour. This serves to signify the role played by education as a contributing factor to economic growth.

In agreement with Barro & Sala-i-Martin (2000), the Y may be spent for consumption (C) or invested in human (I_h) or physical capital (I_K), so we can rewrite the model as follows

$$Y = AK^{\alpha}H^{1-\alpha} = C + I_h + I_K \ (5)$$

Whereas physical and human capital have the same rate of depreciation (δ), the slump of human and physical capital is given by the equations, $H = I_h - \delta_h$, and $K = I_k - \delta_k$, respectively.

According to Mankiw et al. (1992), a higher level of savings or a lower rate of population growth tends to lead to greater compensation and a more advanced level of human capital for a certain amount of human capital accumulation. This implies that the impact of physical capital accumulation and population growth on earnings is more significant when considering human capital. Additionally, human capital is found to be positively correlated with both the percentage of savings and population growth. Therefore, neglecting the role of human capital can result in biased estimates.

The proposals of the model reveal that there are divergences in Romer's model, as the elasticity of income concerning the stock of physical capital does not differ significantly from the portion of the capital derived from income. Even without externalities, the accumulation of physical capital and population expansion has a greater effect on earnings than the Solow model (Mankiw et al., 1992).

Overall, the Solow model recognizes the significance of both human and physical capital. However, the expanded Solow model proposed by Lucas (1988) shows that differences in savings, education, and population growth rate can explain the per capita income variations among countries.

4.3.3 The Romer Model

The AK model of endogenous growth is based on the assumption that diminishing returns do not exist because factors of production can be accumulated and replicated. This premise has been extensively analyzed by several economists, such as Lucas (1988) and Romer (1990), who expanded upon Solow's initial model. However, in their models of endogenous growth, the role of spillover effects is crucial (Barro & Sala-i-Martin, 2000), a factor that Solow did not consider.

Lucas' model differs from the model proposed by Romer in how knowledge is created in transmitted, for Lucas, this occurs through the human capital. In this model, spillover is related to the involvement of intelligent people. Lucas assumes that human capital rather than physical capital is what generates the non-rival and non-excludable scenario (Romer, 1990). Human capital (H) is a measurement of the accumulative outcome of knowledge, whether acquired through formal education or enhancement of skills by practice. The model proposed by Romer separates the rival component of knowledge, the human capital $(H = H_Y + H_A)$, from the non-rival, technological component, (A) (Romer, 1990).

Romer proposed a solution to address the issue of diminishing returns associated with descending scales by positing that knowledge creation was a byproduct of investment (Barro & Sala-i-Martin, 2000). Specifically, he argued that as a firm increases its physical capital, it becomes more efficient in production, leading to a phenomenon he termed "learning by doing" (Barro & Sala-i-Martin, 2000).

The production function of this endogenous growth model may be expressed in the following manner, as demonstrated.

$$Y_i = AL_i^{1-\alpha}.\sum_{j=1}^{N}(X_{ij})^{\alpha} \quad (6)$$

As variables L_i and K_i continually represent the previously mentioned inputs, A_i the knowledge available, X_{ij} use of j type of a specific type of intermediate merchandise, and N is the number of varieties of intermediates to the firm i. The technology factor is a job enhancer, thus the steady state occurs only when A_i grows at a steady rate (Barro & Sala-i-Martin, 2000).

The model proposed by Romer is reasoned on three assumptions. The first is technology changes, which tend to improve since technological change is a way to continue capital accumulation, and these two added factors contribute to the increase in workers' productivity (Romer, 1990).

The second is that technological change, most of the time, of intentional agents' actions in response to market demands. This makes technological change endogenous to the growth model (Romer, 1990), which differs from the model proposed by Solow, in which technology is considered an exogenous factor.

Finally, the third premise lies in the costs of elaborating new production instructions, and this would only have the initial cost for the creation later, these new instructions can be used repeatedly at zero cost. This premise is taken as the definitive feature of technology (Romer, 1990). After creating the new knowledge, this knowledge "spills" promptly for the country's entire economy. This assumption tells us that a technological change in the firms corresponds to the general learning of the economy and the proportional change in the stock of capital (Barro & Sala-i-Martin, 2000)

These premises have features of Rivalry and Excludability. Rivalry is had with a purely technological characteristic. A rival is characterized by the fact that only one agent can use, in a way, all can use a non-rival good without impediment. Excludability is the junction of the technological sector and the legal system. A product is Excludability if the intellectual property proprietor can prevent others from using its creation (Romer, 1990). In this context, the economic growth models the goods are a set of non-rival but excludable. The first premise can be considered non-rival and partially excludable since it assumes that accumulation is a fundamental part of growth. The second assumption is that technological progress occurs through actions (investment decisions of the agents), so the interest for that decision tends to get benefits, so we can consider a partially excludable characteristic. The third premise assumes that technology is non-rival (Romer, 1990).

For Romer, non-rivalry has two characteristics of high importance for growth theory, merchandise characterized as non-rival can be accumulated without limits at the per capita level. The second is to treat knowledge as a non-rival commodity, in this way, the spillover of knowledge becomes a reality (Romer, 1990).

The essence of the model Romer is learning by doing and knowledge spillovers, this way, it is possible to replace A_i with K in the production function, thus the production function of the firms (i) can be rewritten $Y_i = F(K_i, KL)$. K and L being constant companies face descending scale returns, but, if each firm expands K_i, it is expected that K increases and occurs spillovers, according to Romer's premises, it would increase the productivity of taking the companies and consequently the economy (Barro & Sala-i-Martin, 2000). In addition, if K_i and K increase with a fixed L, this continuity will promote endogenous growth (Barro & Sala-i-Martin, 2000).

Romer considers that a new product demands η labour unit, so an expansion of N, which improves output and labour productivity, tends to raise wages. In addition, it is assumed that the cost of developing a new product reduces as long as society accumulates new ideas, and the number of products is represented by N (Barro & Sala-i-Martin, 2000). Part of the work is supposed to be applied in production (λ) and another in research and development (R&D) $(1-\lambda)$, so the changes in N depends on the amount of work dedicated to R&D. So the technological change can be written as $N/N = (1-\lambda)\,L/\eta$. To sum up, the cost of developing a new product remains constant in terms of commodities (Barro & Sala-i-Martin, 2000).

Exposed to Romer's arguments, we can mathematically describe his model as follows

$$Y_i = AL_i^{1-\alpha} NX_i^{\alpha} = AL_i^{1-\alpha}.(NX_i)^{\alpha}.N^{1-\alpha} \ (7)$$

It should be noted that technological progress occurs with the increase of N. Variable A turns out to be a multiplier, a productivity parameter (Barro & Sala-i-Martin, 2000).

In equation (7), it is understood that the product has constant scale returns in L_i and NX_i (total amount of inputs), for a given N.

For certain amounts of L_i, X_i, and Y_i, the variable N increases as the reason for the term $N^{1-\alpha}$, (Barro & Sala-i-Martin, 2000). Therefore, the effect of technological progress is captured. According to (Barro & Sala-i-Martin, 2000), it is a reflection of straight out the intermediate goods (NX_i) in an extensive N. There is an increase due to decreasing returns for each X_{ij}. Considering constant L_i, equation (7) assumes that the NX_i increase will have decreasing scale returns if this increase is a consequence of an expansion in X_i, to a given N. If there is an increase in NX_i from the expansion of N to a given X_i, there are no decreasing returns. Thus, there is a technological change in n expansion, but circumvent the downward trend of returns, this characteristic face is the basis for endogenous growth (Barro & Sala-i-Martin, 2000).

In agreement with Romer, research is precisely associated with the accessibility of human capital in an economy. This also depends on the inventory of knowledge available for an individual to do as a researcher (Romer, 1990). Knowing the non-rival characteristic, possible from the assumption that any individual acting in the research sector would have free access to all stock of knowledge, $A = \mu H_A A$, where μ is a productivity parameter and H_A the interpretation of the total human capital working with the investigation (Romer, 1990). It is believed that more people dedicated to research expect greater productivity. In addition, the greater the knowledge available, the greater the productivity (Romer, 1990). So it gets clear that the marginal product of human capital (H), people who work in the manufacturing sector, expand in dimension to technology (A) (Romer, 1990).

The inclusion of technical progress in the model of Romer fills a gap in the model developed by Solow, which he considered an exogenous variable. So, the greater the knowledge available, the greater the productivity (Romer, 1990). So it gets clear that the marginal product of human capital (H), people who work in the manufacture sector, stretch in magnitude to technology (A) (Romer, 1990). In addition, Romer proposes that free foreign commerce can boost economic growth due to the relationship between countries with different technological levels.

4.4. Model Specifications

The current study aims to expand upon the models of endogenous growth put forth by Lucas and Romer, which build upon the model developed by Solow. In Solow's model, economic growth is primarily driven by technological progress, while Romer's model incorporates the concept of technological spillover, where technological advances are widely available. On the other hand, Lucas' model posits that technological progress is strongly linked to human capital, i.e., each person's education and individual skills. Building on these existing frameworks, the present research seeks to incorporate institutional variables into the model, offering a more comprehensive understanding of the factors driving economic growth.

4.4.1. Model Presentation

According to the literature review, we now expose the endogenous growth models in which the present work proposes to expand, and the production equation will be estimated in this research.

$$Y_t = A_t^{\beta_1} K_t^{\beta_2} L_t^{\beta_3} EC_t^{\beta_4} EPU_t^{\beta_5} DHI_t^{\beta_6} \mu^e \quad (8)$$

Where Y_t is the GDP (Growth Domestic Product), A_t is the technological progress, L_t for labour, or human capital, EC_t is the energy production, EPU_t is (Global Economy Policy Uncertain Index) measures the political and economic stability, DHI_t (Development Human Index) and μ is the error.

As the work expands the models of Romer and Lucas, we have the variable, which is the technical progress represented by $A_t = FD$, in which FD stands for financial development as a proxy for technological progress, the same strategy applied by (Ifa & Guetat, 2022). In addition, we divide L_t into two variables to capture the effect of the skilled (H_1) and unskilled (H_2) workforce, thus $L_t = (H_1 + H_2)$, so we have in these variables the ideas of Lucas's models. Finally, the decomposition of energy production (EC_t), we consider the consumption of gas (NGC), oil (OC), coal (CC), and renewable energy (RC), so $EC_t = (CC_t + NGC_t + OC_t + RC_t)$. The following equation (9) is the expanded endogenous growth model that will be predicted in this work.

$$Y_t = FD_t^{\beta_1} H_{1t}^{\beta_2} H_{2t}^{\beta_3} K_t^{\beta_4} CC_t^{\beta_5} NGC_t^{\beta_6} OC_t^{\beta_7} RC_t^{\beta_8} EPU_t^{\beta_9} DHI_t^{\beta_{10}} \mu^e \quad (9)$$

To simplify, equation (9) is placed in logarithmic form, in this way, it becomes a linear function, as can be seen

$$lnY_t = \beta_0 + \beta_1 lnFD_t + \beta_2 lnH_{1t} + \beta_3 lnH_{2t} + \beta_4 lnK_t + \beta_5 lnCC_t + \beta_6 lnNGC_t + \beta_7 lnOC_t + \beta_8 lnRC_t + \beta_9 lnEPU_t + \beta_{10} lnDHI_t + \varepsilon_t \quad (10)$$

It is necessary to apply the partial derivation technique to demonstrate the relationship and how model variables impact production. Although the model applied in the estimates has more than three independent variables for simplification, we will be in a model with three explanatory variables. So if f is a function of A, K, and L, its partial derivative is defined by

$$f_A(A,K,L) = \lim_{h \to 0} \frac{f(A+h,K,L) - f(A,K,L)}{h} \quad (11)$$

The resolution is made by keeping K and L constant and deriving $f(A,K,L)$ about A (Stewart, 2013). As said, the model of this work is a production function of endogenous growth

$$Y = FD^{\beta_1}.K^{\beta_2}.H_1^{1-\beta_3}.H_2^{1-\beta_4}.EC^{\beta_5}.EPU^{\beta_6}.DHI^{\beta_7} \quad (12)$$

Where Y is the output, A the technological progress, K stands for the capital, and L the workforce are the independent variables or the function's inputs, in this way, we have the function in logarithm form from the equation (8). Therefore, the first-order partial derivation formula for the proposed model is

$$\frac{\partial Y}{\partial X_i} = \lim_{h \to 0} \frac{f(FD+h,K,H_1,H_2,EC,EPU,DHI) - f(FD,K,H_1,H_2,EC,EPU,DHI)}{h} \quad (13)$$

The first-order derivative tells us the trend of the function, whether it is an ascending or descending function. In addition, this can be interpreted as the rate of variation. In other words, being $Y = f(FD, K, H_1, H_2, EC, EPU, DHI)$, so $f_k = \partial Y/\partial K$ it is interpreted as the variation of Y concerning to K if the other independent variables are unchanged (Stewart, 2013), for example.

Applying first-order derivatives partial in equation (12), we got the following results:

$$\begin{cases} \frac{\partial Y}{\partial FD} = \beta_1 FD^{\beta_1 - 1}.K^{\beta_2}.H_1^{1-\beta_3}.H_2^{1-\beta_4}.EC^{\beta_5}.EPU^{\beta_6}.DHI^{\beta_7} \\ \frac{\partial Y}{\partial K} = \beta_2 K^{\beta_2 - 1}.FD^{\beta_1}.H_1^{1-\beta_3}.H_2^{1-\beta_4}.EC^{\beta_5}.EPU^{\beta_6}.DHI^{\beta_7} \\ \frac{\partial Y}{\partial H_1} = (1-\beta_3)H_1^{-\beta_3}.FD^{\beta_1}.H_2^{1-\beta_4}.EC^{\beta_5}.EPU^{\beta_6}.DHI^{\beta_7} \\ \frac{\partial Y}{\partial H_2} = (1-\beta_4)H_2^{-\beta_4}.FD^{\beta_1}.H_1^{1-\beta_3}.EC^{\beta_5}.EPU^{\beta_6}.DHI^{\beta_7} \\ \frac{\partial Y}{\partial EC} = \beta_5 EC^{\beta_5 - 1}.FD^{\beta_1}.K^{\beta_2}.H_1^{1-\beta_3}.H_2^{1-\beta_4}.EPU^{\beta_6}.DHI^{\beta_7} \\ \frac{\partial Y}{\partial EPU} = \beta_6 EPU^{\beta_6 - 1}.FD^{\beta_1}.K^{\beta_2}.H_1^{1-\beta_3}.H_2^{1-\beta_4}.EC^{\beta_5}.DHI^{\beta_7} \\ \frac{\partial Y}{\partial DHI} = \beta_7 DHI^{\beta_7 - 1}.FD^{\beta_1}.K^{\beta_2}.H_1^{1-\beta_3}.H_2^{1-\beta_4}.EC^{\beta_5}.EPU^{\beta_6}. \end{cases} \quad (14)$$

By dividing the first-order derivative by the production function $\left(\frac{\frac{\partial Y}{\partial FD}}{Y}\right)$, we have

$$\frac{\frac{\partial Y}{\partial FD}}{Y} = \frac{(\beta_1 FD^{\beta_1 - 1}.K^{\beta_2}.H_1^{1-\beta_3}.H_2^{1-\beta_4}.EC^{\beta_5}.EPU^{\beta_6}.DHI^{\beta_7})xFD}{FD^{\beta_1}.K^{\beta_2}.H_1^{1-\beta_3}.H_2^{1-\beta_4}.EC^{\beta_5}.EPU^{\beta_6}.DHI^{\beta_7}} \rightarrow \frac{\frac{\partial Y}{\partial FD}}{Y} = \frac{(\beta_1 FD^{\beta_1 - 1})xFD}{FD^{\beta_1}} \rightarrow \frac{\frac{\partial Y}{\partial FD}}{Y} = \beta_1 \quad (15)$$

The results of equation (20) show us the degree of variation of the product (Y) about the variables considered (FD). For example, keeping all the variables constant, if FD increases by 1%, the product (Y) will vary in β_1 intensity, so we have the marginal productivity of the financial development. The same relationship can be expanded to the other variables. Thus, the linear link between the explanatory and dependent variables is demonstrated, as in equation (21).

$$\begin{cases} \dfrac{\frac{\partial Y}{\partial FD}}{Y} = \dfrac{\left(\beta_1 FD^{\beta_1-1}.K^{\beta_2}.H_1^{1-\beta_3}.H_2^{1-\beta_4}.EC^{\beta_5}.EPU^{\beta_6}.DHI^{\beta_7}\right)xFD}{FD^{\beta_1}.K^{\beta_2}.H_1^{1-\beta_3}.H_2^{1-\beta_4}.EC^{\beta_5}.EPU^{\beta_6}.DHI^{\beta_7}} \rightarrow \dfrac{\frac{\partial Y}{\partial FD}}{Y} = \dfrac{(\beta_1 FD^{\beta_1-1})xFD}{FD^{\beta_1}} \rightarrow \dfrac{\frac{\partial Y}{\partial FD}}{Y} = \beta_1 \\ \dfrac{\frac{\partial Y}{\partial K}}{Y} = \dfrac{\left(\beta_2 K^{\beta_2-1}.FD^{\beta_1}.H_1^{1-\beta_3}.H_2^{1-\beta_4}.EC^{\beta_5}.EPU^{\beta_6}.DHI^{\beta_7}\right)xK}{FD^{\beta_1}.K^{\beta_2}.H_1^{1-\beta_3}.H_2^{1-\beta_4}.EC^{\beta_5}.EPU^{\beta_6}.DHI^{\beta_7}} \rightarrow \dfrac{\frac{\partial Y}{\partial K}}{Y} = \dfrac{(\beta_2 K^{\beta_2-1})xK}{K^{\beta_2}} \rightarrow \dfrac{\frac{\partial Y}{\partial K}}{Y} = \beta_2 \\ \dfrac{\frac{\partial Y}{\partial H_1}}{Y} = \dfrac{\left[(1-\beta_3)H_1^{-\beta_3}.FD^{\beta_1}.K^{\beta_2}.H_2^{1-\beta_4}.EC^{\beta_5}.EPU^{\beta_6}.DHI^{\beta_7}\right]xH_1}{FD^{\beta_1}.K^{\beta_2}.H_1^{1-\beta_3}.H_2^{1-\beta_4}.EC^{\beta_5}.EPU^{\beta_6}.DHI^{\beta_7}} \rightarrow \dfrac{\frac{\partial Y}{\partial H_1}}{Y} = \dfrac{(1-\beta_3)H_1^{1-\beta_3}}{H_1^{1-\beta_3}} \rightarrow \dfrac{\frac{\partial Y}{\partial H_1}}{Y} = (1-\beta_3) \\ \dfrac{\frac{\partial Y}{\partial H_2}}{Y} = \dfrac{\left[(1-\beta_4)H_2^{-\beta_4}.FD^{\beta_1}.K^{\beta_2}.H_1^{1-\beta_3}.EC^{\beta_5}.EPU^{\beta_6}.DHI^{\beta_7}\right]xH_2}{FD^{\beta_1}.K^{\beta_2}.H_1^{1-\beta_3}.H_2^{1-\beta_4}.EC^{\beta_5}.EPU^{\beta_6}.DHI^{\beta_7}} \rightarrow \dfrac{\frac{\partial Y}{\partial H_2}}{Y} = \dfrac{(1-\beta_4)H_2^{1-\beta_4}}{H_2^{1-\beta_4}} \rightarrow \dfrac{\frac{\partial Y}{\partial H_2}}{Y} = (1-\beta_4) \\ \dfrac{\frac{\partial Y}{\partial EC}}{Y} = \dfrac{\left(\beta_5 EC^{\beta_5-1}.FD^{\beta_1}.K^{\beta_2}.H_1^{1-\beta_3}.H_2^{1-\beta_4}.EPU^{\beta_6}.DHI^{\beta_7}\right)xEC}{FD^{\beta_1}.K^{\beta_2}.H_1^{1-\beta_3}.H_2^{1-\beta_4}.EC^{\beta_5}.EPU^{\beta_6}.DHI^{\beta_7}} \rightarrow \dfrac{\frac{\partial Y}{\partial EC}}{Y} = \dfrac{(\beta_5 EC^{\beta_5-1})xEC}{EC^{\beta_5}} \rightarrow \dfrac{\frac{\partial Y}{\partial EC}}{Y} = \beta_5 \\ \dfrac{\frac{\partial Y}{\partial EPU}}{Y} = \dfrac{\left(\beta_6 EPU^{\beta_6-1}.FD^{\beta_1}.K^{\beta_2}.H_1^{1-\beta_3}.H_2^{1-\beta_4}.EC^{\beta_5}.DHI^{\beta_7}\right)xEPU}{FD^{\beta_1}.K^{\beta_2}.H_1^{1-\beta_3}.H_2^{1-\beta_4}.EC^{\beta_5}.EPU^{\beta_6}.DHI^{\beta_7}} \rightarrow \dfrac{\frac{\partial Y}{\partial EPU}}{Y} = \dfrac{(\beta_6 EPU^{\beta_6-1})xEPU}{EPU^{\beta_3}} \rightarrow \dfrac{\frac{\partial Y}{\partial EPU}}{Y} = \beta_6 \\ \dfrac{\frac{\partial Y}{\partial DHI}}{Y} = \dfrac{\left(\beta_7 DHI^{\beta_7-1}.FD^{\beta_1}.K^{\beta_2}.H_1^{1-\beta_3}.H_2^{1-\beta_4}.EC^{\beta_5}.EPU^{\beta_6}\right)xDHI}{FD^{\beta_1}.K^{\beta_2}.H_1^{1-\beta_3}.H_2^{1-\beta_4}.EC^{\beta_5}.EPU^{\beta_6}.DHI^{\beta_7}} \rightarrow \dfrac{\frac{\partial Y}{\partial DHI}}{Y} = \dfrac{(\beta_7 DHI^{\beta_7-1})xDHI}{DHI^{\beta_7}} \rightarrow \dfrac{\frac{\partial Y}{\partial DHI}}{Y} = \beta_7 \end{cases} \quad (16)$$

Therefore, predicting the causal relationship between the model's variables is possible.

4.5. Materials and Methods

4.5.1 Data

The present study focuses on investigating the economic behaviour of 21 countries, namely Australia, Brazil, Canada, Chile, Colombia, France, Germany, Greece, Ireland, Italy, Korea, Netherlands, Russia, Spain, United Kingdom, and the USA, during the period between 2009 and 2019. This timeframe has been deliberately chosen to examine the economic trends between the two global crises, namely the 2008 subprime crisis, which resulted from the collapse of the American real estate market, and the ongoing COVID-19 pandemic, which emerged in early 2020. Studying the economic patterns during this period aims to comprehensively understand how the global economy has fared in the intervening years.

This research aims to assess the impact of certain variables, specifically the $GEPU_t$ indicator of Political and Economic Stability, on the Gross Domestic Product. Consequently, the dataset used in this study is restricted to countries included in the indicator.

The data used to estimate the results are taken from secondary sources. Gross Domestic Product (Y_t) and Gross Capital Formation (K_t), both in dollars constant in 2015 values, and Labor force with basic education (H_{1t}) and, Labor force with advanced education (H_{2t}) were withdrawn from the World Development Indicators (WDI). FD_t represents financial development, used as a proxy for technological progress, in which we use the Financial Development Index, computed by the International Monetary Fund (IMF). Metric metrics for measuring energy consumption (Coal Consumption (CC_t), Natural Gas (NGC), Oil (OC_t), and Renewable Energy (RC_t) are available in the database of British Petroleum (BP).

Finally, the variable capture economic development, represented by the Human Development Index (DHI_t).

Although the countries China, India, and Japan are included in the GEPU database, which served as the foundation for our sample, they were excluded from the analysis due to missing values in the other variables used to estimate the results.

The variables under consideration were transformed into logarithmic forms as the production function is exponential. This approach provides an alternative to linearizing the equation and enables the interpretation of the coefficients through the concept of elasticities in the estimation results.

4.6. Methodology

4.6.1. Generalized Method of Moments (GMM)

The issue of heteroscedasticity is a common challenge encountered by researchers, necessitating effective handling strategies. Currently, a prevalent approach to address heteroskedasticity of unknown form is the utilization of the Generalized Method of Moments (GMM) as outlined by (Baum et al., 2003). This method relies on orthogonality conditions, enabling efficient estimation in the presence of such heteroskedasticity. Moreover, GMM estimation is widely employed for models with endogenous variables, particularly lagged dependent variables, especially in situations with limited time horizons (Kripfganz, 2019).

The efficiency of GMM is advantageous for ensuring consistency even in the presence of arbitrary heteroskedasticity. However, this advantage is counterbalanced by the potential for suboptimal performance in finite sample sizes (Baum et al., 2003). Given the trade-off involving the risk of consistency loss, the current study incorporates alternative methodologies beyond the efficient Generalized Method of Moments.

The foundational principle of GMM lies in the assumption that the instruments Z are exogenous, denoted by $E(Z_i u_i) = 0$. The set of L instruments provides L moments, forming the basis for the estimation within the GMM framework (Kripfganz, 2019).

$$g_i(\widehat{\beta}) = Z_i' \hat{u}_i = Z_i'(y_i - X_i\hat{\beta}) \ (17)$$

$L \ x \ 1$ is g_i. The exogenity shows the existence of L moments conditions, this condition is satisfied by the function, $E\{g_i(\beta)\} = 0$, the actual value of β (Baum et al., 2003). A sample moment corresponds to each of the L moment equations (Baum et al., 2003), and can be written as follow:

$$\bar{g}(\hat{\beta}) = \frac{1}{n}\sum_{i=1}^{n} \bar{g}(\hat{\beta}) = \frac{1}{n}\sum_{i=1}^{n} Z_i'(y_i - X_i\hat{\beta}) = \frac{1}{n} Z' \, \hat{u} \ (18)$$

The idea behind GMM (Generalized Method of Moments) is to select an estimator for β by finding a solution to the equation $\bar{g}(\hat{\beta}) = 0$ (Baum et al., 2003). The GMM estimator aims to minimize a quadratic form through the equation

$$\hat{\theta} \quad = arg \min_{\theta} \left(\sum_{i=1}^{N} m_i(\theta) \right)' W \left(\sum_{i=1}^{N} m_i(\theta) \right) \text{ (19)}$$

If in the equation that will be estimated $L = K$, it is possible to assume that many equations exist (L moments conditions) as the K coefficients in $(\hat{\beta})$. If $\bar{g}(\hat{\beta}) = 0$ can be solved in this scenario. The resulting GMM method estimator is essentially the same as the IV estimator (Baum et al., 2003).

If $L > K$ there are more equations than unknowns, in this scenario is not possible to find a $\hat{\beta}$ that will ensure that all L sample moment conditions are precisely zero. Typically, the model is characterized by a high degree of overidentification, where the number of moment conditions (L) greatly exceeds the number of parameters to be estimated (K) (Kripfganz, 2019). A large number of instruments compared to the size of the cross-sectional sample can lead to biased estimates of coefficients and standard errors and reduce the power of specification tests (Roodman, 2009b). To solve this problem it is applied an $L\ x\ L$ weighting matrix W and utilize for building a quadratic form within the moment conditions (Baum et al., 2003). An asymptotically efficient estimator necessitates the use of an optimal weighting matrix, which is essentially a consistent estimate of the inverse of the asymptotic covariance matrix $m(\hat{\theta})$ (Kripfganz, 2019).

$$W(\hat{\theta}) = \left(\frac{1}{N} \sum_{i=1}^{N} m_i(\hat{\theta}) m_i(\hat{\theta})' \right)^{-1} \quad \text{(20)}$$

The weight matrix, $W(\hat{\theta})$, can be derived from an inefficient initial GMM estimator, which results from selecting a suboptimal W during the estimation process (Kripfganz, 2019). Thus, give the GMM function:

$$J(\hat{\beta}) = n\bar{g}(\hat{\beta})' W \bar{g}(\hat{\beta}) \text{ (21)}$$

The optimal value for $\hat{\beta}$, which minimizes $J(\hat{\beta})$, can be estimated using a GMM estimator. The GMM estimator that achieves maximum efficiency is the one that employs an optimal weighting matrix W, which minimizes the estimator's asymptotic variance (Baum et al., 2003). The one-step difference generalized method of moments (diff-GMM) approach is computationally efficient, but it requires a strong assumption of homoskedasticity to ensure its validity. In contrast, the one-step system GMM (sys-GMM) approach may lead to inefficiencies even under homoscedasticity (Kripfganz, 2020). The feasible efficient GMM estimator, which is a two-step procedure, can be expressed as follows (Kripfganz, 2019):

$$\hat{\hat{\theta}} \quad = arg \min_{\beta} \left(\frac{1}{N} \sum_{i=1}^{N} m_i(\beta) \right)' W(\hat{\theta}) \left(\frac{1}{N} \sum_{i=1}^{N} m_i(\beta) \right) \quad (22)$$

The one-step Generalized Method of Moments (GMM) estimator exhibits heteroskedasticity consistency but loses its efficiency property (Kripfganz, 2019). The two-step estimator exhibits asymptotic efficiency, conditional on a specified set of instruments. However, in the context of finite samples, estimating the optimal weighting matrix may be susceptible to variations that stem from the arbitrary selection of an initial weighting matrix (Kripfganz, 2020).

The GMM presents a computationally efficient method for obtaining consistent and asymptotically distributed estimators of statistical model parameters (Salkind, 2013). Compared to the maximum likelihood (ML) estimator, which is typically regarded as the optimal estimator in classical statistical paradigms, the GMM may provide a more suitable alternative in scenarios where dependence on the probability distribution exists. This is because the GMM is founded on the population moment condition, which allows for estimating the model coefficients based on information derived from the model (Salkind, 2013).

In general, it can be observed that the variable, denoted as $y_{i,t-1}$, exhibits a correlation with the fixed effects in the error term. This correlation leads to the emergence of what is commonly known as "dynamic panel bias" (Nickell, 1981). The abovementioned relationship can produce biased estimators if an appropriate methodology is not employed. Specifically, the estimated coefficients may be overestimated due to the incorrect attribution of predictive power to the relationship, which pertains to the fixed effects (Roodman, 2009a). Concerning the sample size of the current study, the value of $T = 11$. A larger sample size would likely lead to a reduced impact of each year on the others and potential mitigation of the endogeneity problem. An approach to tackle this issue involves the use of instrumental variables for $y_{i,t-1,}$ and other endogenous variables that are hypothesized to be uncorrelated with the fixed effects. This strategy is integrated within the System GMM methodology (Roodman, 2009a).

The difference and system GMM estimators are commonly used techniques for estimating parameters in panel data settings with "small T, large N" dimensions, where the number of time periods is limited, and there are many individuals. These methods prove particularly useful when the independent variables are not strictly exogenous, and when they are correlated with past and current error terms. Moreover, they have the capability to handle fixed effects, heteroskedasticity, and autocorrelation within individuals (Roodman, 2009a)

4.6.2. Bias-Corrected Estimation

When analyzing panel data models that include a lagged dependent variable and unobserved group-specific heterogeneity, the conventional "fixed effects" (FE) and "random effects" (RE) estimators may produce biased results if the time horizon is limited. This means that the estimates obtained from these models may not accurately reflect the true relationship between the variables being studied. Therefore, it is important to carefully consider the choice of the estimator and the length of the time horizon when conducting panel data analysis (Nickell, 1981).

Quasi–maximum likelihood (QML) can be an alternative approach to the panel-data scenario in which the time horizon is not extensive. In this context, it usually applies the Ordinary Least Square (OLS) or Generalized Least Square (GLS) is for random or fixed effects because, according to (Kripfganz, 2016), the use of initial observations to condition estimates may result in bias due to the correlation between the lagged dependent variable and the combined error term. Quantile maximum likelihood (QML) estimators can exhibit significantly higher efficiency if all the regressors are strictly exogenous; however, this entails additional assumptions concerning the initial observations (Kripfganz & Breitung, 2022).

Given that the analytical nature of the bias is established, the bias-corrected (BC) estimator can rectify it directly at the origin by adapting the corresponding moment conditions. In addition, the fixed-effects/random-effects (FE/RE) estimators maintain their characteristic property of low variance. The bias-corrected (BC) estimator can handle higher-order autoregressive models and offers both FE and RE variations. Additionally, the BC estimator is a moment-based estimator with a well-defined asymptotic distribution, facilitating the straightforward computation of standard errors. Furthermore, standard errors can be adapted to account for cross-sectional dependence by applying robust techniques (Kripfganz & Breitung, 2022).

A generic Dynamic panel-data model can be described as:

$$y_{it} = \sum_{j=1}^{p} \lambda y_{i,t-1} + x_{it}'\beta + \varepsilon_{it} \qquad \varepsilon_{it} = u_i + \alpha_{it} \; (23)$$

In which, x_{it}' is a vector of time-varying variables (Kripfganz, 2016). In dealing with panel-data estimation, it is necessary to address whether the fixed or random effects will be applied, this decision is taken through the interpretation of Hausman's Test.

The fundamental assumptions of the model are as follows: (High-order) autoregressive model, given only minimal regularity conditions on the initial observations, it is possible to model the dependent variable with p lags. The regressors are assumed to be strictly exogenous x_{it}, regarding the idiosyncratic error term, the following assumptions are made: $E[x_{it}u_{is}] = 0$ for all t and s. There exist unobserved group-specific factors in the model, FE, $E[x_{it}\alpha_i] \neq 0$, or for RE $E[x_{it}\alpha_i] = 0$. The model assumes that the idiosyncratic errors are serially uncorrelated, such that the expected value of their product is zero for all periods t and s. However, the errors may exhibit heteroskedasticity, such that the expected value of the square of the error term is σ_i (Kripfganz & Breitung, 2022).

To simplify the model, it is assumed that $p = 1$ and $\theta = (\lambda_1, \beta')'$. The estimator known as the fixed effects and bias-corrected estimator with just identification solves the following:

$$\hat{\theta} = arg\min_{\theta}\left(\sum_{i=1}^{N} m_i(\theta)\right)'\left(\sum_{i=1}^{N} m_i(\theta)\right) \quad (24)$$

While the estimator, referred to as the random effects and bias-corrected estimator with over-identification, solves the following:

$$\hat{\theta}^{(j)} = arg\min_{\theta}\left(\sum_{i=1}^{N} m_i(\theta)\right)' W\left(\sum_{i=1}^{N} m_i(\theta)\right) \quad (25)$$

In the context of finite element analysis, we employ an adjusted profile likelihood estimator for our BC estimation. This estimator is designed to handle scenarios where the dependent variable exhibits a sole lag. In addition to the before mentioned benefits, it should be noted that the BC estimator in question does not necessitate a preliminary consistent estimator (Kripfganz & Breitung, 2022).

4.7. Results and Discussions

This study proposes estimating two distinct models: model 1, represented by equation 19, and Model 2, represented by equation 20. The main difference between these models lies in their treatment of the labour force. While model 1 considers the total labour force, model 2 considers the level of education (basic, intermediate, and advanced) to capture its interaction with economic growth.

$$Y_t = \beta_0 + \beta_1 FD_t + \beta_2 HT_{1t} + \beta_3 K_t + \beta_4 CC_t + \beta_5 NGC_t + \beta_6 OC_t + \beta_7 RC_t + \beta_8 lnEPU_t + \beta_9 DHI_t + \varepsilon_t \quad (26)$$

$$Y_t = \beta_0 + \beta_1 FD_t + \beta_2 H_{1t} + \beta_3 H_{2t} + \beta_4 H_{3t} + \beta_5 K_t + \beta_6 CC_t + \beta_7 NGC_t + \beta_8 OC_t + \beta_9 RC_t + \beta_{10} EPU_t + \beta_{11} DHI_t + \varepsilon_t \quad (27)$$

Which is the technical progress represented by $A_t = FD$, in which FD stands for financial development as a proxy for technological progress, the same strategy applied by (Ifa & Guetat, 2022). In addition, we divide HT_t into three variables to capture the effect of basic education (H_1), intermediate education (H_2), and advanced education (H_3), thus $HT = (H_1 + H_2 + H_3)$, so we have in these variables the ideas of Lucas's models. Finally, the decomposition of energy production (EC_t), we consider the consumption of gas (NGC), oil (OC), coal (CC), and renewable energy (RC).

It has been determined that converting the equations into log-log form will facilitate interpreting the results. This approach allows for direct analysis of the concept of elasticity, thereby simplifying the overall interpretation process.

Based on the economic growth models examined in this study and specific characteristics of the GMM approach, the technical progress (FD), the labor force ($HT_{1t}, H_{1t}, H_{2t}, H_{3t}$), and capital ($K_t$) are regarded as endogenous variables. That said, all other variables are considered exogenous.

Considering the characteristics of the sample examined in this study, which have a relatively short time frame, the methodologies were chosen. Moreover, the GMM methodology produces robust estimators when heteroscedasticity is present, a condition addressed in this dataset.

To evaluate the association among the error terms in the sample, cross-sectional independence tests, specifically the Pesaran, Frees, and Friedman tests, are utilized. The null hypothesis assumes cross-sectional independence. The outcomes of the tests are inconclusive, as the Pesaran and Frees tests suggest the presence of cross-sectional dependence for the Model 1 fixed effects and random effects, and for the Model 2 for fixed effects, whereas the Pesaran test suggests otherwise for the random effects in Model 2. The Wooldridge test is employed to check the hypothesis of no autocorrelation in panel data. The findings suggest that, at a 1% significance level, there is insufficient evidence to reject the null hypothesis, thereby indicating the absence of autocorrelation in the sample.

Furthermore, the Modified Wald test is employed to investigate heteroscedasticity. The results reveal that, at a 1% confidence level, the null hypothesis cannot be rejected, implying that the sample exhibits constant variance. The outcomes of the tests are presented in Table 4.1.

Table 4.1 – Diagnostic Tests

Model 1	Fixed Effects	Random Effects
Pesaran's test of cross-sectional independence	-0.201	-0.021
Frees' test of cross-sectional independence	0.895	1.444
Friedman's test of cross-sectional independence	9.333	11.051
Average absolute value of the off-diagonal elements	0.321	0.349
Modified Wald test for groupwise heteroskedasticity	2260.54***	
Wooldridge test for autocorrelation in panel data	10.658***	
Model 2	**Fixed Effects**	**Random Effects**
Pesaran's test of cross-sectional independence	0.074	2.327**
Frees' test of cross-sectional independence	0.87	1.379
Friedman's test of cross-sectional independence	10.01	16.98
Average absolute value of the off-diagonal elements	0.312	0.361
Modified Wald test for groupwise heteroskedasticity	2655.78***	
Wooldridge test for autocorrelation in panel data	11.546***	

Note: significance level at 1%***, 5%**, and 10%* to evaluate the results.

Due to the non-normal distribution of errors, which implies the presence of heteroscedasticity, diagnostic tests were conducted to confirm this observation. To address this issue, the Generalized Method of Moments (GMM) was chosen as the preferred estimation technique. The main advantage of GMM is its ability to provide consistent estimates even in the presence of heteroscedasticity.

Table 4.2 presents the outcomes of Model 1 estimates obtained through the Dynamic Panel-Data Estimation approach.

Table 4.2 – Dynamic Panel-Data Estimations Model 1

Variables	Dynamic panel-data estimation, one-step system GMM	Dynamic panel-data estimation, two-step system GMM	Dynamic panel-data estimation, one-step difference GMM	Dynamic panel-data estimation, two-step difference GMM
Gross Domestic Product				
L1.	0.9852593***	0.9549475***	0.8485602***	0.9950902***
Financial Denvelopment	-0.0206229	-0.0151843	0.4455175*	0.5273991**
Total Labor Force	-0.022785	-0.0498197*	0.3740659	0.1828019
Gross Fixed Capital Formation	0.0206585	0.0498907*	-0.1600128	-0.2108619
Arellano-Bond test for AR(1) in levels:	1.9**	2.53***	-1.41	-1.45
Arellano-Bond test for AR(2) in levels:	0.85	1.51	0.43	0.39

Note: significance level at 1%***, 5%**, and 10%* to evaluate the results.

The dynamic models exhibit satisfactory specification as evidenced by the rejection of the null hypothesis for the absence of second-order autocorrelation. Results indicate that financial development and gross fixed capital formation, when statistically significant, display a positive relationship with economic growth, contributing to a growth rate increase of 0.5% and 0.05%, respectively, for every 1% expansion. Conversely, the labor force exerts a negative impact on economic growth, with a 1% increase in the labor force tending to reduce growth by approximately 0.05%.

Table 4.3 presents the outcomes of Model 1 estimates obtained through the Generalized Method of Moments (GMM) approach.

Table 4.3 - Generalized Methods of Moments Estimations Model 1

Variables	Generalized method of moments estimation Lag(1)	Generalized method of moments estimation Lag(1)	Generalized method of moments estimation Lag(2)	Generalized method of moments estimation Lag(2)
Gross Domestic Product				
L1.	0.4364427***	0.9504841***	0.6670739***	1.370425***
L2.	.	.	-0.2041014	-0.3906307***
Financial Denvelopment	-0.0860321	-0.0050739	-0.0632148	-0.0036301
Total Labor Force	0.1822645***	-0.052679***	0.2355862***	-0.024077***
Gross Fixed Capital Formation	0.1843049***	0.0515629***	0.1628012***	0.022236***
Constant	.	0.0540493	.	0.0354822

Note: significance level at 1%***, 5%**, and 10%* to evaluate the results.

The analysis of GMM reveals the significance of two variables, workforce and gross fixed capital formation, which are considered fundamental for growth models proposed by (Lucas, 1988) and (Romer, 1990). Moreover, the labour force variable demonstrates an inverse relationship with economic activity, indicating its negative impact on economic growth, in the event of a 1% increase in the labor force, a corresponding reduction in GDP by approximately 0.02% is anticipated. In contrast, gross capital formation exhibits both economic significance and the expected signal, consistent with prevailing macroeconomic theories, to illustrate, a 1% increase in capital formation is expected to result in a corresponding economic growth of approximately 0.02%. The lack of statistical significance regarding financial development, used as a proxy for technical progress, aligns with the finding reported by (Fatimah et al., 2021).

Table 4.4 presents the estimates obtained from Model 2, which aimed to isolate the effect of the workforce on economic growth based on different educational levels, namely basic, intermediate, and advanced.

Table 4.4 - Dynamic Panel-Data Estimation Model 2

Variables	Dynamic panel-data estimation, one-step system GMM	Dynamic panel-data estimation, two-step system GMM	Dynamic panel-data estimation, one-step difference GMM	Dynamic panel-data estimation, two-step difference GMM
Gross Domestic Product				
L1.	1.025985***	1.024861***	0.6662438	0.7805235
Financial Denvelopment	-0.0697613*	-0.0645436*	0.3605896	0.2713114
Advanced Education	-0.0959228	-0.1092329	-1.016749	-0.4321895
Basic Education	0.0181539	0.0216017	-0.2073786	-0.0947404
Intermediate Education	0.0195079	0.0354481	0.365844	0.26053
Gross Fixed Formation	-0.0003549	-0.0006878	-0.0371898	-0.088691
Arellano-Bond test for AR(1) in levels:	2.22**	2.5***	-1.16	-0.68
Arellano-Bond test for AR(2) in levels:	1.43	1.9**	-0.47	0.13

Note: significance level at 1%***, 5%**, and 10%* to evaluate the results.

The results of Model 2 regarding the decomposed workforce reveal a lack of statistical significance for the education metrics among the variables considered in the endogenous growth models, with only technological progress (represented by financial development in this study) displaying a negative relationship. Specifically, a 1% decrease in technological progress is projected to correspond to a 0.06% increase in GDP growth. Similar to Model 1, Model 2 demonstrates satisfactory specification, as evidenced by the absence of second-order autocorrelation.

Table 4.5 presents the GMM estimates obtained for Model 2, as said before this model difference are the metrics for education.

Table 4.5 - Generalized Methods of Moments Estimations Model 2

Variables	Generalized method of moments estimation Lag(1)	Generalized method of moments estimation Lag(1)	Generalized method of moments estimation Lag(2)	Generalized method of moments estimation Lag(2)
Gross Domestic Product				
L1.	0.4878106***	1.012709***	0.6220815***	1.496763***
L2.	.	.	-0.1132745	-0.4919981***
Financial Denvelopment	-0.011913	-0.0330548**	-0.0111192	-0.008293
Advanced Education	-0.2980019	-0.0568408	-0.2807287*	-0.0078254
Basic Education	-0.0722636	0.0052765	-0.0602104	-0.0037107
Intermediate Education	0.0282526	0.0331935	0.0006312	-0.0021034
Gross Fixed Formation	0.1777782***	0.0014848	0.1650124***	-0.0010362
Constant	.	-0.0788169	.	0.0386178

Note: significance level at 1%***, 5%**, and 10%* to evaluate the results.

Similar findings were observed in the estimates based on disaggregated labor force data, albeit without statistical significance, except for advanced education. While the results did not align with initial expectations, they were partially consistent with prior research conducted by (Bowen & Qian, 2017), and contrary to the findings reported by (Clarke et al., 2015), the results indicate the opposite relationship. The unexpected outcome concerning education prompts a desire to investigate the underlying reasons. It is possible that the limited representation of individuals with advanced education within the population and the high costs associated with training this particular workforce could account for this phenomenon. The model also indicates a significant negative effect on financial development. These findings challenge the conventional notion that technological advancements contribute positively to economic growth, and this conclusion contradicts the results reported by previous studies such as (Ponce et al., 2021) and (Asafo-Adjei et al., 2021).

Table 4.6 presents an expanded model incorporating variables previously treated as exogenous, aligning with the framework proposed by Lucas and Romer.

Table 4.6 - Bias-corrected Estimation Model 1

Variables	Bias-corrected Estimation FE Robust	Bias-corrected estimation RE Robust	Bias-corrected estimation FE Lag (1)	Bias-corrected estimation RE Lag (1)
Gross Domestic Product				
L1.	0.4440578***	0.9160004***	0.4633708***	0.860774***
Financial Denvelopment	0.0129838	0.0394355	0.0117613	0.0139339
Total Labor Force	-0.150541	-0.0678303**	-0.1945559**	-0.0751394
Gross Fixed Capital Formation	0.1661582***	0.0671242***	0.1591666***	0.0861273
GEPU (x4)	-0.0192954**	-0.0089639**	-0.0176556***	-0.0065603
Natural Gas Consumption	-0.0027993	0.0118005**	-0.0107759	0.0121031*

Oil Consumption	0.0480523*	-0.0226054**	0.0544219**	-0.0230536
Coal Consumption	-0.0016052	0.0016313	0.0018803	-0.0064444
Renewable Consumption	0.0192099**	0.0047087	0.0125147	0.0080932***
DHI	0.7404824**	0.0277155	0.4957054	0.5340972
Constant	4.033113**	0.342385	4.706418***	0.613681
Hansen test of the overidentifying restrictions	13.2732*		2.589	
Generalized Hausman test	192.2839***		3637.8831***	
Arellano-Bond test for autocorrelation of the first-differenced residuals				
H0: no autocorrelation of order 1:	-0.9702		-0.4879	
H0: no autocorrelation of order 2:	-1.4867		-0.0568	
Variables	Bias-corrected estimation FE Lag(2)	Bias-corrected estimation RE Lag(2)	Bias-corrected estimation FE Lag(3)	Bias-corrected estimation RE Lag(3)
Gross Domestic Product				
L1.	0.6890672***	1.243532	0.7836068***	1.159665***
L2.	-0.1585891*	-0.3428193***	-0.1102303	-0.2627109
L3.	.	.	-0.0151187	0.0136519
Financial Denvelopment	-0.0012694	0.0254415	0.007974	0.0417078
Total Labor Force	-0.1462781	-0.0482538*	-0.1614799	-0.0505131
Gross Fixed Capital Formation	0.1258258***	0.0527879**	0.0867776***	0.050894
GEPU	-0.0160405**	-0.0093615*	-0.0185021*	-0.0129026
Natural Gas Consumption	-0.0243556*	0.010396**	-0.0360617*	0.0112078**
Oil Consumption	0.0475627*	-0.0138653*	0.0509538*	-0.01515
Coal Consumption	0.0005615	-0.0065704	0.0001882	-0.0040211
Renewable Consumption	0.0072523	0.0063358***	-0.0019188	0.0050974***
DHI	0.6258352*	0.4052841	0.6643258	0.2624024
Constant	4.08641**	0.5678005	4.070281***	0.5665459
Hansen test of the overidentifying restrictions	3.2943		6.4125	
Generalized Hausman test	1014.6526***		715.8827***	
Arellano-Bond test for autocorrelation of the first-differenced residuals				
H0: no autocorrelation of order 1:	-1.0975		-1.1029	
H0: no autocorrelation of order 2:	-1.0417		-1.1486	
H0: no autocorrelation of order 3:	.		1.4657	

Note: significance level at 1%***, 5%**, and 10%* to evaluate the results.

Although the labor force variable lacks statistical significance, it shows an inverse relationship with economic activity, suggesting a detrimental effect on economic growth. On the other hand, gross capital formation demonstrates both economic significance and the anticipated directional relationship, which aligns with dominant macroeconomic theories. Additionally, the GEPU variable, which measures political stability, displays an inverse association with GDP, suggesting that an increase in uncertainty or political instability would likely negatively affect economic growth. This finding is in line with prior academic research, as indicated by Feng (1997), Uddin et al. (2017), Aydin (2022), and Asafo-Adjei et al. (2021), with the latter underscoring the heightened sensitivity of less developed economies to instabilities and uncertainties in the political and economic domains.

The variables influencing energy consumption exhibit a mixture of results: natural gas consumption displays a positive relationship, while oil consumption exhibits an inverse relationship. Conversely, there is a positive correlation between renewable energy consumption and economic growth, which is consistent with previous studies conducted by Ben Jebli et al. (2019), Ben Mbarek et al. (2018), Balsalobre-Lorente et al. (2018), Aydin (2022), and Kamoun et al. (2019). However, Oliveira and Moutinho (2021) found the opposite result for the BRICS. The observed direct relationship between renewable energy consumption and the inverse relationship for oil consumption may indicate a shift in the energy consumption and production profile towards sustainable growth that is less harmful to the environment.

The proxy for social development, the Human Development Index (HDI), bears significant importance. As reported in the literature review conducted by Hung (2022), Adewale Alola et al. (2021), Kaewnern et al. (2023), Ponce et al. (2021), and Khan et al. (2022), the positive correlation between HDI and economic growth is consistent with previous findings. This correlation underscores the notion that political and economic stability, in conjunction with economic growth, tends to mitigate inequality. However, financial development can have the opposite effect.

The estimated results of Model 2 aim to capture the impact of educational level on the economy, the results can be seen in Table 4.7.

Table 4.7 - Bias-corrected Estimation Model 2

Variables	Bias-corrected Estimation FE Robust	Bias-corrected estimation RE Robust	Bias-corrected estimation FE Lag(1)	Bias-corrected estimation RE Lag(1)
Gross Domestic Product				
L1.	0.4223524***	0.9254811***	0.4245002***	0.9035991***
Financial Denvelopment	-0.0068477	0.076383***	-0.0158768	0.0568887
Advanced Education	-0.1716836	0.1513377	-0.1897303	0.1032096
Basic Education	-0.0300188	-0.0104837	-0.0333724	-0.0095338
Intermediate Education	0.062623	-0.1419524*	0.1211298	-0.0734225
Gross Fixed Formation	0.1698909***	0.0411059***	0.1658186***	0.0552733
GEPU	-0.0162206**	-0.0216577***	-0.0153359**	-0.0223737**
Natural Gas Consumption	-0.0178665	0.0099575*	-0.0270575	0.0067036
Oil Consumption	0.0550772**	-0.0498281***	0.0585983***	-0.0496291
Coal Consumption	-0.0025621	-0.0011314	-3.61E-06	-0.0060998
Renewable Consumption	0.0081202	-0.0061507	0.0029695	-0.0047809
DHI	0.6753484**	0.3917423*	0.5525335	0.6173173
Constant	2.161191***	-0.1061318	2.057371***	-0.2966595
Hansen test of the overidentifying restrictions	9.0352*		3.3147	

Generalized Hausman test	940.099***		1355.9515	
Arellano-Bond test for autocorrelation of the first-differenced residuals				
H0: no autocorrelation of order 1:	-1.0319		-1.0618	
H0: no autocorrelation of order 2:	-1.5394		-0.9976	

Variables	Bias-corrected estimation FE Lag(2)	Bias-corrected estimation RE Lag(2)	Bias-corrected estimation FE Lag(3)	Bias-corrected estimation RE Lag (3)
Gross Domestic Product				
L1.	0.6615329***	1.268123***	0.7409402***	1.156506***
L2.	-0.165949**	-0.3617548	-0.0903439	-0.2304475
L3.	.	.	-0.0457241*	-0.0203602
Financial Denvelopment	-0.019102	0.0672731	0.0000737	0.0939207
Advanced Education	-0.173708*	0.143969	-0.0894289	0.1768033
Basic Education	-0.0323599	-0.0109898	-0.0186516	-0.0163332
Intermediate Education	0.1349918*	-0.0666825	0.0653784	-0.0925525
Gross Fixed Formation	0.1317946***	0.0390322	0.0952346***	0.039718
GEPU	-0.014799**	-0.0192265	-0.0183949*	-0.0212018**
Natural Gas Consumption	-0.0375075**	0.0040354	-0.041161**	0.0036089
Oil Consumption	0.0537483**	-0.0313878*	0.0595668**	-0.0348343
Coal Consumption	-0.0007362	-0.0045679	-0.0008719	-0.0021593
Renewable Consumption	0.0004321	-0.00257	-0.0043804	-0.0051101
DHI	0.7021795**	0.5582068	0.7749778*	0.4804654
Constant	2.111248***	-0.1384664	1.851409***	-0.17033
Hansen test of the overidentifying restrictions	2.2777		0.967	
Generalized Hausman test	359.2819***		376.3888***	
Arellano-Bond test for autocorrelation of the first-differenced residuals				
H0: no autocorrelation of order 1:	-1.2631		-1.094	
H0: no autocorrelation of order 2:	-0.3409		-1.8324*	
H0: no autocorrelation of order 3:	.		1.9300**	

Note: significance level at 1%***, 5%**, and 10%* to evaluate the results.

Surprisingly, the findings reveal that workers with advanced education harm the economy, which contradicts the anticipated relationship. However, the positive relationship and statistical significance observed for intermediate education suggest that economic growth may be linked to the promotion and facilitation of technical courses tailored to the labour market's needs. This finding highlights the importance of aligning education with the demands of the labour market to foster economic development.

The Human Development Index (HDI), utilized as a proxy for social development, is of considerable significance. As noted in the literature review conducted by Hung (2022), Adewale Alola et al. (2021), Kaewnern et al. (2023), Ponce et al. (2021), and Khan et al. (2022), the positive association between HDI and economic growth is consistent with prior research. This linkage highlights that stability in politics and economics, in conjunction with economic growth, tends to alleviate inequality.

Furthermore, the GEPU variable negatively impacts GDP, indicating that heightened uncertainty or political instability will likely harm economic growth. Similar relations were observed in Model 1.

Regarding energy consumption, the results are mixed once more. However, this model reveals an inversion of signals: oil consumption exhibits a positive relationship with economic growth, while natural gas consumption displays a negative association.

4.8. Conclusions

In this study, we have presented the results of two distinct models, namely Model 1 and Model 2, which aimed to investigate the relationship between technological progress, represented here by the financial development, labour force, gross fixed formation, the GEPU as a proxy for political stability, energy consumption, human development and economic growth. The main difference between these models lies in their treatment of the labour force, with Model 2 considering the level of education to capture its interaction with economic growth.

This study faces significant limitations due to its reliance on an index as the primary analytical tool. While indices are commonly used in academic research, they may not fully capture the complex and multifaceted nature of real-world situations, as previously noted by Foster et al. (2012) regarding a different indicator. Additionally, the sampling period used in this study may be insufficient for rigorous, long-term statistical inference, which could explain the discrepancies observed compared to previous research, particularly concerning outcomes resulting from changes to institutional metrics.

The results obtained from Model 1 through the GMM approach indicate that the financial development variable is non-significant for economic growth. On the other hand, gross capital formation displays both economic significance and the expected signal, consistent with prevailing macroeconomic theories, while the labour force displays a negative relation. Additionally, the GEPU variable, which measures political stability, exhibits an inverse association with GDP, suggesting that instability or political uncertainty would likely negatively affect economic growth. Furthermore, the observed direct relationship between renewable energy consumption and the inverse relationship for oil consumption may indicate a shift in the energy consumption and production profile towards sustainable growth that is less harmful to the environment.

The findings from Model 2, which aimed to isolate the effect of the workforce on economic growth based on different educational levels, reveal that intermediate education and advanced are statistically significant. Surprisingly, workers with advanced education harm the economy, which contradicts the anticipated relationship. However, the positive relationship and statistical significance observed for intermediate education suggest that economic growth may be linked to the promotion and facilitation of technical courses tailored to the labour market's needs.

Regarding future studies, it is recommended to conduct an examination, analysis, and, where feasible, comprehension of the reasons behind the occurrence of unexpected outcomes, especially why basic and advanced education is not directly related to economic growth, since the majority of the population have at least the basic education, and to assess whether these are in alignment with the prevailing academic discourse. This may involve investigating whether such outcomes can be attributed to specific features of the database or whether a discernible pattern of change in the economic landscape may be driving these results.

The results obtained from both models suggest that aligning education with the demands of the labour market to foster economic development is crucial. In conclusion, our study highlights the significance of various economic factors in driving economic growth and calls for policymakers to consider these factors when formulating policies to promote sustainable economic development.

References

Ã, C. H., & Siu, K. W. (2007). A dynamic equilibrium of electricity consumption and GDP in Hong Kong : An empirical investigation. Energy Policy, 35, 2507–2513. https://doi.org/10.1016/j.enpol.2006.09.018

Ã, I. O., Abdoli, G., Farahani, Y. G., Abosedra, S., Dah, A., Ghosh, S., Ahmed, M., Azam, M., Akadiri, S., Bekun, F. V., Taheri, E., Akadiri, A., Akinlo, A. E., Ameyaw, B., Oppong, A., Abruquah, L. A., Ashalley, E., Apergis, N., Payne, J. E., … Andrews, D. W. K. (2010). A literature survey on energy – growth nexus. Energy Policy, 38(1), 340–349. https://doi.org/10.1016/j.enpol.2009.09.024

Abderrahmani, F., & Be, F. (2013). Electricity consumption and economic growth in Algeria : A multivariate causality analysis in the presence of structural change. Energy Policy, 55, 286–295. https://doi.org/10.1016/j.enpol.2012.12.004

Abosedra, S., Dah, A., & Ghosh, S. (2009). Electricity consumption and economic growth , the case of Lebanon. Applied Energy, 86(4), 429–432. https://doi.org/10.1016/j.apenergy.2008.06.011

Acemoglu, D., Naidu, S., Restrepo, P., & Robinson, J. A. (2019). Democracy does cause growth. Journal of Political Economy, 127(1), 47–100. https://doi.org/10.1086/700936

Adeleye, B. N., Bengana, I., Boukhelkhal, A., Shafiq, M. M., & Abdulkareem, H. K. K. (2022). Does Human Capital Tilt the Population-Economic Growth Dynamics? Evidence from Middle East and North African Countries. Social Indicators Research, 162(2), 863–883. https://doi.org/10.1007/s11205-021-02867-5

Adewale Alola, A., Ozturk, I., & Bekun, F. V. (2021). Is clean energy prosperity and technological innovation rapidly mitigating sustainable energy-development deficit in selected sub-Saharan Africa? A myth or reality. Energy Policy, 158(May), 112520. https://doi.org/10.1016/j.enpol.2021.112520

Agasisti, T., & Bertoletti, A. (2022). Higher education and economic growth: A longitudinal study of European regions 2000–2017. Socio-Economic Planning Sciences, 81(August 2020), 100940. https://doi.org/10.1016/j.seps.2020.100940

Ameyaw, B., Oppong, A., Abruquah, L. A., & Ashalley, E. (2017). Causality Nexus of Electricity Consumption and Economic Growth : An Empirical Evidence from Ghana. Open Journal of Business and Management, 1–10. https://doi.org/10.4236/ojbm.2017.51001

Asafo-Adjei, E., Boateng, E., Isshaq, Z., Idun, A. A. A., Owusu, P., & Adam, A. M. (2021). Financial sector and economic growth amid external uncertainty shocks: Insights into emerging economies. PLoS ONE, 16(11 November 2021), 1–26. https://doi.org/10.1371/journal.pone.0259303

Aslan, A. (2013). Causality Between Electricity Consumption and Economic Growth in Turkey : An ARDL Bounds Testing Approach. Energy Sources, Part B: Economics, Planning, and Policy, October 2014, 37–41. https://doi.org/10.1080/15567241003681882

Aydin, M. (2022). The impacts of political stability, renewable energy consumption, and economic growth on tourism in Turkey: New evidence from Fourier Bootstrap ARDL approach. Renewable Energy, 190, 467–473. https://doi.org/10.1016/j.renene.2022.03.144

Baldwin, J. N., Borrelli, S. A., & New, M. J. (2011). State Educational Investments and Economic Growth in the United States: A Path Analysis. Social Science Quarterly, 92(1), 226–245. https://doi.org/10.1111/j.1540-6237.2011.00765.x

Baldwin, N., & Borrelli, S. A. (2008). Education and economic growth in the United States: Cross-national applications for an intra-national path analysis. Policy Sciences, 41(3), 183–204. https://doi.org/10.1007/s11077-008-9062-2

Balsalobre-Lorente, D., Shahbaz, M., Roubaud, D., & Farhani, S. (2018). How economic growth , renewable electricity and natural resources contribute to CO 2 emissions ? Energy Policy, 113(May 2017), 356–367. https://doi.org/10.1016/j.enpol.2017.10.050

Baranzini, A., Weber, S., Bareit, M., & Mathys, N. A. (2013). The causal relationship between energy use and economic growth in Switzerland ☆. Energy Economics, 36, 464–470. https://doi.org/10.1016/j.eneco.2012.09.015

Barro, R. J., & Sala-i-Martin, X. (2000). Economic Growth. MIT Press.

Baum, C. F., Schaffer, M. E., & Stillman, S. (2003). Instrumental Variables and GMM: Estimation and Testing. The Stata Journal: Promoting Communications on Statistics and Stata, 3(1), 1–31. https://doi.org/10.1177/1536867x0300300101

Belloumi, M., & Alshehry, A. S. (2016). The Impact of Urbanization on Energy Intensity in Saudi Arabia. Sustainability, 1–17. https://doi.org/10.3390/su8040375

Ben Jebli, M., Ben Youssef, S., & Apergis, N. (2019). The dynamic linkage between renewable energy, tourism, CO 2 emissions, economic growth, foreign direct investment, and trade. Latin American Economic Review, 28(1). https://doi.org/10.1186/s40503-019-0063-7

Ben Mbarek, M., Abdelkafi, I., & Feki, R. (2018). Nonlinear Causality Between Renewable Energy, Economic Growth, and Unemployment: Evidence from Tunisia. Journal of the Knowledge Economy, 9(2), 694–702. https://doi.org/10.1007/s13132-016-0357-9

Bond, S. R. (2002). Dynamic panel data models: a guide to micro data methods and practice. Portuguese Economic Journal, 1(2), 141–162. https://doi.org/10.1007/s10258-002-0009-9

Bowen, W. M., & Qian, H. (2017). State spending for higher education: Does it improve economic performance? Regional Science Policy and Practice, 9(1), 7–23. https://doi.org/10.1111/rsp3.12086

Çakar, N. D., Gedikli, A., Erdoğan, S., & Yıldırım, D. Ç. (2021). Exploring the nexus between human capital and environmental degradation: The case of EU countries. Journal of Environmental Management, 295(June). https://doi.org/10.1016/j.jenvman.2021.113057

Chen, J., Jin, F., Ouyang, G., Ouyang, J., & Wen, F. (2019). Oil price shocks, economic policy uncertainty and industrial economic growth in China. PLoS ONE, 14(5), 1–19. https://doi.org/10.1371/journal.pone.0215397

Clarke, W., Jones, A. T., & Lacy, B. (2015). Education spending and workforce quality as determinants of economic growth. Journal of Rural and Community Development.

Elfaki, K. E., Poernomo, A., Anwar, N., & Ahmad, A. A. (2018). Energy Consumption and Economic Growth : Empirical Evidence for Sudan. International Journal of Energy Economics and Policy, 8(5), 35–41.

Emir, F., & Bekun, F. V. (2019). Energy intensity , carbon emissions , renewable energy , and economic growth nexus : New insights from Romania. Energy & Environment. https://doi.org/10.1177/0958305X18793108

Faggian, A., Partridge, M., & Malecki, E. J. (2017). Creating an Environment for Economic Growth: Creativity, Entrepreneurship or Human Capital? International Journal of Urban and Regional Research, 41(6), 997–1009. https://doi.org/10.1111/1468-2427.12555

Fan, Q., Goetz, S. J., & Liang, J. (2016). The interactive effects of human capital and quality of life on economic growth. Applied Economics, 48(53), 5186–5200. https://doi.org/10.1080/00036846.2016.1173180

Fatimah, N., Sulaiman, C., Jumadil, S., & Suriyani, M. (2021). Effects of Human Capital and Innovation on Economic Growth in Selected ASEAN Countries: Evidence from Panel Regression Approach*. Journal of Asian Finance, 8(7), 43–0054. https://doi.org/10.13106/jafeb.2021.vol8.no7.0043

Feng, Y. (1997). Democracy, political stability and economic growth. British Journal of Political Science, 27(3), 391–418. https://doi.org/10.1017/S0007123497000197

Foster, J. E., Horowitz, A. W., & Méndez, F. (2012). An axiomatic approach to the measurement of corruption: Theory and applications. World Bank Economic Review, 26(2), 217–235. https://doi.org/10.1093/wber/lhs008

Ganda, F. (2022). The Environmental Impacts of Human Capital in the BRICS Economies. Journal of the Knowledge Economy, 13(1), 611–634. https://doi.org/10.1007/s13132-021-00737-6

Hamdi, H., Sbia, R., & Shahbaz, M. (2014). The nexus between electricity consumption and economic growth in Bahrain. Economic Modelling, 38, 227–237. https://doi.org/10.1016/j.econmod.2013.12.012

Hansen, lars peter. (1982). Large Sample Properties of Generalized Method of Moments Estimators. Econometrica, 50(4), 1029–1054.

Hong Vo, D., Tran, N. P., & Nguyen, H. M. (2021). Does financial development improve human capital accumulation in the Southeast Asian countries? Cogent Business and Management, 8(1). https://doi.org/10.1080/23311975.2021.1932245

Huang, S. Z., Chien, F., & Sadiq, M. (2022). A gateway towards a sustainable environment in emerging countries: the nexus between green energy and human Capital. Economic Research-Ekonomska Istrazivanja , 35(1), 4159–4176. https://doi.org/10.1080/1331677X.2021.2012218

Hung, N. T. (2022). Effect of economic indicators, biomass energy on human development in China. Energy and Environment, 33(5), 829–852. https://doi.org/10.1177/0958305X211022040

Ifa, A., & Guetat, I. (2022). Analysing short-run and long-run causality relationship among public spending, renewable energy consumption, non-renewable energy consumption and economic growth: Evidence from eight of South Mediterranean Countries. Energy Exploration and Exploitation, 40(2), 554–579. https://doi.org/10.1177/01445987211049304

Iyke, B. N. (2015). Electricity consumption and economic growth in Nigeria : A revisit of the energy-growth debate. Energy Economics, 51, 166–176. https://doi.org/10.1016/j.eneco.2015.05.024

Jorgenson, D. W., & Fraumeni, B. M. (1992). Investment in Education and U.S. Economic Growth. The Scandinavian Journal of Economics, 94, S51. https://doi.org/10.2307/3440246

Kablamaci, B. (2017). A re-examination of causal relation between economic growth and energy consumption: Evidence from 91 countries. Economics Bulletin, 37(2), 790–805.

Kaewnern, H., Wangkumharn, S., Deeyaonarn, W., Yousaf, A. U., & Kongbuamai, N. (2023). Investigating the role of research development and renewable energy on human development: An insight from the top ten human development index countries. Energy, 262(PB), 125540. https://doi.org/10.1016/j.energy.2022.125540

Kamoun, M., Abdelkafi, I., & Ghorbel, A. (2019). The Impact of Renewable Energy on Sustainable Growth: Evidence from a Panel of OECD Countries. Journal of the Knowledge Economy, 10(1), 221–237. https://doi.org/10.1007/s13132-016-0440-2

Kasim, M. (2017). Endogenous growth : Dynamic technology augmentation of Solow ' s model.

Khan, H., Weili, L., & Khan, I. (2022). The effect of political stability, carbon dioxide emission and economic growth on income inequality: evidence from developing, high income and Belt Road initiative countries. Environmental Science and Pollution Research, August. https://doi.org/10.1007/s11356-022-22675-9

Kripfganz, S. (2016). Quasi–maximum likelihood estimation of linear dynamic short-T panel-data models. Stata Journal, 16(4), 1013–1038. https://doi.org/10.1177/1536867x1601600411

Kripfganz, S. (2019). Generalized method of moments estimation of linear dynamic panel data models. London Stata Conference, 1–128. http://www.kripfganz.de/stata/

Kripfganz, S. (2020). Introduction System GMM Postestimation Special features Summary Generalized method of moments estimation of linear dynamic panel data models. http://www.kripfganz.de/stata/

Kripfganz, S., & Breitung, J. (2022). Bias-corrected estimation of linear dynamic panel data models (pp. 1–15).

Li, P., & Ouyang, Y. (2019). The dynamic impacts of financial development and human capital on co2 emission intensity in china: An ardl approach. Journal of Business Economics and Management, 20(5), 939–957. https://doi.org/10.3846/jbem.2019.10509

Lucas, R. E. (1988). On The Mechanics of Economic Development. Journal of Monetary Economics, 22(February), 3–42.

Maitra, B. (2016). Investment in Human Capital and Economic Growth in Singapore. Global Business Review, 17(2), 425–437. https://doi.org/10.1177/0972150915619819

Majidi, A. F. (2017). Foreign Trade, Human Capital and Economic Growth: Evidence from Asian Countries. International Journal of Asian Social Science, 7(12), 942–948. https://doi.org/10.18488/journal.1.2017.712.942.948

Mankiw, N. G. (2009). Macroeconomics (W. Publishers (ed.); 7th ed.). https://www.ptonline.com/articles/how-to-get-better-mfi-results

Mankiw, N. G., Romer, D., & Weil, D. N. (1992). A Contribution to the Empirics Of Economic Growth. The Quarterly Journal of Economics, May.

Matousek, R., & Tzeremes, N. G. (2021). The asymmetric impact of human capital on economic growth. Empirical Economics, 60(3), 1309–1334. https://doi.org/10.1007/s00181-019-01789-z

Narayan, S. (2016). Predictability within the energy consumption-economic growth nexus: Some evidence from income and regional groups. Economic Modelling, 54, 515–521. https://doi.org/10.1016/j.econmod.2015.12.037

Nazlioglu, S., Kayhan, S., & Adiguzel, U. (2014). Electricity Consumption and Economic Growth in Turkey: Cointegration, Linear and Nonlinear Granger Causality. Energy Sources, Part B: Economics, Planning, and Policy, April 2015. https://doi.org/10.1080/15567249.2010.495970

Ngo, T., Trinh, H. H., Haouas, I., & Ullah, S. (2022). Examining the bidirectional nexus between financial development and green growth: International evidence through the roles of human capital and education expenditure. Resources Policy, 79(September), 102964. https://doi.org/10.1016/j.resourpol.2022.102964

Nguyen, H. M., Bui, N. H., Vo, D. H., & McAleer, M. (2019). Energy consumption and economic growth: Evidence from Vietnam. Journal of Reviews on Global Economics, 8(ii), 350–361. https://doi.org/10.6000/1929-7092.2019.08.30

Nickell, S. (1981). Biases in dynamic models with fixed effects. Econometrica, 26(1), 29–31. https://doi.org/10.1016/0165-1765(88)90046-8

Nindi, A. G., & Odhiambo, N. (2014). Energy consumption and economic growth in Mozambique: an empirical investigation. Environmental Economics.

Oliveira, H., & Moutinho, V. (2021). Do Renewable, Non-Renewable Energy, Carbon Emissions And Kof Globalization Influencing Economic Growth? Evidence From Brics' Countries. The 8th International Conference on Energy and Environment Research ICEER 2021.

Ouedraogo, N. S. (2013). Energy consumption and human development: Evidence from a panel cointegration and error correction model. Energy, 63, 28–41. https://doi.org/10.1016/j.energy.2013.09.067

Pinzón, K. (2018). Dynamics between energy consumption and economic growth in Ecuador: A granger causality analysis. Economic Analysis and Policy, 57, 88–101. https://doi.org/10.1016/j.eap.2017.09.004

Ponce, P., Álvarez-García, J., Medina, J., & Del Río-Rama, M. de la C. (2021). Financial development, clean energy, and human capital: Roadmap towards sustainable growth in América Latina. Energies, 14(13), 1–16. https://doi.org/10.3390/en14133763

Prasetyo, P. E., & Kistanti, N. R. (2020). Human capital, institutional economics and entrepreneurship as a driver for quality & sustainable economic growth. Entrepreneurship and Sustainability Issues, 7(4), 2575–2589. https://doi.org/10.9770/jesi.2020.7.4(1)

Romer, P. M. (1990). Endogenous Technological Change. Journal of Political Economy, 98(5).

Roodman, D. (2009a). How to do xtabond2: An introduction to difference and system GMM in Stata. Stata Journal, 9(1), 86–136. https://doi.org/10.1177/1536867x0900900106

Roodman, D. (2009b). Practitioners' corner: A note on the theme of too many instruments. Oxford Bulletin of Economics and Statistics, 71(1), 135–158. https://doi.org/10.1111/j.1468-0084.2008.00542.x

Roser, M. (2014). Human Development Index (HDI). Published Online at OurWorldInData.Org. Retrieved from: "https://Ourworldindata.Org/Human-Development-Index" [Online Resource].

Salkind, N. (2013). Generalized Method of Moments. Encyclopedia of Measurement and Statistics. https://doi.org/10.4135/9781412952644.n185

Sayar, G., Erdas, M. L., & Destek, G. (2020). The Effects of Financial Development, Democracy and Human Capital on Income Distribution in Developing Countries: Does Financial Kuznets Curve Exists? Journal of Applied ..., 10(2), 76–95. http://search.ebscohost.com/login.aspx?direct=true&profile=ehost&scope=site&authtype=crawler&jrnl=1927033X&AN=144290706&h=0jDuUpu1f68OqNrwFvcd0mYJ3zLSyurEY4F7DT9zT0TeX5GYAzWwtpLN0pePRDBcwaTVmaNZoHjKiIMprimtkA%3D%3D&crl=c

Shahbaz, M., Chaudhary, A. R., & Shahzad, S. J. H. (2018). Is energy consumption sensitive to foreign capital inflows and currency devaluation in Pakistan? Applied Economics, 50(52), 5641–5658. https://doi.org/10.1080/00036846.2018.1488059

Shahbaz, M., Mallick, H., Mahalik, M. K., & Loganathan, N. (2015). Does globalization impede environmental quality in India? Ecological Indicators, 52, 379–393. https://doi.org/10.1016/j.ecolind.2014.12.025

Shidong, L., Chupradit, S., Maneengam, A., Suksatan, W., Phan The, C., & Nguyen Ngoc, Q. (2022). The moderating role of human capital and renewable energy in promoting economic development in G10 economies: Evidence from CUP-FM and CUP-BC methods. Renewable Energy, 189, 180–187. https://doi.org/10.1016/j.renene.2022.02.053

Solarin, S. A., & Opeyemi, B. M. (2011). Multivariate Causality Test on Electricity Consumption, Capital, Labour and Economic Growth for Nigeria. Journal of Business & Economics, February 2011.

Stewart, J. (2013). Cálculo, volume 2 (Vol. 2).

Tang, C. F., Tan, B. W., & Ozturk, I. (2016). Energy consumption and economic growth in Vietnam. Renewable and Sustainable Energy Reviews, 54, 1506–1514. https://doi.org/10.1016/j.rser.2015.10.083

Turna, Y., & Ceylan, R. (2022). The Relationship Between Economic Growth And Physical Capital, Human Capital And Energy Consumption In Turkey: Nardl Approach. Mehmet Akif Ersoy University Journal of Economics and Administrative Sciences Faculty, 223–242.

Uddin, M. A., Ali, M. H., & Masih, M. (2017). Political stability and growth: An application of dynamic GMM and quantile regression. Economic Modelling, 64(May), 610–625. https://doi.org/10.1016/j.econmod.2017.04.028

Widarni, E., & Bawono, S. (2021). Human Capital, Technology, and Economic Growth: A Case Study of Indonesia. The Journal of Asian Finance, Economics and Business, 8(5), 29–35. https://doi.org/10.13106/jafeb.2021.vol8.no5.0029

Xuan, P. P., Chin, L., & Ismail, N. W. (2018). Energy consumption and real GDP nexus: A Malaysian case demonstrating the importance of trade openness. International Journal of Business and Society, 19(2), 449–463.

Zafar, M. W., Zaidi, S. A. H., Khan, N. R., Mirza, F. M., Hou, F., & Kirmani, S. A. A. (2019). The impact of natural resources, human capital, and foreign direct investment on the ecological footprint: The case of the United States. Resources Policy, 63(May), 101428. https://doi.org/10.1016/j.resourpol.2019.101428

Chapter 5 – The Impact of Renewable and Non-Renewable Energy Sources and KOF Globalization Measures on Economic Growth: A Study of BRICS Countries[3]

5.1. Introduction

The relationship between economic growth and energy consumption, whether renewable or non-renewable, has been extensively researched. However, there is a gap in the literature regarding the relationship between measures of globalization, energy consumption, economic growth, and the interaction between the globalization measures. This study addresses the research gap concerning the interaction between globalization metrics and Gross Domestic Product (GDP). Specifically, it investigates the cross-effects of these indicators on GDP. Additionally, the study examines the relationship between the consumption of renewable and non-renewable energies and economic growth, considering both linear and non-linear behaviors. These research questions are inspired by the concept of the Environmental Kuznets Curve (EKC), which explores the relationship between environmental degradation and economic development.

Dreher (2006) has shown a positive impact of globalization on economic growth. Countries with fewer restrictions on economic flows tend to have higher economic growth rates, as demonstrated by Kali and Reyes (2007), who found a positive relationship between the number of trading partners and economic growth. Kim and Lin (2016) analyzed international trade to stimulate growth in both the short and long-term and found that higher economic openness reduces short-term growth volatility.

Based on data from the World Development Indicators (WDI), the proportion of renewable energy consumption in BRICS countries has exhibited a decline from 1990 to 2019. Nevertheless, it is noteworthy that this decline in consumption does not necessarily indicate a corresponding decrease in production. In fact, information sourced from British Petroleum (BP) reveals an increase in renewable energy production. Consequently, the consumption of non-renewable energy has increased, increasing the environmental pressure. According to data from BP, carbon dioxide emissions have exhibited an

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Viana Espinosa de Oliveira, H., & Moutinho, V. (2022). Do renewable, non-renewable energy, carbon emission and KOF globalization influencing economic growth? Evidence from BRICS' countries. *Energy Reports*, *8*, 48–53. https://doi.org/10.1016/j.egyr.2022.01.031

upward trajectory in the observed period for the BRICS economies. These numbers suggests that the economic expansion of these countries has exerted environmental pressures. It is imperative to undertake an investigation into the association between renewable energy consumption and economic growth within the BRICS economies, aiming to enhance our comprehension of this relationship towards achieving sustainable growth.

Although the relationship between globalization and economic growth is well-studied, further research is needed to understand the connections between measures of globalization, energy consumption and economic growth. This study focuses on BRICS countries, which have a significant global presence and comprise nearly half of the world's population. It aims to explore the relationship between economic growth, renewable and non-renewable energy, and KOF globalization measures in these countries. Previous research on this topic in the BRICS context is limited. The study proposes a model that considers the interactions among KOF globalization measures in economic, social, and political dimensions to explain the trade-off between economic growth, globalization, and energy consumption. The findings will inform policies and strategies for economic growth in BRICS countries while considering the effects of globalization.

The paper is organized as follows: Section 2 presents a brief literature review, Section 3 describes the data and methodologies used, Section 4 presents the findings and discussions, and Section 5 provides concluding remarks summarizing the main findings.

5.2. Literature Review

Recent research has investigated the relationship between economic growth, globalization, and energy consumption using different methodologies and metrics. Commonly used metrics for measuring globalization include the KOF globalization index, FDI, and international trade. However, there is no consensus on the impact of these variables on the economy. The associations observed are highly contingent on the specific characteristics of the economies analyzed in each sample.

In a study by Radulović and Kostić (2020) on 19 Eurozone countries, they found that economic and social globalization had a positive short-term impact on economic growth, while political globalization had a negative impact. In the long run, only economic globalization had a positive effect on the economy. Gasimli et al. (2022) observed a positive relationship between KOF Globalization metrics and sustainable growth in the CIS region. Another study by Haini et al. (2023) examined the relationship between the Social KOF index, tourism, and economic growth in 143 countries. They found that the Social KOF index positively influenced tourism, which in turn contributed to economic growth.

Shahbaz et al. (2020) conducted a study on 34 economies, finding positive impacts of renewable energy consumption in 22 economies, negative effects in three countries, and no significant results in nine countries. Radmehr et al. (2022) identified a bidirectional causal relationship between GDP and renewable energy consumption in the G7 countries. Dimitriadis et al. (2021) analyzed 68 developing economies and found positive relationships between CO_2 emissions, renewable and non-renewable energy consumption, and economic growth. Acheampong et al. (2021) found a positive impact of energy consumption on economic growth but mixed results for political and economic globalization indicators in 23 emerging economies. Ehigiamusoe (2022) discovered that KOF indicators positively influenced economic growth in low-income African countries, while economic globalization did not enhance growth, and non-renewable energy consumption contributed to economic activity.

For the BRICS economies between the years 2000-2018, Iqbal et al. (2023) found that carbon emissions, renewable energy consumption, foreign direct investment, and exports had a positive relationship with economic growth. In an analysis of 25 member countries of the European Union, Androniceanu and Georgescu (2023) observed that energy consumption, CO_2 emissions, and foreign direct investment had a positive impact on GDP. Santiago et al. (2020) investigated the impact of KOF indicators of globalization, economic freedom, and energy consumption on economic growth in Latin America and the Caribbean. The study found positive effects of globalization, specifically its social and economic indicators, on economic growth. However, the political indicator had a negative impact. Additionally, economic freedom was associated with a decrease in economic growth. Energy consumption, on the other hand, showed a positive association with economic activity.

Chica-Olmo et al. (2020) used a spatial approach to investigate the relationship between renewable energy consumption and economic growth in 26 European countries. By considering spillover effects, the study revealed that the interaction between countries impacts renewable energy consumption, which in turn contributes to economic growth. The findings suggest that increased renewable energy consumption in one country positively affects the economic growth of neighboring countries, indicating interdependence within the region.

Keshavarzian and Tabatabaienasab (2021) investigated the impact of renewable and non-renewable energy consumption on economic growth in OPEC member countries. The findings showed mixed results, with growth effects observed for renewable energy consumption in Ecuador and feedback effects in Saudi Arabia and the United Arab Emirates. Neutrality was found in Nigeria, Angola, Iraq, Venezuela, and Congo. For non-renewable energy consumption, feedback effects were observed in Ecuador, the United Arab Emirates, Iran, Saudi Arabia, Nigeria, Venezuela, and Congo, while conservation effects were found in Algeria and Iraq.

Pereira et al. (2021) reported a negative relationship between renewable energy utilization and economic growth in a sample of 161 countries over 59 years. Gyamfi et al. (2020) observed a positive relationship between economic growth, non-renewable energy consumption, and CO_2 emissions in E7 economies. Espoir et al. (2023) revealed that both non-renewable and renewable energy consumption contribute to economic growth in Africa, with non-renewable sources having a higher marginal contribution. Etokakpan et al. (2020) highlighted the positive impact of natural gas consumption and globalization on Malaysia's economic growth. Ivanovski et al. (2021) found a positive impact of both renewable and non-renewable energy consumption on economic growth in 39 economies from 1990 to 2015. Chen et al. (2020) found that only OECD countries showed a positive relationship between renewable energy consumption and economic performance in a global sample of 103 countries from 1990 to 2015. Mukhtarov (2022) reported a positive association between renewable energy consumption and economic growth in OECD countries, with unidirectional causality in both the short and long term.

Zhang et al. (2022) identified an inverted U-shaped relationship between renewable energy consumption and economic growth in a sample of 34 countries from 2007 to 2017, with an optimal point of renewable energy consumption at 58%, beyond which further consumption leads to a slowdown in economic growth.

5.3. Data and Methodology

This study analyzes BRICS economies from 1990 to 2019 using data from World Development Indicators, KOF Swiss Economic Institute, and BP database. It investigates the relationships among renewable and non-renewable energy consumption, economic growth (GDP), and KOF globalization measures. The goal is to estimate three equations to understand the interrelationships and the production equation.

$$GDP_{it} = \alpha_i + \beta_1 NonRen_{it} + \beta_2 NonRen^2{}_{it} + \beta_3 \mathrm{KOFECDFxKOFSODF}_{it} + \beta_4 \mathrm{KOFECDJxKSODJ}_{it} + \beta_5 \mathrm{KOFECDFxKOFPODF}_{it} + \beta_6 \mathrm{KOFECDJxKOFPODJ}_{it} + \beta_7 \mathrm{KOFSODFxKOFPODF}_{it} + \beta_8 \mathrm{KOFSODJxKOFPODJ}_{it} + \mu_{it} \quad (28)$$

$$GDP_{it} = \alpha_i + \beta_1 Ren_{it} + \beta_2 Ren^2{}_{it} + \beta_3 \mathrm{KOFECDFxKOFSODF}_{it} + \beta_4 \mathrm{KOFECDJxKSODJ}_{it} + \beta_5 \mathrm{KOFECDFxKOFPODF}_{it} + \beta_6 \mathrm{KOFECDJxKOFPODJ}_{it} + \beta_7 \mathrm{KOFSODFxKOFPODF}_{it} + \beta_8 \mathrm{KOFSODJxKOFPODJ}_{it} + \mu_{it} \quad (29)$$

$$GDP_{it} = \alpha_i + \beta_1 NonRen_{it} + \beta_2 NonRen^2{}_{it} + \beta_3 Ren_{it} + \beta_4 Ren^2{}_{it} + \beta_5 \mathrm{KOFECDFxKOFSODF}_{it} + \beta_6 \mathrm{KOFECDJxKSODJ}_{it} + \beta_7 \mathrm{KOFECDFxKOFPODF}_{it} + \beta_8 \mathrm{KOFECDJxKOFPODJ}_{it} + \beta_9 \mathrm{KOFSODFxKOFPODF}_{it} + \beta_{10} \mathrm{KOFSODJxKOFPODJ}_{it} + \mu_{it} \quad (30)$$

The variables considered in this study include economic growth (GDP_{it}), consumption of renewable ($\mathrm{Renewable}_{it}$) and non-renewable (NonRen_{it}) energies, renewable² ($\mathrm{Ren}^2{}_{it}$) and non-renewable² ($\mathrm{NonRen}^2{}_{it}$) to capture the non-lienar relationship. Additionally, KOF indicators such as economic de jure ($\mathrm{KOFECDJ}_{it}$) and de facto ($\mathrm{KOFECDF}_{it}$), social de jure ($\mathrm{KOFSODJ}_{it}$) and de facto ($\mathrm{KOFSODF}_{it}$), and political de facto ($\mathrm{KOFPODF}_{it}$) and de jure ($\mathrm{KOFPODJ}_{it}$) are used as measures of economic, social, and political factors. The variables are logged for ease of interpretation.

5.3.1. Diagnostic Tests

To address the issue of interdependence among macroeconomic variables, this study conducts a cross-dependence test using methods suggested by Pesaran (2020) and Frees (1995).

According to De Hoyos and Sarafidis (2006), the null hypothesis CD d $\rightarrow$ N (0, 1) for N $\rightarrow \infty$ and T sufficiently large indicates no cross-dependency. The CD test is particularly useful for dynamic and heterogeneous models and those with angular coefficient and error variations, but it may encounter difficulties when the mean correlation of the sample pair is zero (Altıntaş & Kassouri, 2020). To mitigate this issue, the statistic of the sum of square and equal classification correlation coefficients is calculated to ensure that the results are not affected by this problem.

Heteroscedasticity is a common issue that may arise in panel data analysis, where the variance of the error term is not constant across the observations. To examine the presence of this problem in the residuals of a fixed-effects regression, the Modified Wald Test is applied (Baum, 2001). This test tests the null hypothesis of equal variances ($\theta_i^2 = \theta^2$) for $i = 1, \ldots Ng$, where Ng denotes the number of cross-sectional units.

5.3.2. Stationarity Tests

This study uses two unit-root tests: Maddala and Wu (first-generation) and CIPS (second-generation) to assess variable stationarity.

Like the IPS test, the Maddala and Wu Test estimate an individual regression for each panel unity with Phillips-Perron parameters. The authors compare the p-values obtained from the individual tests for unit-roots in each of the panel's cross-sections (Maddala & Wu, 1999).

The Levin and Lin and IPS unit-root tests rely on the assumption of uncorrelated error terms. However, if this assumption is violated and there is cross-correlation present in the sample, the test statistics may become unreliable as their distributions become unknown (Maddala & Wu, 1999). To address this issue, one possible approach is to utilize the bootstrap method to obtain empirical distributions of the test statistics. By doing so, reliable inferences can be made (Maddala & Wu, 1999).

The proposed test suggests breaking down the $H_0: \rho_i = 0$ into multiple sub-hypotheses ($H_{0i}: \rho_i = 0$), and if any of these sub-hypotheses are rejected, then the entire H_0 is rejected (Maddala & Wu, 1999).

The regular first-generation test may lead to incorrect conclusions in the presence of cross-sectional dependence. To address this problem, CIPS was created by (Pesaran, 2014) by combining two first-generation tests, the Augmented Dickey-Fuller (ADF) and Im-Pesaran-Shin (IPS) (Mudalip et al., 2019). The basic panel stationarity test is established on the simple average of each cross-sectional augmented statistic called CADF (Pesaran, 2007). This statistic can be applied to formulated alternative versions of the t-bar, the P test, and, the inverse normal test, this test is simple and intuitive (Pesaran, 2007). This test is known as CIPS. Due to specific characteristics, such as the null distribution of each CADF, these statistics are asymptotically independent nuisance bounds (Pesaran, 2007). The CIPS statistic is given by:

$$CIPS = \frac{1}{N} \sum_{'=1}^{N} CADF_i \quad (31)$$

The $CADF_i$ statistic will be not cross-sectionally independent, overdue the presence of a common factor. This test has reliable settings and can report for serial correlation (Altıntaş & Kassouri, 2020).

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5.3.3. Westerlund Panel Co-Integration

Westerlund (2007) introduced a novel panel cointegration test that avoids imposing common factor restrictions. This test assesses the null hypothesis of non-cointegration by examining whether the error-correction term in a conditional error-correction model (ECM) is zero. Rejecting this hypothesis indicates the presence of co-integration.

$$\Delta y_{it} = \delta_i' d_t + \alpha_i y_{i,t-1} + \lambda_i' x_{i,t-1} + \sum_{j=1}^{p_i} \alpha_{ij} \Delta y_{i,t-j} + \sum_{j=-q_i}^{p_i} \gamma_{ij} \Delta x_{i,t-j} + e_{it} \quad (32)$$

In which, $\lambda_i' = -\alpha_i \beta_i'$. The parameter α_i determines the rate at which the system adjusts back to the equilibrium relationship $y_{i,t-1} - \beta_i' x_{i,t-1}$ following an abrupt shock. If $\alpha_i < 0$ there is an error-correction, this suggests that the variables are cointegrated, if $\alpha_i = 0$ the error-correction does not exist, so in this scenario, no cointegration. That said, the null hypothesis of no cointegration can be expressed as $H_0: \alpha_i = 0$, but the alternative hypothesis depends on what is being assumed regarding the homogeneity of α_i (Persyn & Westerlund, 2008).

In the case of the two tests known as the group-mean test, there is no assumption of equality for the parameter α. This means that H_0 is tested against the H_1^g which states that $\alpha_i < 0$ for at least one i. The other pair of tests, referred to as panel tests, assume that αi is equal for all i and are thus designed to test the null hypothesis against the alternative hypothesis which states that 0$\alpha_i = \alpha < 0$ for all i (Persyn & Westerlund, 2008).

The tests exhibit favorable properties in small-sample scenarios, including minimal size distortions and higher power compared to other commonly used residual-based panel cointegration tests (Westerlund, 2007).

5.3.4. Autoregressive Distributed Lag

The study utilized the Autoregressive Distributed Lag (ARDL) methodology to obtain the estimates. In cases where a natural ordering of variables exists, such as when one variable in the system is considered the response variable to the others, a single-equation ARDL model can provide a simplified analysis and enable more efficient inference (Kripfganz & Schneider, 2018). The selection of ARDL is justified by its capability to generate reliable outcomes even with a limited sample size, which was the case for this study. Additionally, it is advantageous because it allows for the application of the limit test regardless of whether the explanatory variables are purely integrated of order zero ($I(0)$), purely integrated of order one ($I(1)$), or co-integrated (Narayan & Narayan, 2005).

The ARDL model can be conveniently converted to the Error-Correction (EC) form, which disentangles the long-run association from the short-run dynamics. When the variables are nonstationary, the long-run relationship incorporated in an EC model corresponds to a cointegrating relationship (Kripfganz & Schneider, 2018). In addition, this procedure provides empirical robustness for the short and long-term (Shahbaz et al., 2018). If the variables are co-integrate, estimates made through the ECM below:

$$\Delta y_{it} = \emptyset_i(y_{i,t-1} - \theta'_i X_{it}) + \sum_{j=1}^{p-1} \lambda_{ij}^* \Delta y_{i,t-j} + \sum_{j=0}^{q-1} \delta'^*_{ij} \Delta X_{i,t-j} + \mu_i + \epsilon_{it} \quad (33)$$

in which $\emptyset_i = -(1 - \sum_{j=1}^{p} \lambda_{ij})$, $\theta_i = \sum_{j=0}^{p} \delta_{ij} / (1 - \sum_k \lambda_{ik})$, $\lambda_{ij}^* = -\sum_{m=j+1}^{q} \lambda_{im}$ with $j = 1, 2, \ldots, p-1$, e $\delta'^*_{ij} = \sum_{m=j+1}^{q} \delta_{im}$ com $j = 1, 2, \ldots, q-1$ (Scapelli, 2010).

To address issues related to estimating a static model, it is possible to construct a regression equation that includes lagged values of both the dependent and independent variables. Expanding the model in this manner aims to achieve a dynamically complete model, in which the error term does not exhibit serial correlation (Kripfganz & Schneider, 2018).

To estimate the results in this article a traditional specification from ARDL (p, q_i) is used:

$$y_{it} = \sum_{j=1}^{p} \lambda_{ij} y_{i,j-t} + \sum_{j=0}^{p} \delta_{ij} X_{i,t-j} + \mu_i + \epsilon_{it} \quad (34)$$

Where p is the number of lags of the dependent variable, q is the number of lags from the independent variables,$i = 1, 2, \ldots, N$,$t = 1, 2, \ldots, T$, X_{it} it's a vector $(kx1)$ of independent variables, δ_{ij} it's an unknown vector parameter, λ_{ij} are scalars, μ_i it's the specific term from each sector (Scapelli, 2010). This approach is better for the assumption of this study because of the small number of countries and years in the sample.

The ARDL approach has advantages such as handling variables with and without unit-root without integration order testing. It enables the estimation of short- and long-term coefficients in a single step and allows for statistical inference (Kripfganz & Schneider, 2018). However, it is important to test for cointegration despite these advantages (Kripfganz & Schneider, 2018).

In this study, the Pooled Mean Group (PMG), Mean Group (MG), Fully Modified Ordinary Least Squares (FMOLS), and Dynamic Ordinary Least Squares (DOLS) estimators are employed to estimate the results.

The Mean Group (MG) approach, proposed by Pesaran and Smith (1995), allows for variation in intercepts, coefficients, and error variances across different groups. It obtains panel estimators by calculating the mean of coefficients estimated separately for each cross-section. Although the consistency of these estimators in capturing average long-term coefficients has been demonstrated, their efficiency may be compromised when the coefficients are homogeneous. Panel estimators, being unweighted averages of individual estimators, are sensitive to outliers and shocks in the variable series, which can introduce bias in the estimation process.

The Pooled Mean Group (PMG) estimator, introduced by Pesaran, Shin, and Smith (1999), strikes a balance between estimating separate equations for each group and using traditional fixed and random effects estimators. It allows for different intercepts, short-run coefficients, and error variances across groups while imposing constraints on the long-run coefficients to be identical. Of particular interest is the mean of the estimates, known as the Mean Group (MG).

The PMG estimator enables the estimation of a common long-run coefficient without assuming identical dynamics across countries. This approach avoids the unrealistic assumption of uniform dynamics among all countries (Pesaran et al., 1999).

The long-run coefficients, and the group-specific error-correction coefficients, can be estimated through Maximum Likelihood (ML). The Maximum Likelihood Estimators (MLEs) obtained from this estimation approach are commonly referred to as PMG estimators. The term "pooled" signifies the pooling of information across groups, as the long-run coefficients are assumed to be homogeneous. Moreover, the PMG estimators involve calculating the mean values of the estimated error-correction coefficients and other short-run parameters across the groups in the analysis (Pesaran et al., 1999). The standard PMG functional specification is a frequently employed method for representing the long-run relationship between variables and can be expressed as follows:

$$\Delta y_{it} = \emptyset_i + \sum_{k=1}^{p} \gamma_{ij}\, \Delta y_{i,t-j} + \sum_{k=0}^{q} \mu_{ij}\, \Delta x_{i,t-j} + \delta_{1ij} y_{i,t-j} + \delta_{2ij} x_{i,t-j} + \varepsilon_{it} \quad (35)$$

In which, $\delta_{1ij} = -(1 - \sum_{j=1}^{q} \lambda_{ij})$; $\delta_{2ij} = \sum_{j=o}^{q} \omega_{ij}$; $\gamma_{ij} = -\sum_{m=j+1}^{p} \lambda_{im}$, $i = 1, \dots, N$ is the cross-section unit, $t = 1, \dots, T$ represents the period (time), ω_{ij} and λ_{ij} represent the vectors for the independent variables. The aforementioned model also indicates the presence of cointegration between the variables through δ_1 and δ_2. Accordingly, the null hypothesis of no cointegration between the variables is $H_0\colon \delta_{1i} = \delta_{2i} = 0$, while the alternative hypothesis is $H_1\colon \delta_{1i} \neq \delta_{2i} \neq 0$ (Bildirici, 2014).

The central objective of the FMOLS approach, as proposed by Pedroni (1996), is to concentrate solely on the information relevant to the long-run hypothesis of interest, while accommodating the potential heterogeneity of short-run dynamics (Pedroni, 2000). The FMOLS estimator is obtained by applying adjustments to the OLS estimator to address endogeneity and serial correlation (Kao & Chiang, 2000).

The PMG approach is commonly used in economic studies due to empirical evidence supporting similar long-term equilibrium relationships across different groups. In contrast, the MG approach assumes heterogeneity in these relationships. The FMOLS and DOLS methodologies, adapted from time series theory, correct for endogeneity and serial correlation of the regressors and yield better results than OLS (Kao & Chiang, 2000).

DOLS is a parametric panel estimator, proposed by Kao and Chiang (1997) that aggregates observations within the within-dimension, and it has been shown to possess an asymptotic distribution equivalent to that of the panel FMOLS estimator (Pedroni, 2001). An important advantage of the estimators based on the between-dimension approach is their ability to accommodate greater flexibility in the presence of heterogeneity in the cointegrating vectors, owing to the pooling of data in a particular form (Pedroni, 2001). In particular, whereas the test statistics based on the within-dimension estimators are intended to test the null hypothesis $H_0: \beta_1 = \beta_0$ for all individuals against the alternative hypothesis $H_1: \beta_i = \beta_A \neq \beta_0$, in which the value β_A is identical for all individuals (Pedroni, 2001). The tests developed for the between-dimension approach are designed to test the same null hypothesis as the within-dimension, but a different alternative hypothesis $H_1: \beta_i \neq \beta_0$, allowing for the possibility that the values of beta i are not constrained to be the same under the alternative hypothesis (Pedroni, 2001).

Using estimators based on the between-dimension approach offers an additional advantage by providing more informative interpretations of point estimates, particularly when the actual cointegrating vectors display heterogeneity (Pedroni, 2001).

The estimator for the panel FMOLS in the between-dimension approach, utilizing group means, can be expressed as follows:

$$\hat{\beta}^*_{GFM} = N^{-1} \sum_{i=1}^{N} \left(\sum_{t=1}^{T} (p_{it} - \bar{p}_i)^2 \right)^{-1} \cdot \left(\sum_{t=1}^{T} (p_{it} - \bar{p}_i) s^*_{it} - T\hat{\gamma}_i \right) \quad (36)$$

The group-mean panel estimator DOLS can be described as follows:

$$\hat{\beta}^*_{GD} = \left[N^{-1} \sum_{i=1}^{N} \left(\sum_{t=1}^{T} z_{it} z'_{it} \right)^{-1} \left(\sum_{t=1}^{T} z_{it} \tilde{s}_{it} \right) \right] \quad (37)$$

5.3.5. Causality Test

This test provides the ability to account for both dimensions of heterogeneity observed in the data, specifically the heterogeneity of causal relationships and the heterogeneity of the regression model. Its purpose is to test for Granger causality within this framework (Dumitrescu & Hurlin, 2012).

The extension proposed by Dumitrescu and Hurlin (2012) is designed to detect causality in panel data, based on the original framework proposed by Granger (1969). The underlying regression equation is as follows:

$$y_{i,t} = \alpha_i + \sum_{k=1}^{K} \gamma_{ik} y_{i,t-k} + \sum_{k=1}^{K} \beta_{ik} x_{i,t-k} + \varepsilon_{it}, with\ i = 1, \dots, N, and\ t = 1, \dots, T \quad (38)$$

$x_{i,t}$ and $y_{i,t}$ for each i in period t. The coefficients in the equation are permitted to differ across individuals (indicated by the i subscripts) but are assumed to be time-invariant. The lag order K is assumed to be uniform for all individuals, and the panel data must be balanced, meaning that there there are no missing observations for any individual throughout the entire.

The DH test examines the presence of causality by evaluating the significant effects of past values of variable x on the current value of variable y. Hence, the null hypothesis can be formulated as follows: $H_0: \beta_{i1} = \cdots = \beta_{ik} = 0 \quad \forall_i = 1, \ldots, N$ (Lopez & Weber, 2017). This corresponds to no causality across all individuals in the panel. The DH test assumes that there may be causality for some individuals but not necessarily for all. Therefore, the alternative hypothesis is expressed as: $H_1: \beta_{i1} = \cdots = \beta_{ik} = 0 \ \forall_i = 1, \ldots, N_1;\ \beta_{i1} \neq 0 \ or \ldots or \ \neq \beta_{ik} = 0 \ \ \forall_i = N_1 + 1, \ldots, N$ (Lopez & Weber, 2017).

5.4. Results and Discussions

5.4.1 Results

The Wooldridge test for autocorrelation in panel data is conducted to examine the absence of autocorrelation in the sample. The test results, at a 1% confidence level, do not provide sufficient evidence to reject the null hypothesis, indicating no presence of autocorrelation. Additionally, the Modified Wald test for heteroscedasticity suggests that the sample does not exhibit a constant variance, with the null hypothesis not being rejected at a 1% confidence level. Cross-sectional independence tests, including the Pesaran, Frees, and Friedman tests, are employed to assess the relationship between the error terms. The test results in Table 5.1 present mixed findings, with the Friedman and Frees tests suggesting the existence of cross-sectional dependence, while the Pesaran test indicates the opposite, supporting cross-sectional independence.

Table 5.1 – Diagnostic Test

Tests	Fixed Effects	Random Effects
Pesaran's test of cross-sectional independence	-2.103	2.118***
Frees' test of cross-sectional independence	0.728*	0.422*
Friedman's test of cross-sectional independence	14.347***	31.679***
Average absolute value of the off-diagonal elements	0.359	0.301
Modified Wald test for groupwise heteroskedasticity	22.24***	
Wooldridge test for autocorrelation in panel data	41.823***	

Note: *** means statistically significant at 1%, 5%, and 10%, respectively

After analyzing cross-sectional dependence, we check for the existence of unit-roots using the Mandala and Wu test and the CIPS test. However, the presence of cross-sectional dependence may make the Mandalla and Wu test unreliable, so we also use the CIPS test. We find that, with mixed results, we cannot conclude the stationarity of the variables due to this. Table 5.2 provides the results of the unit-root tests.

Table 5.2 – Unit-Root Tests

	1st Generation Unit-Root		2nd Generation Unit-Root	
Level	Without-Trend	With-Trend	Without-Trend	With-Trend
GDP	13.041	16.464*	-1.043	0.705
Renewable	19.164**	10.740	-2.834***	2.711
Non-Renewable	13.395	3.891	-1.532*	1.278
KOFECDF	28.559***	2.421	-0.942	0.215
KOFECDJ	27.451***	17.889**	-2.683***	-2.853***
KOFSODF	4.593	0.686	-2.333***	-1.380*
KOFSODJ	40.107***	1.727	-0.535	0.776
KOFPODF	11.168	8.613	-0.921	1.768
KOFPODJ	147.629***	59.293***	-7.222***	-7.708***
1st Difference	Without-Trend	With-Trend	Without-Trend	With-Trend
GDP	5.854	14.097	-4.704***	-4.036***
Renewable	19.870**	8.836	-2.824***	3.138
Non-Renewable	15.287	9.930	-2.673***	0.368
KOFECDF	23.548***	4.928	-0.694	-0.301
KOFECDJ	17.101*	4.286	-1.083	-1.453*
KOFSODF	7.128	1.081	-2.472***	--1.741**
KOFSODJ	15.280	3.940	-1.643**	-0.800
KOFPODF	19.258**	12.712	-0.095	2.191
KOFPODJ	100.320***	34.307***	-2.612***	-3.929***

Note: *** means statistically significant at 1%, 5%, and 10%, respectively

Co-integration tests were used to verify the presence of a long-term equilibrium relationship between variables. The Westerlund panel co-integration test was chosen due to cross-sectional dependence. Results in Table 5.3 indicate rejection of the null hypothesis at a 1% significance level. In summary, strong evidence of co-integration was found, confirming a long-term equilibrium relationship among the examined variables.

Table 5.3 – Westerlund ECM Panel Cointegration

Westerlund Tests	Co-integration Tests	
	Value	P-Value
Gt	-2.609	0.597
Ga	-7.969	0.982
Pt	-4.442	0.871
Pa	-6.391	0.955
Variance Ratio		
	Value	P-Value
Gt	-1.268	1.000
Ga	-4.640	1.000

Pt	-1.924	1.000
Pa	-3.422	0.999

Table 5.4 and 5.5 shows results from PMG, MG, FMOLS and DOLS techniques. MG allows heterogeneity in intercepts, coefficients, and error variances. PMG accommodates variations in error variances, short-term coefficients, and intercepts while maintaining uniformity in long-term coefficients. The FMOLS and DOLS estimations approaches are renowned for providing more robust results compared to OLS. Table 15 displays the outcomes of the equation 3.

Table 5.4 – PMG, MG, FMOLS and DOLS Estimations

Equation 1					Equation 2				
Variables	PMG	MG	FMOLS	DOLS	Variables	PMG	MG	FMOLS	DOLS
Short-Run					Short-Run				
Non-Renewable	1.123714**	0.8736854	0.84***	0.8	Renewable	-5.027657	0.2561648***	0.14***	0.04
Non-Renewable^2			-0.68	-2.59	Renewable^2			-0.65**	-2.53
KOFECDFxKOFSODF	-7.211516	-0.4625135	0.12***	-0.04	KOFECDFxKOFSODF	56.2205	-0.0849553	0.3***	0.66
KOFECDJxKOFSODJ	6.08916	-0.2473809	0.49**	1.98	KOFECDJxKOFSODJ	26.43525	0.7528385	0.41***	2.61
KOFECDFxKOFPODF	0.3233991	1.486437	-0.12***	0.43	KOFECDFxKOFPODF	318.77***	-1.455503**	-0.3***	-0.37
KOFECDJxKOFPODJ	-3.923421	0.9902525	0.83***	3.09	KOFECDJxKOFPODJ	180.4944**	-1.852158	0.99***	4.1
KOFSODFxKOFPODF	5.5121	0.4459506	0.49***	-0.09	KOFSODFxKOFPODF	-85.0533	0.3040865	0.15***	-1.25
KOFSODJxKOFPODJ	1.920029	-0.3193675	15.2***	0	KOFSODJxKOFPODJ	-337.0236	1.383184	20.36***	0
Long-Run					Long-Run				
ECT	0.0014328	- 0.228201***			ECT	- 0.000238***	-0.2877859*		
Non-Renewable	(omitted)	(omitted)	0.25***	0.49	Renewable	(omitted)	(omitted)	0.03***	0.05
Non-Renewable^2	0.1190975**	0.1837852*	0.3***	0.1	Renewable^2	0.0001214	0.0198239	0.34	0.14
KOFECDFxKOFSODF	0.1409697*	0.004116	-0.15***	-0.22	KOFECDFxKOFSODF	0.1346663***	0.0979443	-0.18***	-0.24
KOFECDJxKOFSODJ	-0.0784035	-0.0361349	-0.37***	-0.37	KOFECDJxKOFSODJ	-0.019206	-0.0570925	-0.43***	-0.15
KOFECDFxKOFPODF	-0.1589035	-0.0117523	0.09**	0.23	KOFECDFxKOFPODF	-0.1501785	-0.1340192	0.12***	-0.15
KOFECDJxKOFPODJ	0.0667826	0.0507838	-0.09	-0.09	KOFECDJxKOFPODJ	0.0527172	0.0801695	-0.08	0.23
KOFSODFxKOFPODF			0.09***	0.31	KOFSODFxKOFPODF			0.1***	0.36
KOFSODJxKOPODJ	0.0105997	0.0420253	0.04***	0.04	KOFSODJxKOPODJ	-0.0221757	-0.0236681	0.03***	0.03
Constant	0.037693***	4.232396			Constant	-0.239289***	10.74109*		

Note: *** means statistically significant at 1%, 5%, and 10%, respectively.

The PMG estimation in equation 1 reveals that, in the short term, only renewable energy consumption is statistically significant. A 1% increase in renewable energy consumption corresponds to approximately a 1.2% GDP growth, holding other factors constant. The variable "Non-Renewable^2" also shows significance, indicating a non-linear relationship between GDP and renewable energy consumption. The interaction term "KOFECDFxKOFSODF" is also significant, capturing the combined effect of KOF

Economic de facto and KOF Social de facto. However, in the long term, equation 1 lacks statistical significance, as the ECT statistic is not negatively and significantly associated. Nonetheless, the MG estimates demonstrate a long-term relationship, showing a non-linear "U" shape pattern between economic growth and non-renewable energy consumption. Initially, as the economy expands, non-renewable energy consumption decreases up to a certain threshold, beyond which the relationship becomes positive. These findings highlight the short-term significance of renewable energy consumption for economic growth. However, in the long term, the non-linear relationship between economic growth and non-renewable energy consumption suggests the importance of considering environmental impacts and recognizing the limits of expanding the economy without sustainable practices.

The FMOLS estimates reveal a positive short-term relationship between non-renewable energy consumption and economic growth. A 1% increase in consumption is associated with an expected 0.84% growth in GDP, assuming other variables remain constant. However, the non-linear relationship is not statistically significant. In terms of the KOF indicators' cross-effects, all except KOFECDFxKOFPODF show statistical significance and a positive relationship with short-term economic growth. In the long term, both the linear and non-linear relationships are statistically significant, but there is no evidence of an inverted "U" relationship.

In the long-term relationship, the significance and coefficient signs of the cross-effects of the KOF indicators undergo changes. KOFECDFxKOFPODF, KOFSODFxKOFPODF, and KOFSODJxKOPODJ show positive coefficients, indicating a positive impact on economic growth. Conversely, KOFECDFxKOFSODF and KOFECDJxKOFSODJ exhibit negative coefficients, suggesting a negative impact on economic growth.

The PMG estimation results in equation 2 indicate that, in the short term, only KOFECDFxKOFPODF and KOFECDJxKOFPODJ exhibit statistical significance with a positive effect on economic growth. The significant and negative ECT statistic suggests the presence of a long-term relationship. Among the variables of interest, only KOFECDFxKOFSODF is statistically significant and positively associated with economic growth. The MG approach reinforces the importance of "Renewables" in driving short-term economic growth. The significant and negative cross-effect of KOFECDFxKOFPODF implies a detrimental impact on economic growth. However, none of the variables of interest are statistically significant in the long term.

FMOLS estimates show a positive short-term relationship between renewable energy consumption and economic growth. A 1% increase in renewable energy consumption is associated with a 0.14% GDP growth, while maintaining other variables constant. In the short term, a significant inverted "U" relationship exists between renewable energy consumption and economic growth. Increasing renewable energy consumption initially boosts GDP, but beyond a certain threshold, it reverses and hampers economic growth. All cross-effects demonstrate statistical significance and positive coefficients, except for KOFECDFxKOFPODF, which exhibits a negative coefficient. In the long run, renewable energy consumption continues to contribute to economic growth, but the non-linear relationship lacks statistical significance. Among the cross-effects, KOFECDFxKOFSODF and KOFECDJxKOFSODJ negatively impact economic growth, while KOFECDFxKOFPODF, KOFSODFxKOFPODF, and KOFSODJxKOPODJ have a positive influence.

Equation 1 highlights the intricate relationship between non-renewable energy consumption, KOF indicators, and economic growth. Non-renewable energy consumption exhibits a positive link with short-term economic growth. Equation 2 findings indicate the substantial influence of KOFECDFxKOFPODF and KOFECDFxKOFSODF variables on both short-term and long-term economic growth, with the "Renewables" variable contributing to short-term growth. However, further investigation is required to comprehend the dynamics and significance of other variables in the long-term relationship.

Table 5.5 – PMG, MG, FMOLS and DOLS Estimations

Equation 3				
Variables	PMG	MG	FMOLS	DOLS
Short-Run				
Non-Renewable	74.03963	0.1123231		
Non-Renewable^2			0.11***	0.82
Renewable	-11.2108	0.0677931		
Renewable^2			0.01***	-0.17
KOFECDFxKOFSODF	255.897	-2.393119	0.34***	-1.48
KOFECDJxKOFSODJ	-85.30876	-0.8517488	-0.16***	1.63
KOFECDFxKOFPODF	1163.27	3.377192	-0.41***	1.22
KOFECDJxKOFPODJ	657.6277	1.676435	0.1***	-1.63
KOFSODFxKOFPODF	-418.9965	2.443964	-0.12	0.97
KOFSODJxKOFPODJ	-1114.765	-0.2307147	0.07***	1.82
Long-Run				
ECT	-0.000061***	-0.3001577*		
Non-Renewable	(omitted)	(omitted)		
Non-Renewable^2	0.1020991*	0.1189532	0.28***	0.32
Renewable	(omitted)	(omitted)		
Renewable^2	-0.0024201	0.0180706	0.04***	-0.05
KOFECDFxKOFSODF	0.1280245**	0.0472051	-0.36***	0.11
KOFECDJxKOFSODJ	-0.0365932	0.030621	0.28***	0.04
KOFECDFxKOFPODF	-0.1237196	-0.0875518	0.23***	-0.1
KOFECDJxKOFPODJ	0.0662804*	0.006462	-0.23***	0.13
KOFSODFxKOFPODF			0.58**	0.08
KOFSODJxKOFPODJ	-0.0373108	0.0463687	0.14***	0.28
Constant	-0.178824***	9.543488*		

Note: *** means statistically significant at 1%, 5%, and 10%, respectively

Table 5.5 presents estimates for Equation 3, examining the impact of renewable and non-renewable energy consumption on economic growth. The PMG results show no short-term statistical significance. However, in the long term, a significant non-linear relationship emerges for non-renewable energy consumption, following a positive "U" shape pattern. This implies that reducing non-renewable energy consumption contributes to economic growth up to a certain threshold. Optimal non-renewable energy consumption levels are associated with enhanced economic growth, all else being equal. Additionally, the cross-effects of KOFECDFxKOFSODF and KOFECDJxKOFPODJ positively affect economic growth.

To verify the robustness of the cointegration results, the Dumitrescu-Hurlin causality test (2012) was used as an alternative causality test. This test examines the causal relationship between variables in a different manner. The test results, shown in Table 5.6, help determine whether there is Granger-causality, indicating a causal relationship between the variables.

Table 5.6 – Dumitrescu-Hurlin Causality Test Results

Causality	W-Bar	T-Bar	T-bar Tilde	Causality	W-Bar	T-Bar	T-bar Tilde	Causality	W-Bar	T-Bar	T-bar Tilde
GDP-Renewable	10.068	14.3378***	12.3013***	Renewable-GDP	4.1339	4.9551***	4.1766***	Non-Renewable-GDP	4.1943	5.0506***	4.2594***
GDP-Non-Renewable	13.4479	19.6819***	16.9289***	Renewable-Non-Renewable	3.9037	4.5911***	3.8615***	Non-Renewable-Renewable	2.6434	2.5984***	2.1359**
GDP-KOFECDFxKOFSODF	13.9614	20.4938***	17.6320***	Renewable-KOFECDFxKOFSODF	2.3296	2.1023**	1.7063*	Non-Renewable-KOFECDFxKOFSODF	5.5935	7.2630***	6.1751***
GDP-KOFECDJxKOFSODJ	8.9981	12.6460***	10.8364***	Renewable-KOFECDJxKOFSODJ	1.0747	0.1181	-0.0119	Non-Renewable-KOFECDJxKOFSODJ	5.5754	7.2343***	6.1503***
GDP-KOFECDFxKOFPODF	18.3341	27.4075***	23.6187***	Renewable-KOFECDFxKOFPODF	1.6729	1.064	0.8072	Non-Renewable-KOFECDFxKOFPODF	5.828	7.6337***	6.4961***
GDP-KOFECDJxKOFPODJ	8.8562	12.4217***	10.6421***	Renewable-KOFECDJxKOFPODJ	0.9198	-0.1268	-0.2239	Non-Renewable-KOFECDJxKOFPODJ	4.1182	4.9304***	4.1552***
GDP-KOFSODFxKOFPODF	8.3486	11.6191***	9.9472***	Renewable-KOFSODFxKOFPODF	1.7719	1.2205	0.9428	Non-Renewable-KOFSODFxKOFPODF	4.8491	6.0860***	5.1559***
GDP-KOFSODJxKOFPODJ	9.1982	12.9625***	11.1105***	Renewable-KOFSODJxKOFPODJ	0.6258	-0.5916	-0.6264	Non-Renewable-KOFSODJxKOFPODJ	3.2629	3.5780***	2.9842***
Causality	W-Bar	T-Bar	T-bar Tilde	Causality	W-Bar	T-Bar	T-bar Tilde	Causality	W-Bar	T-Bar	T-bar Tilde
KOFECDFxKOFSODF-GDP	2.1756	1.8588*	1.4955	KOFECDJxKOFSODJ-GDP	2.7656	2.7917***	2.3033**	KOFECDFxKOFPODF-GDP	1.7101	1.1228	0.8582
KOFECDFxKOFSODF-Non-Renewable	5.6848	7.4073***	6.3001***	KOFECDJxKOFSODJ-Non-Renewable	1.6562	1.0375	0.7843	KOFECDFxKOFPODF-Non-Renewable	4.4676	5.4828***	4.6336***
KOFECDFxKOFSODF-Renewable	2.7139	2.71***	2.2325***	KOFECDJxKOFSODJ-Renewable	3.4315	3.8446***	3.2150***	KOFECDFxKOFPODF-Renewable	1.9022	1.4265	1.1212
KOFECDFxKOFSODF-KOFECDJxKOFSODJ	7.2998	9.9609***	8.5113***	KOFECDJxKOFSODJ-KOFECDFxKOFSODF	1.4428	0.7002	0.4922	KOFECDFxKOFPODF-KOFECDFxKOFSODF	1.7139	1.1288	0.8634
KOFECDFxKOFSODF-KOFECDFxKOFPODF	3.2613	3.5754***	2.9819***	KOFECDJxKOFSODJ-KOFECDFxKOFPODF	0.3711	-0.9944	-0.9751	KOFECDFxKOFPODF-KOFECDJxKOFPODJ	7.2983	9.9585***	8.5092***
KOFECDFxKOFSODF-KOFECDJxKOFPODJ	9.3816	13.2524***	11.3615***	KOFECDJxKOFSODJ-KOFECDJxKOFPODJ	4.8376	6.0678***	5.1401***	KOFECDFxKOFPODF-KOFECDJxKOFPODJ	7.9728	11.0250***	9.4327***
KOFECDFxKOFSODF-KOFSODFxKOFPODF	3.6086	4.1246***	3.4575***	KOFECDJxKOFSODJ-KOFSODFxKOFPODF	3.4358	3.8513***	3.2208**	KOFECDFxKOFPODF-KOFSODFxKOFPODF	0.8793	-0.1909	-0.2794
KOFECDFxKOFSODF-KOFSODJxKOFPODJ	11.4299	16.4911***	14.1659***	KOFECDJxKOFSODJ-KOFSODJxKOFPODJ	4.052	4.8256***	4.0645***	KOFECDJxKOFSODJ-KOFSODJxKOFPODJ	5.0842	6.4577***	5.4778***

Causality	W-Bar	T-Bar	T-bar Tilde	Causality	W-Bar	T-Bar	T-bar Tilde	Causality	W-Bar	T-Bar	T-bar Tilde
KOFECDJxKOFSODJ-GDP	1.2677	0.4233	0.2524	KOFSODFxKOFPODF-GDP	0.4975	-0.7945	-0.8021	KOFSODJxKOFPODJ-GDP	3.0386	3.2233***	2.6770***
KOFECDJxKOFSODJ-Renewable	1.8936	1.413	1.1094	KOFSODFxKOFPODF-Renewable	4.5193	5.5645***	4.7043***	KOFSODJxKOFPODJ-Renewable	0.7485	-0.3977	-0.4585
KOFECDJxKOFSODJ-Non-Renewable	0.8733	-0.2003	-0.2875	KOFSODFxKOFPODF-Non-Renewable	0.5939	-0.642	-0.6701	KOFSODJxKOFPODJ-Non-Renewable	1.7859	1.2427	0.962
KOFECDJxKOFSODJ-KOFECDJxKOFPODJ	1.3741	0.5915	0.3981	KOFSODFxKOFPODF-KOFECDFxKOFSODF	4.7463	5.9234***	5.0151***	KOFSODJxKOFPODJ-KOFECDFxKOFSODF	1.6975	1.1029	0.8409
KOFECDJxKOFSODJ-KOFECDJxKOFSODJ	2.8116	2.8645***	2.3663***	KOFSODFxKOFPODF-KOFECDJxKOFSODJ	7.2393	9.8651***	8.4283***	KOFSODJxKOFPODJ-KOECDJxKOFSODJ	2.6223	2.5651***	2.1071**
KOFECDJxKOFSODJ-KOFECDFxKOFPODF	1.1714	0.271	0.1205	KOFSODFxKOFPODF-KOFECDFxKOFPODF	4.851	6.089***	5.1585***	KOFSODJxKOFPODJ-KOECDFxKOFPODF	1.1078	0.1704	0.0335
KOFECDJxKOFSODJ-KOFSODFxKOFPODF	1.5469	0.8648	0.6348	KOFSODFxKOFPODF-KOFECDJxKOFPODJ	7.8157	10.7765***	9.2175***	KOFSODJxKOFPODJ-KOECDJxKOFSPODJ	2.0964	1.7336*	1.387
KOFECDJxKOFSODJ-KOFSODJxKOFPODJ	1.3064	0.4845	0.3054	KOFSODFxKOFPODF-KOFSODJxKOFPODJ	9.2962	13.1175***	11.2446***	KOFSODJxKOFPODJ-KOFECDJxKOFPODJ	2.5114	2.3897***	1.9552**

Note: *** means statistically significant at 1%, 5%, and 10%, respectively

The causal analysis reveals that renewable energy consumption has causal relationships with all cross-effects, except KOFECDFxKOFSODF. Two cross-effects, KOFECDFxKOFPODF and KOFSODJxKOPODJ, exhibit bidirectional causality. Additionally, there is a unidirectional causal relationship from KOFECDJxKOFSODJ towards renewable energy consumption. Non-renewable energy consumption only shows a causal relationship towards renewable energy consumption. In terms of cross-effects with GDP, KOFECDFxKOFSODF has a unidirectional causal relationship with GDP, indicating direct effects on economic growth. Similarly, KOECDFxKOFPODF, KOFECDJxKOFSODJ, and KOFSODFxKOFPODF also exhibit causal relationships with GDP.

5.4.2. Discussions

The findings suggest that energy consumption plays a crucial role in the economic growth of the BRICS countries. However, the causality test does not establish a direct causal link from energy consumption to GDP, so it does not support the "growth hypothesis" defined by Ã et al. (2010). Nonetheless, the positive association between GDP and both renewable and non-renewable energy consumption is well-documented in the literature (Acheampong et al., 2021; Androniceanu & Georgescu, 2023; Chen et al., 2020; Chica-Olmo et al., 2020; Dimitriadis et al., 2021; Etokakpan et al., 2020; Iqbal et al., 2023; Ivanovski et al., 2021; Mukhtarov, 2022; Santiago et al., 2020; Shahbaz et al., 2020).

The analysis reveals a U-shaped non-linear relationship between economic growth and renewable and non-renewable energy consumption. Initially, economic growth continues even with decreased energy consumption, but beyond a certain point, increased energy consumption becomes necessary to sustain growth. This finding aligns with the absence of observed causality, indicating a neutral relationship between energy consumption and economic growth in the studied sample. Limited research has explored this non-linear relationship, and notably, our findings for renewable energy consumption differ from those reported by Zhang et al. (2022).

The literature on the relationship between KOF Globalization indicators and economic growth yields diverse findings. This study aims to investigate the simultaneous impact and complex dynamics of these indicators on the economy, considering their characteristics, socio-cultural aspects, and policy implementations. The cross-effects of these indicators present mixed results, highlighting the need for thorough examination. Notable findings include a positive short-term and negative long-term relationship for KOFECDFxKOFSODF and KOFECDJxKOFSODJ. This suggests that initial increased interaction with the global market brings positive outcomes, but over time, it can lead to small business closures, unemployment, and a "brain drain" effect. Conversely, the opposite signs observed for KOFECDFxKOFPODF indicate that certain political-economic decisions initially impede growth but yield positive returns in the long run, for example a fiscal readjustments. Other cross-relationships contribute to both short-term and long-term GDP growth, indicating overall economic benefits brought by globalization.

5.5. Conclusions

This study examines the impact of renewable and non-renewable energy consumption on economic growth, as well as the interactions between KOF Globalization measures (economic, social, and political dimensions) in the BRICS countries. The estimators reveal a positive relationship between energy consumption (renewable and non-renewable) and economic growth, indicating the reliance of these countries on energy consumption for promoting and sustaining economic development. Interestingly, the relationship exhibits a "U-shaped" pattern, implying that as economic activity increases, the consumption of both renewable and non-renewable energies declines. This underscores the need for continuous investment and supportive policies, particularly in renewable energy, to mitigate potential environmental degradation in the long run.

Furthermore, the findings support the existing literature by indicating a positive correlation between globalization and economic growth. Specifically, the KOF Globalization Index, particularly its economic dimensions, demonstrates a significant association with economic growth. This highlights the importance of considering legal frameworks, regulations, and international interactions when analyzing the impact of globalization on various aspects of society and the economy.

However, it is important to acknowledge the limitations of using an index as the analytical tool. While indices are commonly employed in academia, they may not fully capture the intricate and multifaceted nature of real-world situations. Additionally, the sampling period of the study may be deemed insufficient for rigorous long-term statistical inference, which could explain the disparities compared to previous investigations, especially when institutional metrics were modified.

To formulate effective public policies that foster economic growth, enhance human development, and improve overall quality of life, a thorough understanding of the KOF Globalization Index metric is essential. Future research should consider conducting individual country analyses to account for the substantial economic, social, and cultural differences among nations. This approach enables a nuanced understanding of the specific dynamics at play within each country, enhancing the validity and reliability of the findings while avoiding generalizations that may overlook country-specific factors. Additionally, exploring the interplay between the KOF index and economic development, as well as its contribution to social development, is recommended. Replicating the study across other country cohorts would provide valuable insights, as the outcomes obtained are specific to the social and economic framework of the BRICS nations.

By accumulating empirical evidence through rigorous research, policymakers can make informed decisions to pursue sustainable economic growth and improve the overall quality of life for their respective populations.

References

Ã, I. O., Abdoli, G., Farahani, Y. G., Abosedra, S., Dah, A., Ghosh, S., Ahmed, M., Azam, M., Akadiri, S., Bekun, F. V., Taheri, E., Akadiri, A., Akinlo, A. E., Ameyaw, B., Oppong, A., Abruquah, L. A., Ashalley, E., Apergis, N., Payne, J. E., … Andrews, D. W. K. (2010). A literature survey on energy – growth nexus. Energy Policy, 38(1), 340–349. https://doi.org/10.1016/j.enpol.2009.09.024

Acheampong, A. O., Boateng, E., Amponsah, M., & Dzator, J. (2021). Revisiting the economic growth–energy consumption nexus: Does globalization matter? Energy Economics, 102(December 2020), 105472. https://doi.org/10.1016/j.eneco.2021.105472

Altıntaş, H., & Kassouri, Y. (2020). Is the environmental Kuznets Curve in Europe related to the per-capita ecological footprint or CO2 emissions? Ecological Indicators, 113(September 2019). https://doi.org/10.1016/j.ecolind.2020.106187

Androniceanu, A., & Georgescu, I. (2023). The Impact of CO2 Emissions and Energy Consumption on Economic Growth: A Panel Data Analysis. Energies, 16(3), 1–17. https://doi.org/10.3390/en16031342

Baum, C. F. (2001). Residual Diagnostics for Cross-section Time Series Regression Models. The Stata Journal: Promoting Communications on Statistics and Stata, 1(1), 101–104. https://doi.org/10.1177/1536867x0100100108

Bildirici, M. E. (2014). Relationship between biomass energy and economic growth in transition countries : panel ARDL approach. Global Change Biology Bioenergy, 6, 717–726. https://doi.org/10.1111/gcbb.12092

Chen, C., Pinar, M., & Stengos, T. (2020). Renewable energy consumption and economic growth nexus: Evidence from a threshold model. Energy Policy, 139(January), 111295. https://doi.org/10.1016/j.enpol.2020.111295

Chica-Olmo, J., Salaheddine, S. H., & Moya-Fernández, P. (2020). Spatial relationship between economic growth and renewable energy consumption in 26 European countries. Energy Economics, 92. https://doi.org/10.1016/j.eneco.2020.104962

De Hoyos, R. E., & Sarafidis, V. (2006). Testing for cross-sectional dependence in panel-data models. Stata Journal, 6(4), 482–496. https://doi.org/10.1177/1536867x0600600403

Dimitriadis, D., Katrakilidis, C., & Karakotsios, A. (2021). Investigating the dynamic linkages among carbon dioxide emissions, economic growth, and renewable and non-renewable energy consumption: evidence from developing countries. Environmental Science and Pollution Research, 28(30), 40917–40928. https://doi.org/10.1007/s11356-021-13613-2

Dreher, A. (2006). Does globalization affect growth? Evidence from a new index of globalization. Applied Economics, 38(10), 1091–1110. https://doi.org/10.1080/00036840500392078

Dumitrescu, E., & Hurlin, C. (2012). Testing for Granger non-causality in heterogeneous panels. Economic Modelling, 29(4), 1450–1460. https://doi.org/10.1016/j.econmod.2012.02.014

Ehigiamusoe, K. U. (2022). A disaggregated approach to analysing the effects of globalization and energy consumption on economic growth: New insights from low-income countries. International Journal of Finance and Economics, March, 1–21. https://doi.org/10.1002/ijfe.2631

Espoir, D. K., Sunge, R., & Bannor, F. (2023). Economic growth, renewable and nonrenewable electricity consumption: Fresh evidence from a panel sample of African countries. Energy Nexus, 9(June 2022), 100165. https://doi.org/10.1016/j.nexus.2022.100165

Etokakpan, M. U., Solarin, S. A., Yorucu, V., Bekun, F. V., & Sarkodie, S. A. (2020). Modeling natural gas consumption, capital formation, globalization, CO2 emissions and economic growth nexus in Malaysia: Fresh evidence from combined cointegration and causality analysis. Energy Strategy Reviews, 31, 100526. https://doi.org/10.1016/j.esr.2020.100526

Frees, E. W. (1995). Assessing cross-sectional correlation in panel data. Journal of Econometrics, 69(2), 393–414. https://doi.org/10.1016/0304-4076(94)01658-M

Gasimli, O., Haq, I. ul, Munir, S., Khalid, M. H., Gamage, S. K. N., Khan, A., & Ishtiaq, M. (2022). Globalization and Sustainable Development: Empirical Evidence from CIS Countries. Sustainability (Switzerland), 14(22), 1–15. https://doi.org/10.3390/su142214684

Granger, C. W. J. (1969). Methods, Investigating Causal Relations by Econometric Models and Cross-spectral. Econometrica, 37(3), 424–438.

Gyamfi, B. A., Bein, M. A., & Bekun, F. V. (2020). Investigating the nexus between hydroelectricity energy, renewable energy, nonrenewable energy consumption on output: evidence from E7 countries. Environmental Science and Pollution Research, 27(20), 25327–25339. https://doi.org/10.1007/s11356-020-08909-8

Haini, H., Wei Loon, P., Yong, S. K., & Husseini, S. (2023). Does Social Globalization Affect the Relationship Between International Tourism and Economic Growth? Journal of Travel Research. https://doi.org/10.1177/00472875221146779

Iqbal, A., Tang, X., & Rasool, S. F. (2023). Investigating the nexus between CO2 emissions, renewable energy consumption, FDI, exports and economic growth: evidence from BRICS countries. Environment, Development and Sustainability, 25(3), 2234–2263. https://doi.org/10.1007/s10668-022-02128-6

Ivanovski, K., Hailemariam, A., & Smyth, R. (2021). The effect of renewable and non-renewable energy consumption on economic growth: Non-parametric evidence. Journal of Cleaner Production, 286, 124956. https://doi.org/10.1016/j.jclepro.2020.124956

Kali, R., Méndez, F., & Reyes, J. (2007). Trade structure and economic growth. Journal of International Trade and Economic Development, 16(2), 245–269. https://doi.org/10.1080/09638190701325649

Kao, C., & Chiang, M. (2000). On the estimation and inference of a cointegrated regression in panel data. Advances in Econometrics, 15, 179-222.

Keshavarzian, M., & Tabatabaienasab, Z. (2021). Application of Bootstrap Panel Granger Causality Test in Determining the Relationship between Renewable and Non-Renewable Energy Consumption and Economic Growth: a Case Study of OPEC Countries. Technology and Economics of Smart Grids and Sustainable Energy, 6(1), 1–11. https://doi.org/10.1007/s40866-021-00106-x

Kim, D. H., Lin, S. C., & Suen, Y. B. (2016). Trade, growth and growth volatility: New panel evidence. International Review of Economics and Finance, 45(32), 384–399. https://doi.org/10.1016/j.iref.2016.07.006

Kripfganz, S., & Schneider, D. C. (2018). ARDL : Estimating autoregressive distributed lag and equilibrium correction models. London Stata Conference September 7, 2018, 1–44.

Lopez, L., & Weber, S. (2017). Testing for Granger causality in panel data. 4, 972–984. https://doi.org/10.1177/1536867X1801700412

Maddala, G. S., & Wu, S. (1999). A comparative study of unit root tests with panel data and a new simple test. Oxford Bulletin of Economics and Statistics, 61(SUPPL.), 631–652. https://doi.org/10.1111/1468-0084.0610s1631

Mudalip, S. . A., Bakar, M. R. A., P.Jamal, Adam, F., & Alam, Z. M. (2019). Resource-Economic Growth Nexus, Role of Governance, Financial Development, Globalization, and War: A Dynamic Approach. Journal of Economic Integration, 28(4), 853–858.

Mukhtarov, S. (2022). The Relationship between Renewable Energy Consumption and Economic Growth in Azerbaijan. International Journal of Energy Economics and Policy, 12(1), 416–419. https://doi.org/10.32479/ijeep.11948

Narayan, P. K., & Narayan, S. (2005). Estimating income and price elasticities of imports for Fiji in a cointegration framework. Economic Modelling, 22(3), 423–438. https://doi.org/10.1016/j.econmod.2004.06.004

Pedroni, P. (2000). Fully modified OLS for heterogeneous cointegrated panels. Advances in Econometrics, 15, 93-130.

Pedroni, P. (2001). Purchasing power parity tests in cointegrated panels. Review of Economics and Statistics, 83(4), 727–731. https://doi.org/10.1162/003465301753237803

Pereira, R., Sequeira, T., & Cerqueira, P. (2021). Renewable energy consumption and economic growth: a note reassessing panel data results. Environmental Science and Pollution Research, 28(15), 19511–19520. https://doi.org/10.1007/s11356-021-12961-3

Persyn, D., & Westerlund, J. (2008). Error-correction – based cointegration tests for. The Stata Journal, 2, 232–241.

Pesaran, M. H. (2007). A Simple Panel Unit Root Test In The Presence Of Cross-Section Dependence. Journal of Applied Econometrics, 22(2), 265–312. https://doi.org/10.1002/jae.951

Pesaran, M. H. (2014). Journal of Applied Econometrics. 21(August 2012), 1–21. https://doi.org/10.1002/jae

Pesaran, M. H. (2020). General diagnostic tests for cross-sectional dependence in panels. Empirical Economics. https://doi.org/10.1007/s00181-020-01875-7

Pesaran, M. H., Pesaran, M. H., Shin, Y., & Smith, R. P. (1999). Pooled Mean Group Estimation of Dynamic Heterogeneous Panels. Journal of the American Statistical Association, 94(446), 621–634. https://doi.org/10.1080/01621459.1999.10474156

Pesaran, M. H., & Smith, R. (1995). Estimating long-run relationships from dynamic heterogeneous panels. In Journal of Econometrics (Vol. 68, Issue 1). https://doi.org/10.1016/0304-4076(94)01644-F

Radmehr, R., Shayanmehr, S., Ali, E. B., Ofori, E. K., Jasińska, E., & Jasiński, M. (2022). Exploring the Nexus of Renewable Energy, Ecological Footprint, and Economic Growth through Globalization and Human Capital in G7 Economics. Sustainability (Switzerland), 14(19). https://doi.org/10.3390/su141912227

Radulović, M., & Kostić, M. (2020). Globalization and economic growth of eurozone economies. Zbornik Radova Ekonomskog Fakultet Au Rijeci, 38(1), 161–192. https://doi.org/10.18045/zbefri.2020.183

Santiago, R., Fuinhas, J. A., & Marques, A. C. (2020). The impact of globalization and economic freedom on economic growth: the case of the Latin America and Caribbean countries. Economic Change and Restructuring, 53(1), 61–85. https://doi.org/10.1007/s10644-018-9239-4

Scapelli, M. C. (2010). Hysteresis nas exportações manufaturadas brasileiras: uma análise de cointegração com dados em painel.

Shahbaz, M., Chaudhary, A. R., & Shahzad, S. J. H. (2018). Is energy consumption sensitive to foreign capital inflows and currency devaluation in Pakistan? Applied Economics, 50(52), 5641–5658. https://doi.org/10.1080/00036846.2018.1488059

Shahbaz, M., Raghutla, C., Chittedi, K. R., Jiao, Z., & Vo, X. V. (2020). The effect of renewable energy consumption on economic growth: Evidence from the renewable energy country attractive index. Energy, 207, 118162. https://doi.org/10.1016/j.energy.2020.118162

Westerlund, J. (2007). Testing for error correction in panel data. Oxford Bulletin of Economics and Statistics, 69(6), 709–748. https://doi.org/10.1111/j.1468-0084.2007.00477.x

Zhang, W., Hu, J., & Hao, J. (2022). Proportion of renewable energy consumption and economic growth: theoretical and empirical analysis. Environmental Science and Pollution Research, 29(19), 28884–28895. https://doi.org/10.1007/s11356-022-18500-y

Chapter 6 - Impact of Socio-Economic Factors on Human Development: A Dynamic Panel Analysis of African Rural and Urban Contexts[4]

6.1. Introduction

In the pursuit of advancing socio-economic development, nations often prioritize projects that can uplift their communities. Technology stands prominent among the avenues to achieve this objective, aligning with the premises outlined in endogenous growth models. Technical progress, a significant catalyst for heightened productivity, can foster amplified income levels and subsequently enhance the overall quality of life, particularly in economies deemed underdeveloped.

This study is dedicated to comprehending the specific factors that play pivotal roles in elevating human development across a sample of 39 African countries during the spanning period from 2012 to 2022. Given the delineated analytical approach, two distinct models were proposed - one tailored to the rural domain and another specific to urban areas. The rural model's explanatory variables encompassed rural land per capita, the rural workforce, consumption patterns of renewable energies and fossil fuels, accessibility to electricity, gross domestic product (GDP), and corruption levels. Conversely, the urban model incorporated a financial index as a proxy for gauging technical progress, alongside urban population metrics and the same macro variables for the rural model.

Within rural areas, agricultural productivity inherently hinges on the availability of usable land and the labor force allocated to production. These factors significantly contribute to augmenting family income by employing heightened production. Conversely, in the urban context, the production landscape revolves around technology — be it within factories or service provision — underscored by the critical relevance of technical progress and dedicated human labor. Hence, these factors serve as substantial contributors to human development and hence warrant a thorough scholarly investigation.

Some scholars define public corruption as a behavior within the public sector where public officials or individuals in close association irregularly utilize public resources to enrich themselves or their associates (Khumawala & Ramchand, 2005). From an economic vantage point, there is substantial evidence suggesting that corruption impedes economic growth by rendering decision-making based on non-economic criteria less efficient. This reduction in efficiency diminishes the quality of available information for economic agents and subsequently escalates costs (Khumawala & Ramchand, 2005).

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However, it is worth noting that there exists research contending that corruption can, in certain contexts, facilitate development. This occurs when corruption enables economic agents to bypass cumbersome institutions and regulations that otherwise impede market efficiency (Dreher & Gassebner, 2013; Huntington, 1968; Leff, 1964). Given this backdrop, it is paramount to recognize that corruption can exert an influence on economic growth, and since development and growth are intimately intertwined, analyzing how economic activity, as represented by GDP, and the corruption metric, specifically the Corruption Perception Index (CPI), can impact human development becomes a pertinent endeavor.

The contemporary quality of life is profoundly contingent upon the availability of electricity, given its indispensable role in the functioning of households. Consequently, the authors of this study posit that human development is substantively influenced by both the accessibility to and utilization of energy. When examining consumption patterns and the incentives driving shifts in energy production and consumption, the study also investigates whether the consumption of renewable and non-renewable energy sources exerts an influence on human development, recognizing the potential environmental implications associated with these energy matrices.

This study presents a contribution by delving into the analysis of human development, utilizing the Human Development Index as a primary metric. Moreover, it encompasses a comprehensive examination distinguishing between residents of rural and urban areas within the studied sample. Given the context, this research seeks to understand Differential Drivers of Human Development in Rural and Urban Areas. What are the distinct factors that primarily contribute to human development in rural areas compared to urban regions in African countries? How do these factors vary and what policy implications arise from these differences? To the best of the authors' knowledge, prior research employing such analytical differentiation within this particular sample is yet to be documented.

The paper is organized as follows: Section 2 presents a brief literature review, Section 3 describes the theoretical framework, Section 4 presents data and methodologies used, Section 5 presents the findings and discussions, and Section 6 provides concluding remarks summarizing the main findings.

6.2. Literature Review

As is widely acknowledged economic and social development typically represents a primary goal for governing authorities. This pursuit is rooted in the anticipation that such development will lead to an enhanced quality of life for the populace, thereby bolstering the prospects of sustaining political authority. In this section, we undertake a concise review of the contemporary literature about social and economic development over the recent years.

The scholarly discourse often centers on examining the nexus between economic growth and institutional efficacy. In this context, Uddin et al. (2023) posit that institutions assume a pivotal role in a nation's developmental trajectory, prompting the initiation of an investigation into the interplay between development and institutional quality for 70 economies. The findings from this inquiry affirm that institutional quality and globalization benefit development, while inflation, corruption, and unemployment exert adverse effects (Uddin et al., 2023). The findings elucidated by Chen et al. (2023) underscore a noteworthy observation: effective governance significantly influences the Human Development Index (HDI). In the specific context of Jordan, the study did not identify any significant correlation between good governance and human development. Therefore, it can be inferred that, in this particular case, good governance does not exert a discernible influence on the HDI of the country (Radaideh, 2022). Stryzhak et al. (2022) assert that the level of human development is intricately linked to the quality of a society's institutional environment. This assertion is grounded in the findings of their extensive research spanning 188 countries during the years 2017-2019. The empirical results from this research consistently demonstrate a positive and direct correlation between HDI and institutional quality (Stryzhak et al., 2022).

In the case of the 28 member countries of the European Union, Tudorache (2020) elucidates that corruption exerts a detrimental impact on the HDI. This adverse effect extends to educational outcomes, as evidenced by a higher number of school dropouts, and the labor force within the respective nations. Conversely, the study highlights a positive association between HDI and gross capital formation, as well as life expectancy, underscoring the significance of these factors in enhancing overall human development (Tudorache, 2020). Within emerging economies, corruption demonstrates a positive effect on human development, albeit of a relatively small magnitude, a noteworthy contrast to the observed effect of corruption on HDI in Europe (Korez-Vide & Bobek, 2021).

In an ambitious research endeavor, Feruni et al. (2020) sought to examine and compare the interconnections between corruption, economic freedom, urbanization, and economic development across Western Balkan countries and European Union (EU) nations during the period spanning 2009 to 2018. The research outcomes manifest that corruption exerts a detrimental influence on economic development. Conversely, economic freedom and urbanization were found to positively impact economic development for both sets of countries (Feruni et al., 2020). Notably, the impact of corruption appeared to be more severe within the Western Balkan region, significantly impeding their economic development. Conversely, economic freedom and urbanization demonstrated a more pronounced beneficial effect on economic development within the Western Balkans compared to the EU countries (Feruni et al., 2020).

The extant literature extensively deliberates upon the connection between GDP and the utilization of both renewable and non-renewable energy sources, yielding a spectrum of mixed outcomes. Nonetheless, a consistent observation across these studies is the heightened environmental stress associated with the consumption of fossil fuels, which can potentially engender adverse consequences for the populace. In light of this overarching concern, efforts have been made to promote the utilization of renewable energy sources.

Sasmaz et al. (2020) posits an intriguing perspective, suggesting that the replacement of fossil fuels by renewables could potentially hurt human development, despite its positive environmental impact. To investigate this hypothesis, researchers examined the relationship between renewable energy and human development across 28 OECD (Organization for Economic Cooperation and Development) countries from 1990 to 2017. Contrary to Sasmaz et al.'s (2020) expectations, the data analysis revealed a positive impact of renewable energy on human development. This outcome challenges the initial belief and suggests that adopting renewable energy sources can contribute positively to human development. Additionally, the causality test indicated a bidirectional causality relationship between renewable energy and human development, further emphasizing the complex interplay between these variables (Sasmaz et al., 2020).

In this context, the research undertaken by Simionescu (2021) endeavors to examine the interrelationship between greenhouse gas (GHG) emissions and the Human Development Index (HDI) within the context of eight newly admitted members of the European Union. The findings derived from this investigation reveal a discernible negative correlation between these variables (Simionescu, 2021). Evans et al. (2022) proposed a study delving into the reciprocal relationship between human development and sustainable development. As posited by the authors, enhancements in the HDI correlate with reductions in carbon dioxide, GHG, and ecological footprint emissions (Evans et al., 2022). In the context of the Chinese economy, Long et al. (2023) research reveals a negative correlation between the HDI and CO_2 emissions. This suggests that progress in human development can potentially mitigate the effects of pollution, indicating a promising avenue for environmental sustainability (Long et al., 2023). In a broader context, it is plausible to infer that human development enhances overall well-being and fosters environmental amelioration. However, a contrasting relationship was noted in the specific case of Latin America, where an upswing in human development appears to be linked with a considerable environmental toll (Elizabeth & López, 2022). In the context of Pakistan, the research findings indicate a positive relationship between energy production and human development. Conversely, the results present a counterintuitive observation wherein economic growth demonstrates a negative relationship with the Human Development Index in this particular setting (Luqman et al., 2021).

Recognizing a research gap in the examination of how biomass consumption, urbanization, human capital, economic growth, and globalization impact human development on the African continent, Nguea (2023) sought to address this deficiency. The outcomes of this study suggest that urbanization, biomass consumption, economic growth, and globalization collectively tend to have a positive influence on human development in this context (Nguea, 2023).

The accessibility to electricity stands as a foundational pillar that has substantially contributed to the enhancement of overall quality of life throughout the past century. Nevertheless, according to the findings put forth by Acheampong et al. (2021), there exists a conspicuous dearth of literature on the influence of energy accessibility on human development. To address this lacuna, Acheampong et al. (2021) conducted a comprehensive investigation into this relationship, encompassing a dataset spanning 79 countries over the period from 1990 to 2018. The empirical results gleaned from this analysis reveal that access to energy, particularly clean energy sources, exerts a positive impact on human development in the regions of Caribbean-Latin America and sub-Saharan Africa. However, a similar association was not discerned in the context of South Asia. Furthermore, it is noteworthy that macroeconomic variables, including economic growth, trade liberalization, foreign direct investment (FDI), urbanization, and access to credit, play a significant contributory role in fostering economic growth. This conclusion aligns with the observations made by Uddin et al. (2023) in their study concerning a similar relationship among countries. In the context of the Egyptian economy, it is discerned that fluctuations in the global economy exert a negative influence on socioeconomic development, as represented by the Human Development Index (Emara & Mohamed, 2023). Still in the Egyptian economy, Mohamed (2020) research underscores that an increase in corruption tends to negatively influence human development. Conversely, the findings reveal a contrasting relationship, where GDP demonstrates a positive impact on human development (Mohamed, 2020).

Adekoya et al. (2021) conducted an extensive study examining the intricate relationship between renewable energy consumption, CO_2 emissions, and the Human Development Index across a broad spectrum of 126 economies. While the findings exhibit a degree of heterogeneity, a prevailing pattern emerges across the majority of nations under investigation. Specifically, the results indicate a positive influence of renewable energy consumption on HDI, signifying that greater utilization of renewable energy sources tends to enhance human development. However, it is noteworthy that exceptions to this trend are evident in the MENA (Middle East and North Africa) and Central America and Caribbean regions, where the consumption of renewables appears to harm human development. Conversely, in Europe, the effect is positive, indicating a favorable synergy between renewable energy use and human development. Remarkably, a contrasting relationship is observed concerning carbon dioxide emissions, which exhibit a positive correlation with HDI across all regions (Adekoya et al., 2021). This outcome suggests that the increase in CO_2 emissions is intertwined with economic growth, and there appears to be a direct association between emissions and economic development.

Li et al. (2023) conducted a comprehensive analysis of the Resource Curse Hypothesis and Information Technologies (ICT) within the framework of human development, focusing on the economies of BRICS and the Next Eleven (N11). The outcomes of this investigation reveal several key insights. In the case of BRICS economies, it is evident that ICT positively impacts the HDI both in the short and long term, while abundant natural resources correlate with enhanced human development. Conversely, for the N11 group, the study indicates that ICT plays a beneficial role in enhancing HDI. However, a different pattern emerges concerning natural resources; their abundance is associated with a reduction in human development (Li et al., 2023). The outcomes concerning Information and Communication Technology, representative of technical progress, align with the conclusions drawn by Qureshi et al. (2020), whose study pointed to a robust positive relationship between technological innovation and human development, demonstrating a reciprocal effect. This positive effect was consistently observed across all countries in the sample, including those regarded as technologically advanced (Qureshi et al., 2020). The findings regarding the influence of natural resources align with those discovered by Chen et al. (2023), who concluded that the impact of resource abundance varies following the distinct characteristics of economies. Contrary to the relationship observed with natural resource abundance, Dialga and Ouoba (2022) research findings reveal that extractive resources positively impact human development within their sample of 42 countries.

Haabazoka and Mweetwa (2019) explored the correlation between financial inclusion and human development in the Zambian economy. Their research uncovered a positive association, indicating that financial inclusion has a favorable impact on human development (Haabazoka & Mweetwa, 2019). Financial development can be considered a form of technical progress (Ifa & Guetat, 2022).

6.3. Theoretical Framework

In economies categorized as developing, a substantial proportion of the populace can be classified as self-reliant, whereby their earnings are derived from self-employment endeavors. As indicated by Roser (2023), approximately a quarter of the global workforce is engaged in primary sector activities. However, this percentage tends to be more pronounced in economies characterized by lower to middle-income strata, a demographic akin to the focus of this study, namely African nations. Given the prevalent self-employment income structure in these economies, individuals in question allocate a portion of their produced output for personal consumption, while concurrently utilizing a segment of their household resources in the productive process. This leads to the confluence of decisions made in tandem regarding both production and consumption, effectively establishing an intersection between the household and entrepreneurial facets. With this context, we introduce the theoretical model underpinning this study, denoted as the "Deterministic Model of Management of Socio-Economic Development of the Region."

At the core of the model lies the state function delineating regional development, denoted by the vector function $s(t)$ with its components $[x(t), y(t), z(t)]$. Here, $x(t)$ represents the region's population, $y(t)$ signifies the number of jobs within the real sector of the regional economy, and $z(t)$ represents the indicator for energy supply in the region. The vector $u(t)$ encompasses the controlling variables, dictating the desired values for the state vector (Boldyrev et al., 2019). This controlling vector is composed of m-components $[u_1(t), u_2(t), \dots, u_m(t)]$, with each component characterizing a controlling factor (Boldyrev et al., 2019). For instance, $u_1(t)$ corresponds to the coefficient of demographic activity, $u_2(t)$pertains to the coefficient representing people's disincentive for childbearing, $u_3(t)$ is indicative of the region's energy-supply coefficient, and so forth (Boldyrev et al., 2019).

After outlining the fundamental parameters of the model, this study modifies the energy supply coefficient. Now, it comprises three elements: consumption of both renewable and non-renewable energies, and access to electricity. This adjustment aims to comprehensively understand the dynamics of energy supply and demand. Additionally, this work extends the theoretical model by incorporating the financial development index as a proxy for technical progress, see Ifa & Guetat (2022), environmental pressure denoted by carbon dioxide emissions, and the Human Development Index as a metric for assessing socioeconomic development.

This model provides a framework for describing and analyzing the development of diverse dynamic systems, varying in complexity levels (Boldyrev et al., 2019). Following Boldyrev et al. (2019), the model incorporates primary indicators for the region's development: $s_1(t)$ represents the regional population,

$s_2(t)$ signifies the number of jobs in the real sector of the regional economy, and $s_3(t)$denotes the indicator for the regional energy supply and demand.

Through a set of coefficients, the mechanisms for implementing regional policies to achieve public administration goals are established (Boldyrev et al., 2019). Derivation is utilized to estimate variations in the value of a variable. In this context, the derivatives of the variables under analysis represent the natural rates of change. For example, ${ds_1}/{d_t}$ is the population rate change. According to Boldyrev et al. (2019), the population rate change is inherently linked to both the population and the number of jobs within the real economy of the region (s_2) and with (s_3), the energy supply and demand.

The rate of change is directly proportional to the population itself. In other words, a higher population corresponds to a greater growth rate (Boldyrev et al., 2019).

$$\frac{ds_1}{dt} = u_1 s_1 \ (39)$$

u_1 is the demographic activity coefficient.

In this scenario, the number of jobs is determined by the required workforce to produce the goods and services (Boldyrev et al., 2019). As mentioned earlier, the relationship between s_1 and s_2 (population and number of jobs) needs elucidation. Given a value for s_1, s_2 operates to mitigate population growth due to individuals opting not to have children, a factor represented by u_2. Therefore, s_2 tends to diminish the population, and this effect can be quantified as $u_2 s_1 s_2$ (Boldyrev et al., 2019). Conversely, in the opposing direction, the influence of s_3 is positive. Greater availability and consumption of energy lead to an increase in population growth. This relationship is modulated by the u3 indicator representing supply, demand, and access to electricity within the region. Hence, the population is affected as follows: $u_3 s_1 s_3$ (Boldyrev et al., 2019). This relationship can be expressed by the following equation:

$$\frac{ds_1}{dt} = u_1 s_1 - u_2 s_1 s_2 + u_3 s_1 s_3 \ (40)$$

The derivative of s_2 is inversely proportional to the number of jobs. In simpler terms, the more jobs already created, the harder it becomes to increase the number of job opportunities (Boldyrev et al., 2019). For a given value of s_2, if individuals are inclined towards economic development, an increase in the regional population $s_1$will increase the growth rate of economic development in the real sector by $u_4 s_1 s_2$, where u_4 represents the coefficient representing people's interest in economic development (Boldyrev et al., 2019). s_3 tends to contribute to economic development by the magnitude of $u_5 s_2 s_3$, where u_5 is the coefficient of energy demand by businesses. In essence, the greater the energy available for the development of the real sector of the economy, the higher the economic growth (Boldyrev et al., 2019). The same rationale applies to s_3. Naturally, the higher the demand for and consumption of energy by society, the greater the growth rate of the energy supply (Boldyrev et al., 2019). s_1 will decrease the rate of change in energy consumption by an amount $u_8 s_1 s_3$, where u8 is the population's conformity ratio with the energy supply. As the population increases, the rate of change in energy supply decreases. For a given value of s_3, an increase in the number of jobs in the real sector will diminish the rate of change in energy supply by an amount of $u_9 s_2 s_3$, where u9 is the conformity ratio between economic development and energy supply. In simpler terms, the higher the growth rate of the real sector of the regional economy, the lower the energy supply per workplace (Boldyrev et al., 2019). We can formulate the equations for s_2 and s_3 as follows:

$$\frac{ds_2}{dt} = -u_4 s_2 + u_5 s_1 s_2 + u_6 s_2 s_3 \ (41)$$

$$\frac{ds_3}{dt} = u_7 s_3 - u_8 s_1 s_3 - u_9 s_2 s_3 \ (42)$$

Upon presenting the outlined ratios, we arrive at the ensuing development model, incorporating consideration of the variables

$$\frac{ds_1(t)}{dt} = u_1^0 s_1(t) - u_2^0 s_1(t) s_2(t) - u_3^0 s_1(t) s_3(t) + u_4^0 s_1(t) s_4(t) + u_5^0 s_1(t) s_5(t) - u_6^0 s_1(t) s_6(t) + u_7^0 s_1(t) s_7(t) \ (43)$$

$$\frac{ds_2(t)}{dt} = u_8^0 s_2(t) + u_9^0 s_1(t) s_2(t) + u_{10}^0 s_2(t) s_{11}(t) + u_{12}^0 s_2(t) s_4(t) + u_{13}^0 s_2(t) s_5(t) - u_{14}^0 s_2(t) s_6(t) + u_{15}^0 s_2(t) s_7(t) \ (44)$$

$$\frac{ds_3(t)}{dt} = u_{16}^0 s_3(t) - u_{17}^0 s_1(t) s_3(t) - u_{18}^0 s_2(t) s_3(t) + u_{19}^0 s_4(t) s_4(t) + u_{20}^0 s_3(t) s_5(t) - u_{21}^0 s_3(t) s_6(t) + u_{22}^0 s_3(t) s_7(t) \ (45)$$

$$\frac{ds_4(t)}{dt} = u_{23}^0 s_4(t) + u_{25}^0 s_1(t) s_4(t) + u_{26}^0 s_2(t) s_4(t) + u_{27}^0 s_3(t) s_4(t) + u_{28}^0 s_4(t) s_5(t) - u_{29}^0 s_4(t) s_6(t) + u_{30}^0 s_4(t) s_7(t) \ (46)$$

$$\frac{ds_5(t)}{dt} = u_{31}^0 s_5(t) + u_{32}^0 s_1(t) s_5(t) + u_{33}^0 s_2(t) s_5(t) + u_{34}^0 s_3(t) s_5(t) + u_{35}^0 s_4(t) s_5(t) - u_{36}^0 s_5(t) s_6(t) + u_{37}^0 s_5(t) s_7(t) \ (47)$$

$$\frac{ds_6(t)}{dt} = u_{38}^0 s_6(t) - u_{39}^0 s_1(t) s_6(t) - u_{40}^0 s_2(t) s_6(t) - u_{41}^0 s_3(t) s_6(t) - u_{42}^0 s_4(t) s_6(t) - u_{43}^0 s_5(t) s_6(t) + u_{44}^0 s_6(t) s_7(t) \ (48)$$

$$\frac{ds_7(t)}{dt} = u_{45}^0 s_7(t) - u_{46}^0 s_1(t) s_7(t) - u_{47}^0 s_2(t) s_7(t) - u_{48}^0 s_3(t) s_7(t) - u_{49}^0 s_4(t) s_7(t) - u_{50}^0 s_5(t) s_7(t) + u_{51}^0 s_6(t) s_7(t) \ (49)$$

In this study, we extend the model to encompass a broader perspective, focusing on the analysis of socioeconomic development rather than purely economic development. We augment the model by incorporating additional variables such as the Human Development Index (HDI) to capture aspects of economic development, and proxies for technical progress represented by the financial development index and environmental pressure indicated by carbon dioxide emissions. Moreover, this research deeply engages with and expands upon the theoretical framework previously outlined. Recognizing the distinct economic dynamics and developmental patterns within rural and urban contexts, this study bifurcates economic development into these categories. As mentioned earlier, we will estimate two models, each elucidated below, with the selection of variables driven by a thorough review of existing literature. In the model proposed in this work, we have $s_{1R}(t) = RuralPopulation$ and $s_{1U}(t) = UrbanPopulation$; $s_{2R}(t) = Rural\ Job$ and $s_{2U}(t) = Urban\ Job$; $s_3(t) = (RenewableCons + FossilFuelConsump)$; $s_{4R}(t) = CO2_R$ and $s_{4U}(t) = CO2_U$, as proxy for environmental pressure. Finally, $s_5(t) = Techinical\ Progress$, $s_6(t) = CPI$, as a measure for corruption, and finally, $s_{7R}(t) = EletricityAcessRural$ and $s_{7R}(t) = EletricityAcessUrban$. The coefficients, denoted as $u_i(i = 1,2, \ldots ,31)$ represent the controlling factors influencing the socioeconomic development of the region in the context of this study.

$$HDI_R = \beta_1 RuralPopulation + \beta_2 RuralJob + (\beta_3 RenewableCons + \beta_4 FossilFuelConsump) + \beta_5 CO2_R + \beta_6 CPI + \beta_7 TechnicalProgress + \beta_8 EletricityAcessRural \quad (50)$$

The rural population signifies the count of individuals residing in rural areas. A metric termed "rural job" has been devised, representing job opportunities in rural areas, calculated as $Rural\ Labor - Rural\ Unemployment$. Additionally, "Renewable Consumption" denotes the proportion of energy consumption sourced from renewable sources, while "FossilFuelConsump" indicates the proportion of energy consumption derived from non-renewable sources. "ElectricityAccessRural" pertains to the percentage of individuals in rural areas with access to electricity.

The variable "$CO2_R$" serves as a proxy to measure environmental pressure in rural areas. This metric was computed using the formula ${CO2\ total\ emission}/_{Rural\ population}$. "Technical Progress" denotes the state of technology. Lastly, "CPI" represents the Corruption Perception Index, utilized to assess corruption levels. The same set of variables is employed in the urban model, but with data specific to the urban areas. The model is presented as follows:

$$HDI_{Urb} = \beta_1 UrbanPopulation + \beta_2 UrbanJob + (\beta_3 RenewableCons + \beta_4 FossilFuelConsump) + \beta_5 CO2_U + \beta_6 CPI + \beta_7 TechnicalProgress + \beta_8 EletricityAcessUrban \quad (51)$$

6.4. Data

The data utilized in this study were sourced from publicly available secondary sources, ensuring the ease of result replication. Data concerning rural land availability, the rural workforce, electricity accessibility, consumption of renewable and non-renewable energy, and GDP were obtained from the World Development Indicators (WDI) database. Information related to the Corruption Perception Index (CPI) was acquired from the non-governmental organization Transparency International. The data about the Financial Development Index were sourced from the International Monetary Fund (IMF). Lastly, data on the dependent variable, Human Development Index (HDI), were extracted from the United Nations Development Programme (UNDP).

It is important to highlight that the chosen analysis period is a consequence of the availability of CPI data. Notably, a shift in the methodology of the CPI indicator occurred in the year 2012. Hence, the temporal scope of this study encompasses the years 2012 to 2022, encompassing data from 39 African economies. These nations include Algeria, Angola, Benin, Botswana, Burundi, Cameroon, Central African Republic, Chad, Comoros, Democratic Republic of the Congo, and Republic of the Congo, Cote d'Ivoire, Egypt, Eswatini Arab Republic, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Madagascar, Mali, Mauritania, Mauritius, Morocco, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, South Africa, Sudan, Tanzania, Togo, Tunisia, and Uganda.

Table 6.1 and 6.2 present the correlation matrix, these correlations can help us understand how the variables are relate to each other, aiding in further analysis and decision-making.

Table 6.1 - Rural Correlations

	HDI Rural	Rural Population	Rural Job	Renewable Consumption	Fossil Consumption	CO2 Rural	CPI	Technical Progress	Eletricity Acess Rural
HDI Rural	1								
Rural Population	-0.0648	1							
Rural Job	-0.1101	0.9681*	1						
Renewable Consumption	-0.7499*	0.1896*	0.2600*	1					
Fossil Consumption	0.7527*	-0.1899*	-0.2611*	-0.9971*	1				
CO2 Rural	0.7765*	-0.0748	-0.1347*	-0.7227*	0.7230*	1			
CPI	0.5067*	-0.1631*	-0.1253	-0.5371*	0.5324*	0.3725*	1		
Technical Progress	0.6628*	0.0301	-0.0139	-0.6700*	0.6643*	0.6668*	0.5786*	1	
Eletricity Acess Rural	0.7482*	0.1135	0.0504	-0.7014*	0.7013*	0.5922*	0.3290*	0.3290*	1

Note: *1% significance

In the context of rural areas, the Human Development Index (HDI) Rural demonstrates a moderate negative correlation with Rural Job (-0.1101) and a pronounced negative correlation with Renewable Consumption (-0.7499*). Conversely, HDI Rural exhibits a strong positive correlation with Fossil

Consumption (0.7527*), CO2 Rural (0.7765*), Corruption Perception Index (CPI) (0.5067*), Technical Progress (0.6628*), and Electricity Access Rural (0.7482*). Rural Population, on the other hand, portrays a weak negative correlation with HDI Rural (-0.0648) and a robust positive correlation with Rural Job (0.9681*). Notably, Renewable Consumption and Fossil Consumption display a significant negative correlation (-0.9971*). Furthermore, CO2 Rural is notably and positively correlated with Fossil Consumption (0.7230*), along with a moderate positive correlation with Renewable Consumption (-0.7227*) and CPI (0.5324*). Consumer Price Index (CPI) and Technical Progress manifest moderate to strong positive correlations with most variables, suggesting a degree of interdependence among them.

Table 6.2 - Urban Correlations

	HDI Urban	Urban Population	Urban Job	Renewable Consumption	Fossil Consumption	CO2 Urban	CPI	Technical Progress	Eletricity Acess Urban
HDI Urban	1								
Urban Population	0.1700*	1							
Urban Job	0.1237	0.9844*	1						
Renewable Consumption	-0.7474*	-0.0777	0.0042	1					
Fossil Consumption	0.7497*	0.0803	-0.0019	-0.9972*	1				
CO2 Urban	0.7660*	0.2084*	0.1471*	-0.7038*	0.7025*	1			
CPI	0.5309*	-0.1185	-0.1219	-0.5266*	0.5217*	0.4443*	1		
Technical Progress	0.6799*	0.2067*	0.1693*	-0.6618*	0.6560*	0.7498*	0.6092*	1	
Eletricity Acess Urban	0.7497*	0.0803	-0.0019	-0.9972*	1.0000*	0.7025*	0.5217*	0.6560*	1

Note: *1% significance

In the domain of urban areas, the Human Development Index (HDI) Urban demonstrates a weak positive correlation with Urban Population (0.1700*) and Urban Job (0.1237). Urban Population exhibits a moderate positive correlation with Urban Job (0.9844*) and a weak positive correlation with the Consumer Price Index (CPI) (0.1185). Notably, Renewable Consumption and Fossil Consumption present a robust negative correlation (-0.9972*), indicative of an inverse relationship between these variables. Furthermore, CO2 Urban displays a strong positive correlation with Fossil Consumption (0.7025*) and a moderate positive correlation with Renewable Consumption (0.7038*) and CPI (0.5217*). The Consumer Price Index (CPI) and Technical Progress reveal moderate to strong positive correlations with most variables, suggesting a degree of interdependence among them.

6.5. Methodology

6.5.1. Quasi-Maximum Likelihood Estimation (QMLE)

Quasi-maximum Likelihood Estimation (QMLE) is employed to estimate parameters in linear dynamic panel-data models, particularly when facing a limited time horizon and a substantial number of cross-sectional units (Kripfganz, 2016a). With a limited time horizon and a substantial sample size involving numerous countries, the suitability of employing the QMLE methodology in this research is evident. This approach aligns well with the specified circumstances and is apt for deriving meaningful estimations within the context of linear dynamic panel-data models.

In comparison to alternative methodologies like Ordinary Least Squares (OLS) and Generalized Least Squares (GLS) models, which condition on initial observations, employing these approaches can result in biased estimates. This bias stems from the correlation between the lagged dependent variable and the aggregated error term (Kripfganz, 2016a). Quasi-maximum likelihood estimation offers a way to mitigate this bias by modelling the unconditional likelihood function, bypassing the need to condition on initial observations (Kripfganz, 2016a).

The QML estimators present an appealing alternative to other estimation approaches in terms of both efficiency and finite-sample performance, provided that all the underlying assumptions are met (Kripfganz, 2016a). Both QML estimators, whether random or fixed effects, can be described as limited-information maximum-likelihood estimators. They represent specific instances within the framework of structural equation modelling or full-information maximum-likelihood approaches, featuring multiple cross-equation constraints (Kripfganz, 2016a). QML estimators are consistent and offer notable efficiency advantages. However, a trade-off between efficiency and robustness exists. This approach can become inconsistent if the explanatory variables (apart from the lagged dependent variable) cease to be strictly exogenous concerning the idiosyncratic error component. Additionally, if there remains unaccounted serial correlation beyond the first-order autoregressive term, the consistency of the estimators is compromised (Kripfganz, 2016a).

A generic Dynamic panel-data model can be described as:

$$y_{it} = \lambda y_{i,t-1} + x_{it}'\beta + f_i'\gamma + \varepsilon_{it} \qquad \varepsilon_{it} = u_i + e_{it} \quad (52)$$

In which, x_{it}' is a vector of time-varying variables and f_i' is a vector of time-invariant variables (Kripfganz, 2016a). In dealing with panel-data estimation, it is necessary to address whether the fixed or random effects will be applied, this decision is taken through the interpretation of Hausman's Test.

In the dynamic random-effects model, it is assumed that the time-varying regressors x_{it} and the time-invariant regressors f_i are uncorrelated with the error term u_i (Kripfganz, 2016b). The classical random-effects estimator, often employed as a least-squares estimator, treats the initial observations y_{i0} as exogenous. However, in cases where the number of periods is small, this estimator becomes biased due to the correlation of $y_{i,t-1}$ (and consequently y_{i0}) with the error term u_i (Kripfganz, 2016b). To address this correlation using a likelihood-based approach, it is necessary to specify the joint distribution of $y_{i0}, y_{i1}, \dots, y_{it}$ (Kripfganz, 2016b). To mitigate this issue, a proposed approach involves modelling the initial observations as a function of the observed exogenous variables (Bhargava & Sargan, 1983). Given this consideration, we can outline the following model:

$$y_{i0} = \sum_{s=0}^{T^*} x'_{is}\pi_{x,s} + f_i{}'\pi_f + v_{i0} \ (53)$$

Where, $T^* = \min(T_i)$, $Var(v_{i0}) = \sigma_0^2$, $Cov(v_{i0}, e_{it}) = \emptyset\sigma_0^2$ (Kripfganz, 2016b).

In contrast, in the Dynamic Fixed-Effects model, all regressors are permitted to be correlated with the error term u_i (Kripfganz, 2016b). An initial step in addressing this matter involves eliminating the unit-specific error component through a first-difference transformation (Kripfganz, 2016a). As follows:

$$\Delta y_{it} = \lambda\Delta y_{it,t-1} + \Delta x'_{it}\beta + \Delta e_{it} \ (54)$$

The lagged dependent variable is inherently correlated with the transformed error term. Consequently, an estimator that is treated as exogenous is subject to bias (Kripfganz, 2016b). Similar to addressing correlation in the random effects model with a likelihood approach, it's essential to specify the joint distribution of $(\Delta y_{i1}, \Delta y_{i2}, \dots, \Delta y_{iT_i})$ in this context (Kripfganz, 2016b). Similar to the random-effects model, (Hsiao et al., 2002) suggest the following feasible representation for the initial observations in the transformed model (Kripfganz, 2016b, 2016a):

$$\Delta y_{i1} = b + \sum_{s=0}^{T^*} x'_{is}\pi_{,s} + v_{i1} \ (55)$$

In which, $T^* = \min(T_i)$, $Var(v_{i1}) = \omega\sigma_e^2$, $Cov(v_{i0}, \Delta e_{i2}) = -\sigma_e^2$, and $Cov(v_{i0}, \Delta e_{it}) = 0$ for $t > 2$ (Kripfganz, 2016b).

If the serial correlation in u_{it} is absent, then the first-order serial correlation in Δu_{it} is negative, with a correlation coefficient of -0.5. However, there is no evidence of higher-order serial correlation in Δu_{it}. The absence of higher-order serial correlation in Δu_{it} is essential for maintaining the validity of $(y_{i,t-2}, y_{i,t-3}, \dots)$ as instruments. Likewise, this is crucial for the instruments associated with predetermined and endogenous x_{it}. (Arellano & Bond, 1991) propose an asymptotically normally distributed test statistic for the null hypothesis $H_0\!: Corr(\Delta u_{it}, \Delta u_{i,t-j}) = 0$, where $j > 0$ (Kripfganz, 2019).

6.5.2. Generalized Method of Moments (GMM)

Heteroscedasticity is a prevalent issue encountered by researchers, necessitating effective handling. Presently, a common approach to address unknown-form heteroskedasticity is employing the Generalized Method of Moments (GMM) (Baum et al., 2003). This method leverages orthogonality conditions to enable efficient estimation in the presence of such heteroskedasticity. In addition, GMM estimation stands as a prevalent technique for estimating models with endogenous variables, especially lagged dependent variables, in scenarios where the time horizon is limited (Kripfganz, 2019).

Efficient GMM offers the advantage of consistency even in the presence of arbitrary heteroskedasticity. However, this advantage comes at the expense of potentially suboptimal performance in finite sample sizes (Baum et al., 2003). Given the trade-off involving potential loss of consistency, the current study incorporates other methodologies beyond the efficient Generalized Method of Moments.

GMM is founded on the premise that the instruments Z are exogenous, denoted by $E(Z_i u_i) = 0$. The set of L instruments provides L moments, forming the basis for the estimation in the GMM framework (Baum et al., 2003).

$$g_i(\widehat{\beta}) = Z_i' \hat{u}_i = Z_i'(y_i - X_i \hat{\beta}) \quad (56)$$

Denoting $L\,x\,1$ as g_i, the exogeneity condition implies the existence of L moment conditions. This condition is fulfilled by the function $E\{g_i(\beta)\} = 0$, where the specific value of β is referenced (Baum et al., 2003). Each of the L moment equations corresponds to a sample moment and can be expressed as follows:

$$\bar{g}(\hat{\beta}) = \frac{1}{n}\sum_{i=1}^{n} \bar{g}(\hat{\beta}) = \frac{1}{n}\sum_{i=1}^{n} Z_i'(y_i - X_i \hat{\beta}) = \frac{1}{n} Z' \,\hat{u} \quad (57)$$

The fundamental concept of the GMM revolves around selecting an estimator for β by solving the equation $\bar{g}(\hat{\beta}) = 0$ (Baum et al., 2003). The GMM estimator is designed to minimize a quadratic form, expressed through the equation:

$$\hat{\theta} = arg \min_{\theta} \left(\sum_{i=1}^{N} m_i(\theta) \right)' W \left(\sum_{i=1}^{N} m_i(\theta) \right) \quad (58)$$

(Arellano & Bond, 1991) and (Blundell & Bond, 1998) are credited with advancing the Generalized Method of Moments (GMM) model tailored for analyzing dynamic panel data. In the realm of dynamic panel data analysis, the causal relationships about underlying phenomena typically manifest dynamics across time (Ullah et al., 2018). To account for this dynamic relationship, estimation techniques for dynamic panel data incorporate lagged dependent variables as explanatory factors. Lagged values of the dependent variables serve as instruments to mitigate endogeneity. These instruments are commonly referred to as 'internal instruments' since they originate from the established econometric model (Ullah et al., 2018). An excessive number of instruments relative to the cross-sectional sample size can exacerbate finite-sample biases in coefficient and standard error estimates. Additionally, this situation has the potential to weaken the effectiveness of specification tests (Roodman, 2009). To mitigate this issue and decrease the number of instruments, researchers commonly employ two approaches. First, they limit the number of lags used as instruments. Second, they opt for using standard instruments instead of GMM-type instruments (Kripfganz, 2020).

Two primary transformation methods are recognized: the first-difference transformation, often termed the one-step GMM, and the second-order transformation, referred to as the two-step GMM. The one-step difference estimator presents limitations. If the recent value of a variable is missing, applying the first-difference transformation can lead to a substantial loss of observations (Roodman, 2009). Additionally, this method demonstrates efficiency only when assuming homoscedasticity in the data, even in the presence of homoskedasticity, it is important to note that the one-step sys-GMM can still be inefficient (Kripfganz, 2020).

To address this inefficiency, an $L\ x\ L$ weighting matrix W is employed, forming a quadratic form within the moment conditions (Baum et al., 2003). Achieving asymptotic efficiency requires utilizing an optimal weighting matrix, essentially a consistent estimate of the inverse of the asymptotic covariance matrix $m(\hat{\theta})$ (Kripfganz, 2019). Thus, we have an efficient two-step estimate with an optimal weighting matrix (Kripfganz, 2020). The feasible efficient GMM estimator, a two-step procedure, can be expressed as follows (Kripfganz, 2019):

$$\hat{\hat{\theta}} = arg \min_{\beta} \left(\frac{1}{N} \sum_{i=1}^{N} m_i(\beta) \right)' W(\hat{\theta}) \left(\frac{1}{N} \sum_{i=1}^{N} m_i(\beta) \right) \quad (59)$$

The Generalized Method of Moments offers a computationally convenient methodology for attaining consistent and asymptotically distributed estimators for the parameters of statistical models (Salkind, 2013). In a comparison with Maximum Likelihood (ML), which stands as the optimal estimator in a classical paradigm, it may not always be the best choice when dealing with dependencies on the probability distribution. In such scenarios, GMM can emerge as a superior alternative to ML. GMM, rooted in population moment conditions, provides a framework for estimating coefficients based on information derived from the model (Salkind, 2013).

6.6. Results and Discussion

6.6.1. Results

As outlined in the methodology section, the study featured the estimation of models delineated in Tables below, with distinct analyses focusing on development in rural and urban areas, respectively. Tables 6.3 and 6.4 present the model estimates posited by the (Boldyrev et al., 2019), wherein regional development is influenced by three key variables: the population of the region, employment opportunities, and energy consumption.

$$HDI_R = \beta_1 RuralPopulation + \beta_2 RuralJob + (\beta_3 RenewableCons + \beta_4 FossilFuelConsump) \quad (60)$$

Table 6.3 - HDI Rural Model 1 Estimation

Variables	Bias-Corrected Estimation, FE[1]	Bias-Corrected Estimation, RE[1]	Quasi-maximum likelihood estimation[5]	One-Step System GMM	Two-Step System GMM	One-Step Difference GMM	Two-Step Difference GMM	GMM[6]
HDI Rural								
L1.	0.8147602***	0.9423838***	0.7584157***	0.9952832***	0.9952832***	0.4010828***	0.4010828***	0.7115919***
Rural Population	-6.10E-08	-8.78E-09	-2.59e-10	-0.000000005**	-0.000000005**	0.00000026***	0.00000026***	-6.78E-08
Rural Job	1.54E-07	0.0000000376**	1.37e-09	1.92E-08	0.0000000192***	-1.17E-07	-1.17E-07	0.000000259**
Renewable Consumption	-0.0363772**	-0.0150804	-0.0004748***	0.0051176***	0.0051176***	-0.0114149	-0.0114149	-0.0298866
Fossil Consumption	-0.0196114*	0.0024704	-0.0002154**	0.0063534**	0.0063534**	0.0132665	0.0132665	0.0360289
Constant	13.55562***	4.174226	0.1687052***	-	-	-	-	-
Generalized Hausman test	36.5944***		-	-	-	-	-	-
				Arellano-Bond test				
H0: no autocorrelation order 1		-3.5253***	-	3.44***	3.44***	-1.43	-1.43	-
H0: no autocorrelation order 2		-1.7047*	-	1.27	1.27	-0.47	-0.47	-
H0: no autocorrelation order 3		0.1976	-	-	-	-	-	-

Note: *** means statistically significant at 1%, 5%, and 10%, respectively.

$$HDI_{Urb} = \beta_1 UrbanPopulation + \beta_2 UrbanJob + (\beta_3 RenewableCons + \beta_4 FossilFuelConsump) \quad (61)$$

Table 6.4 - HDI Urban Model 1 Estimation

Variables	Bias-Corrected Estimation, FE[1]	Bias-Corrected Estimation, RE[1]	Quasi-maximum likelihood estimation[1]	One-Step System GMM	Two-Step System GMM	One-Step Difference GMM	Two-Step Difference GMM	GMM[2]
HDI Urban								
L1.	0.8021692***	0.8943116***	0.8594035***	0.9942134***	0.9942134***	0.4076943***	0.4076943***	0.6793668***
Urban Population	-8.47e-08**	-4.84e-08*	-1.16e-08	-1.37e-08*	-1.37e-08*	0.000000173**	0.000000173**	-1.18e-07***
Urban Job	2.35e-07**	0.000000182**	3.30e-08	0.0000000473*	0.0000000473*	-2.04E-07	-2.04E-07	4.36e-07***
Renewable Consumption	-0.0427807***	-0.0411126	-0.0004348	0.0055013***	0.0055013***	-0.0105142	-0.0105142	0.0252773
Fossil Consumption	-0.0190645***	-0.0085805	0.0000249	0.0073151***	0.0073151***	0.0202552	0.0202552	0.1014345*
Constant	14.60737***	8.735629**	0.9655169**	-	-	-	-	-
Generalized Hausman test	32.0040***		-	-	-	-	-	-

[5]The Bias-Corrected and Quasi-maximum probability estimates were computed utilising the "xtdpdbc" and "xtdpdqml" commands, respectively.

[6]The GMM model estimation was executed using the "xtdpgmm" command in the Stata software, in alignment with the approach advocated by (Kripfganz, 2020).

Arellano-Bond test

H0: no autocorrelation order 1	-3.5637***	-	3.60***	3.60**	-1.89**	-1.89**	-
H0: no autocorrelation order 2	-2.2958**	-	1.49	1.49	-0.95	-0.95	-
H0: no autocorrelation order 3	0.9714	-	-	-	-	-	-

Note: *** means statistically significant at 1%, 5%, and 10%, respectively.

The findings from bias-corrected estimations exhibit a higher degree of robustness compared to those derived from dynamic panel models. We expect that a similar level of robustness will be attained in the extended model posited within this research, as follows:

$$HDI_R = \beta_1 RuralPopulation + \beta_2 RuralJob + (\beta_3 RenewableCons + \beta_4 FossilFuelConsump) + \beta_5 CO2_R + \beta_6 C + \beta_7 TechnicalProgress + \beta_8 EletricityAcessRural \quad (62)$$

$$HDI_{Urb} = \beta_1 UrbanPopulation + \beta_2 UrbanJob + (\beta_3 RenewableCons + \beta_4 FossilFuelConsump) + \beta_5 CO2_U + \beta_7 TechnicalProgress + \beta_8 EletricityAcessUrban \quad (63)$$

Table 6.5 - HDI Rural Dynamic Panel Estimations

Variables	One-Step System GMM	Two-Step System GMM	One-Step Difference GMM	Two-Step Difference GMM	GMM
HDI Rural					
L1.	0.9911944***	0.993278***	0.3885177***	0.4085023***	0.784136***
Rural Population	-0.00000000623**	-0.0000000051*	0.000000233***	0.000000245***	-1.14e-09*
Rural Job	0.0000000209***	0.0000000202***	-9.28E-08	-1.23E-07	0.00000000372***
Renewable Consumption	0.0069957***	0.0057498***	-0.0003049	-0.0020811	-0.0003816
Fossil Consumption	0.0071215***	0.0069869**	0.0175068	0.0145306	0.0001626
CO2 Rural	6.91246	7.011746	244.9157	164.4152	0.6433892
CPI	-	-	-	-	-
Technical Progress	-	-	-	-	-
Eletricity Acess Rural	0.001821	0.0005056	0.0129293**	0.0099697*	-0.0002084
Constant	-	-	-	-	-
Arellano-Bond test					
H0: no autocorrelation order 1	3.49***	3.46***	-1.25	-1.35	-
H0: no autocorrelation order 2	1.25	1.28	-0.56	-0.69	-

Note: *** means statistically significant at 1%, 5%, and 10%, respectively.

The outcomes derived from the Dynamic-Panel analysis reveal significant insights. First, an increase in population appears to correlate with a decrease in the HDI within the region. Moreover, both renewable and non-renewable energy consumption exhibit statistical significance with a positive association. This indicates that the availability of energy stands as a pivotal factor in promoting human development within rural areas. Additionally, the statistical significance of access to electricity in both the One and Two-Step dynamic panels showcases a positive relationship.

Alternative methodologies were contemplated for both the analysis and discussion of results. This consideration was prompted by the outcomes derived from the conventional dynamic panel model. Moreover, criticisms of these approaches, highlighted by Kripfganz (2016a) and Kripfganz and Breitung (2022), further motivated exploration into alternative analytical methods. The approach is versatile enough to encompass both fixed-effects and random-effects assumptions, accounting for heteroskedastic errors and higher-order autoregressive models. Additionally, it introduces panel-corrected standard errors, enabling robust inference in dynamic models characterized by cross-sectionally correlated errors (Breitung, 2022).

Table 6.6 - HDI Rural and HDI Urban with Bias Correction

Variables	Bias-Corrected Estimation, FE	Bias-Corrected Estimation, RE	Quasi-maximum likelihood estimation	Variables	Bias-Corrected Estimation, FE	Bias-Corrected Estimation, RE	Quasi-maximum likelihood estimation
HDI Rural				HDI Urban			
L1.	0.832614***	0.9726023***	0.7708982***	L1.	0.8597953***	0.9947827***	0.8541919***
Rural Population	-6.69E-08	-4.56E-09	-3.58E-10	Urban Population	-9.56E-09	-5.58E-10	-1.66E-08
Rural Job	0.000000185**	1.53E-08	0.00000000174*	Urban Job	2.77E-08	1.79E-09	4.96E-08
Renewable Consumption	-.0332423**	-0.0015567	-0.000524***	Renewable Consumption	0.0003896	0.000078	0.0051911
Fossil Consumption	-0.0173978	-0.0038365	-.0002208**	Fossil Consumption	0.0003379	-0.0000867	0.0044285
CO2 Rural	114.8887*	34.27981	0.4588441	CO2 Urban	28.26075	1.523375	9.800406
CPI	0.004891	0.0085679*	-6.44E-06	CPI	-0.0010406	0.0000858	-1.49E-03
Technical Progress	1.403009	0.454252	0.0183343	Technical Progress	-0.125884	-0.017625	0.0006035
Eletricity Acess Rural	-0.0098985**	0.004114	-0.0000754*	Eletricity Acess Urban	0.000225	-0.0002332	0.0200275
Constant	11.90402***	1.408652	0.1635245***	Constant	0.9064625	0.0311732	0.5629513
Generalized Hausman test	104.3587***		-	Generalized Hausman test	323.8910***		-
Arellano-Bond test							
H0: no autocorrelation order 1		-3.4627***	-		-1.1389		-
H0: no autocorrelation order 2		-1.6516*	-		-0.3984		-
H0: no autocorrelation order 3		0.1443	-		-0.8756		-

Note: *** means statistically significant at 1%, 5%, and 10%, respectively.

The outcomes of the Arellano-Bond test indicate a lack of substantiated serial correlation in the differenced errors. This conclusion is drawn based on the rejection of the null hypothesis, as signified by a p-value.

The variable "Rural Job" exhibits statistical significance with a positive coefficient in this context. This suggests that an increase in job opportunities within the rural area is expected to augment regional development. Similarly, a rise in environmental pressure, specifically carbon dioxide emissions, is associated with an increase in development. On the contrary, there exists a negative relationship renewable and fossil energy matrix, which is statistically significant. Lastly, access to electricity is also statistically significant but demonstrates a negative coefficient. Expanding electricity accessibility appears to correspond with a reduction in the Human Development Index for this region.

Table 6.7 - HDI Urban Dynamic Panel Estimations

Variables	One-Step System GMM	Two-Step System GMM	One-Step Difference GMM	Two-Step Difference GMM	GMM
HDI Urban					
L1.	0.9893467***	0.99168***	0.3923191***	0.4131628***	0.7888289***
Urban Population	-0.0000000139*	-0.0000000153*	0.000000204**	0.000000202***	-0.0000000208**
Urban Job	0.0000000464**	0.0000000525**	-2.76E-07	-0.000000329**	0.0000000637**
Renewable Consumption	0.0062799***	0.0057305***	0.0018142	0.0035699	-0.0019774
Fossil Consumption	0.007383***	0.0073742***	0.0192165	0.016714	-0.001229
CO2 Urban	31.11184	19.61172	955.2682***	771.9346***	2.552254
CPI	-	-	-	-	-
Technical Progress	-	-	-	-	-
Eletricity Acess Urban	0.0025469	0.0012872	0.002135	0.0066448	0.0015277
Constant	-	-	-	-	-
Arellano-Bond test					
H0: no autocorrelation order 1	3.64***	3.61***	-1.76*	-1.52	-
H0: no autocorrelation order 2	1.51	1.49	-0.6	-0.88	-
H0: no autocorrelation order 3	-	-	-	-	-

Note: *** means statistically significant at 1%, 5%, and 10%, respectively.

In the realm of urban socio-economic development, the findings from dynamic panel estimations present a complex array of outcomes. Results derived from the One and Two-Step System estimations reveal that urban population growth is associated with a decline in human development, whereas an increase in employment opportunities correlates with an enhancement in the urban HDI. This underscores the connection between individual well-being and earning potential, implying that some form of compensation significantly impacts overall welfare. Furthermore, energy consumption exhibits statistical significance with a positive influence on urban development.

Conversely, access to electricity does not exhibit statistical significance. This observation suggests that within urban areas, where such infrastructure is generally well established, its presence may not distinctly contribute to fostering development. The Two-Step Difference model results indicate that a rise in job opportunities tends to impede development in urban areas. Conversely, an increase in population yields the opposite effect. A similar relationship is evident concerning environmental pressure, where an upsurge in emissions correlates with improved development. This could suggest that heightened economic activity, often positively associated with emissions, might elucidate the observed enhancement in development—an indication of the potential benefits economic growth can offer.

In conclusion, the conventional GMM analysis underscores two critical relationships in the context of urban socio-economic development. Firstly, it reveals that an increase in urban population has an adverse impact on human development within the urban landscape. Secondly, employment exhibits a positive association, indicating that higher employment rates contribute to an improvement in the Urban Human Development Index.

6.6.2. Discussion

The observed inverse relationship between population growth and the HDI in rural areas can be rationalized within the context of the predominantly underdeveloped economies in the sample. An upsurge in the rural population in these economies is anticipated to potentially lead to food scarcity, subsequently diminishing the quality of life and life expectancy for individuals. Moreover, this population increase may result in heightened unemployment in the future, exerting a detrimental influence on regional development. Given that rural employment is typically associated with a positive impact on regional development, the adverse effects of unemployment become evident. Rural jobs play a direct role in enhancing regional development, as employment provides individuals with income, enabling them to access goods that enhance their quality of life and, consequently, contribute to the overall human development of the region.

The analysis of energy consumption, encompassing both renewables and fossil fuels, yields a negative impact on the rural Human Development Index. The inverse relationship resonates with the outcomes elucidated by Adekoya et al. (2021).

The inverse relationship might be attributed to the cost implications or technological barriers associated with renewable energy generation. Given the underdeveloped economic status of the region, individuals may face challenges in affording and accessing advanced renewable energy technologies. Consequently, the trade-offs required to adopt these technologies could outweigh the benefits, ultimately resulting in a more detrimental impact on the rural HDI.

Lastly, the analysis of fossil fuel consumption show a negative relationships. The observed negative relationship may be linked to the environmental degradation resulting from fossil fuel consumption. The adverse impact on the environment poses a concern, potentially outweighing the benefits and contributing to a decline in the rural HDI. An alternative viewpoint in the debate could be linked to the economic implications of the prevailing energy matrix. Despite the ongoing shift towards sustainable energy sources, the consumption of fossil fuels remains pivotal for the global economy. Consequently, given the persistently high demand for these resources, their prices in the international market often soar. This scenario poses a significant challenge for the current context of African economies. Consequently, a considerable trade-off is necessitated, exerting a detrimental impact on the HDI within this region. This effects underscore the intricate balance between cost-efficiency and environmental sustainability in energy consumption and its repercussions on regional development.

An intriguing aspect highlighted in the existing literature is the notion that an escalation in the HDI typically leads to a reduction in environmental pressure (Evans et al., 2022; Long et al., 2023; Simionescu, 2021). This perspective suggests that advancing human development could serve as a mechanism to mitigate environmental degradation. However, the outcomes observed in this study present a contrasting relationship. Specifically, in this sample, CO_2 emissions exhibit a positive impact on HDI, aligning with the findings of Adekoya et al. (2021).

The association of CO_2 emissions can elucidate this positive correlation between CO_2 emissions and HDI with heightened economic activity. Economic growth is an essential prerequisite for human development, and CO_2 emissions are often linked to increased economic endeavors. Given the underdeveloped status of the economies in this study, this result could signify that these regions have yet to reach a turning point where human development becomes a primary factor contributing to environmental preservation. The findings underscore the complex interplay between economic growth, human development, and environmental sustainability, particularly in developing economies.

The literature on corruption's impact on human development lacks consensus. Some studies, like Feruni et al. (2020), Tudorache (2020), and Uddin et al. (2023), highlight corruption's detrimental effects on development. Conversely, others, such as Korez-vide and Bobek (2021), indicate a positive relationship, aligning with the findings in this sample. Corruption involves the irregular use of public resources for personal gain (Khumawala & Ramchand, 2005). In this scenario, state agents might expedite bureaucratic processes through illicit payments, potentially enhancing local HDI in these regions.

Modern lifestyle heavily depends on electricity, which is vital for well-being, ranging from food preservation to leisure. However, the findings present a nuanced picture. On one hand, a decrease in rural electricity access could enhance the Human Development Index (HDI), suggesting an unexpected positive relationship. Conversely, a positive correlation was found, indicating that improving electricity access tends to enhance the HDI in the region, aligning with the observations of Acheampong et al. (2021), warranting a thorough investigation. Ideally, individual-level data for each country in the sample should be examined if available.

As previously outlined, this research focuses on both rural and urban domains. The preceding paragraphs discuss the outcomes related to the Rural Human Development Index.

The bias-corrected estimates did not yield robust results for the urban area.

6.7. Conclusions

The primary objective of this study was to investigate the impact of population, jobs, renewable and non-renewable energy consumption, access to electricity, environmental pressure, corruption and technological progress — on the Human Development Index (HDI) across 39 African economies. The analysis was conducted separately for both rural and urban areas.

In the rural context, the findings suggest that a rise in population has a detrimental impact on the HDI, while an increase in job opportunities contributes to its improvement. However, the influence of renewable and non-renewable energy consumption, as well as access to electricity, yielded negative results. Intriguingly, environmental pressure was found to positively influence HDI. Lastly, an unexpected result was observed: corruption was positively associated with HDI in rural areas.

Regarding the urban area analysis, a parallel relationship was observed concerning the increase in population, similar to the rural context. An increase in urban population correlates with a decrease in the regional HDI. Conversely, an increase in employment positively impacts urban human development. Unlike the rural areas, energy consumption (both renewable and non-renewable) positively influences development in urban areas, representing a distinct result. Lastly, CO_2 emissions, serving as a proxy for environmental pressure, have a positive impact on the Human Development Index in the urban region. However, these outcomes were derived using conventional GMM models, and the bias-corrected estimates did not exhibit robustness in their findings.

This comparative analysis between rural and urban areas holds significant value for policymakers. Informed decision-making based on statistical insights is crucial for policy formulation. Tailoring policies to the specific needs of each area can enhance their effectiveness, ensuring a more targeted and impactful approach to address the distinct requirements of rural and urban regions.

A significant limitation of this study is the restricted time horizon imposed by a change in the Corruption Perception Index (CPI) methodology. This change limited the observations to 11 years. To address this limitation, an effort was made to include as many African countries as possible in the sample. However, this approach could introduce issues, given that countries have unique contextual challenges. For future research endeavors, it is advisable to uphold the existing variables and contemplate conducting analyses for smaller cohorts of countries, or potentially delve into individual analyses, contingent upon the availability of substantial data. Moreover, it is crucial to integrate variables that encompass essential aspects such as access to safe drinking water, adequate sewage facilities, and the abundance of vital natural resources into the analytical framework. This approach would allow for a more in-depth and context-specific understanding of the dynamics at play.

References

Acheampong, A. O., Erdiaw-kwasie, M. O., & Abunyewah, M. (2021). Does energy accessibility improve human development ? Evidence from energy-poor regions. Energy Economics, 96, 105165. https://doi.org/10.1016/j.eneco.2021.105165

Adekoya, O. B., Olabode, J. K., & Ra, S. K. (2021). Renewable energy consumption , carbon emissions and human development : Empirical comparison of the trajectories of world regions. Renewable Energy, 179, 1836–1848. https://doi.org/10.1016/j.renene.2021.08.019

Arellano, M., & Bond, S. (1991). Some Tests of Specification for Panel Carlo Application to Data : Evidence and an Employment Equations. The Review of Economic Studies, 58(2), 277–297.

Baum, C. F., Schaffer, M. E., & Stillman, S. (2003). Instrumental Variables and GMM: Estimation and Testing. The Stata Journal: Promoting Communications on Statistics and Stata, 3(1), 1–31. https://doi.org/10.1177/1536867x0300300101

Bhargava, A., & Sargan, J. D. (1983). Estimating dynamic random effects models from panel data covering short time periods. In Econometrica (Vol. 51, Issue 6, pp. 3–28). https://doi.org/10.1142/9789812773319_0001

Blundell, R., & Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. Journal of Econometrics, 87(1), 115–143. https://doi.org/10.1016/S0304-4076(98)00009-8

Boldyrev, Y., Chernogorskiy, S., Shvetsov, K., Zherelo, A., & Kostin, K. (2019). A mathematical model of regional socio-economic development of the russian arctic zone. Resources, 8(1), 1–10. https://doi.org/10.3390/resources8010045

Breitung, J., Kripfganz, S., & Hayakawa, K. (2022). Bias-corrected method of moments estimators for dynamic panel data models. Econometrics and Statistics, 24, 116–132. https://doi.org/10.1016/j.ecosta.2021.07.001

Chen, Y., Khurshid, A., Rauf, A., Yang, H., & Cantemir, A. (2023). Natural resource endowment and human development: Contemporary role of governance. Resources Policy, 81(January), 103334. https://doi.org/10.1016/j.resourpol.2023.103334

Dialga, I., & Ouoba, Y. (2022). Resources , Environment and Sustainability How do extractive resources affect human development ? Evidence from a panel data analysis. Resources, Environment and Sustainability, 7(April 2021), 100046. https://doi.org/10.1016/j.resenv.2022.100046

Dreher, A., & Gassebner, M. (2013). Greasing the wheels? The impact of regulations and corruption on firm entry. Public Choice, 155(3–4), 413–432. https://doi.org/10.1007/s11127-011-9871-2

Elizabeth, V., & López, R. (2022). Los efectos del IDH sobre las emisiones de CO2 en América Latina y el Caribe Effects of the HDI on CO2 Emissions in Latin America and the Caribbean. Apuntes Del CENES, 41(74), 141–175.

Emara, A. M., & Mohamed, N. M. A. (2023). Global economic fl uctuations and human development : how is the impact transmitted in Egypt? Review of Economics and Political Science, 8(4), 250–270. https://doi.org/10.1108/REPS-06-2020-0072

Evans, E., Opoku, O., Dogah, K. E., & Adewale, O. (2022). The contribution of human development towards environmental sustainability. Energy Economics, 106(March 2021), 105782. https://doi.org/10.1016/j.eneco.2021.105782

Feruni, N., Hysa, E., Panait, M., Gabriela, I., & Brezoi, A. (2020). The Impact of Corruption , Economic Freedom and Urbanization on Economic Development: Western Balkans versus EU-27. Sustainability, 12, 1–22.

Haabazoka, L., & Mweetwa, C. (2019). The Relationship Between Financial Inclusion and Economic Development in the New Digital Era for Developing Countries . A Case of Zambia. Springer Nature Switzerland, 1, 1072–1090. https://doi.org/10.1007/978-3-030-69415-9

Hsiao, C., Pesaran, M. H., & Tahmiscioglu, A. K. (2002). Maximum likelihood estimation of fixed effects dynamic panel data models covering short time periods. Journal of Econometrics, 109, 107–150.

Huntington, S. P. (1968). Political order in changing societies. In Political Order in Changing Societies. https://doi.org/10.5771/0506-7286-1970-2-257

Ifa, A., & Guetat, I. (2022). Analysing short-run and long-run causality relationship among public spending, renewable energy consumption, non-renewable energy consumption and economic growth: Evidence from eight of South Mediterranean Countries. Energy Exploration and Exploitation, 40(2), 554–579. https://doi.org/10.1177/01445987211049304

Khumawala, S., & Ramchand, L. (2005). Country Level Corruption and Frequency of Issue in the U.S. Market. Journal of Public Budgeting, Accounting & Financial Management, 341–364.

Korez-vide, R., & Bobek, V. (2021). Culture , corruption and economic development: The case of emerging economies. Acta Oeconomica, March. https://doi.org/10.1556/032.2021.00005

Kripfganz, S. (2016a). Quasi–maximum likelihood estimation of linear dynamic short-T panel-data models. Stata Journal, 16(4), 1013–1038. https://doi.org/10.1177/1536867x1601600411

Kripfganz, S. (2016b). xtdpdqml : Quasi-Maximum Likelihood Estimation of Linear Dynamic Panel Data Models in Stata. In Stata Journal (Issue forthcoming, pp. 1–22).

Kripfganz, S. (2019). Generalized method of moments estimation of linear dynamic panel data models. London Stata Conference, 1–128. http://www.kripfganz.de/stata/

Kripfganz, S. (2020). Introduction System GMM Postestimation Special features Summary Generalized method of moments estimation of linear dynamic panel data models. http://www.kripfganz.de/stata/

Kripfganz, S., & Breitung, J. (2022). Bias-corrected estimation of linear dynamic panel data models (pp. 1–15).

Leff, N. H. (1964). Economic Development Through Bureaucratic Corruption. American Behavioral Scientist, 8(3), 8–14. https://doi.org/10.1177/000276426400800303

Li, Y., Zhang, W., Zhao, B., Sharp, B., Gu, Y., Xu, S., & Rao, L. (2023). Natural resources and human development : Role of ICT in testing the resource-curse hypothesis in N11 and BRICS countries. Resources Policy, 81(November 2022), 1–7. https://doi.org/10.1016/j.resourpol.2023.103400

Long, H., Li, W., & Otrakçı, C. (2023). Sustaining environment through natural resource and human development : Revisiting EKC curve in China through BARDL. Resources Policy, 85(PB), 103973. https://doi.org/10.1016/j.resourpol.2023.103973

Luqman, M., Li, Y., Khan, S. U. D., & Ahmad, N. (2021). Quantile nexus between human development, energy production, and economic growth: the role of corruption in the case of Pakistan. Environmental Science and Pollution Research. https://doi.org/10.1007/s11356-021-14744-2

Mohamed, A. (2020). The Impact of Cprruption on Human Development in Egypt. Asian Economic and Financial Review, 10(5), 574–589. https://doi.org/10.18488/journal.aefr.2020.105.574.589

Nguea, S. M. (2023). Improving human development through urbanization, demographic dividend and biomass energy consumption. Sustainable Development, July, 1–19. https://doi.org/10.1002/sd.2528

Qureshi, M. A., Qureshi, J. A., Ahmed, A., Qaiser, S., Ali, R., & Sharif, A. (2020). The Dynamic Relationship Between Technology Innovation and Human Development in Technologically Advanced Countries: Fresh Insights from Quantiles-on-Quantile Approach. Social Indicators Research, 152(2), 555–580. https://doi.org/10.1007/s11205-020-02451-3

Radaideh, R. M. H. (2022). The Impact of Good Governance on Human Development in Jordan : A Case Study. Journal of Educational and Social Research, 12(5), 81–95.

Roodman, D. (2009). A Note on the Theme ofToo Many Instruments. Oxford Bulletin of Economicsand Statistics, 1, 135–158. https://doi.org/10.1111/j.1468-0084.2008.00542.x

Roser, M. (2023). Employment in agriculture. Our World in Data. Retrieved from https://ourworldindata.org/employment-in-agriculture

Salkind, N. (2013). Generalized Method of Moments. Encyclopedia of Measurement and Statistics. https://doi.org/10.4135/9781412952644.n185

Sasmaz, M. U., Sakar, E., & Yayla, Y. E. (2020). The Relationship between Renewable Energy and Human Development in OECD Countries: A Panel Data Analysis. Sustainability, 12(7450), 1–16.

Simionescu, M. (2021). The nexus between economic development and pollution in the European Union new member states . The role of renewable energy consumption. Renewable Energy, 179, 1767–1780. https://doi.org/10.1016/j.renene.2021.07.142

Stryzhak, O., National, S. K. K., Tupa, M., & Rodzik, J. (2022). Relationship Between the Level of Human Development and Institucional Quality. Economics & Sociology, 15(2), 274–295. https://doi.org/10.14254/2071-789X.2022/15-2/1

Tudorache, M. (2020). Human Development in the European Union and its Determinants. Journal of EU Research in Business, 2020. https://doi.org/10.5171/2020.215473

Uddin, I., Ahmad, M., Ismailov, D., Eid, M., Akhmedov, A., Khasanov, S., & Ul, M. (2023). Research in Globalization Enhancing institutional quality to boost economic development in developing nations : New insights from CS-ARDL approach. Research in Globalization, 7(June), 100137. https://doi.org/10.1016/j.resglo.2023.100137

Ullah, S., Akhtar, P., & Zaefarian, G. (2018). Dealing with endogeneity bias: The generalized method of moments (GMM) for panel data. Industrial Marketing Management, 71(January), 69–78. https://doi.org/10.1016/j.indmarman.2017.11.010

Chapter 7 – General Conclusions

This doctoral thesis centers it is focus on comprehending the dynamics of economic growth and socio-economic development. The current study adopted a dual research structure, comprised of two distinct phases. The initial approach entailed a theoretical examination, which involved identifying prevailing trends and gaps in the existing literature. Subsequently, the second approach employed an empirical approach for the study's foundation.

The examination of economic growth and development is conducted by employing classical models that encompass considerations of an investment in capital, technological advancements, and the labor force. Furthermore, this exploration takes into account the institutional perspective, scrutinizing economic policies, globalization, and the impact of corruption.

In light of the contemporary emphasis on behavioral change in response to environmental degradation and the imperative of constructing a more sustainable society, the study also delves into the role of both renewable and non-renewable energy consumption.

Throughout the course of this research, a multitude of recommendations has been articulated in alignment with the findings from each analysis. In this section, we undertake the task of summarizing and comparing the challenges and recommendations that emerge from each analysis. The objective is to highlight the most viable recommendations that can be effectively implemented by policymakers and governments. By identifying the challenges that emanate from these complex relationships, we can propose tailored and refined solutions. Therefore, it is paramount to accurately identify the pertinent issues associated with this multifaceted subject matter.

7.1. Economic Growth

The analysis of economic growth in this study was conducted using two distinct models. The first model was based on the principles of endogenous growth, drawing inspiration from the contributions of Lucas and Romer. This model aimed to expand upon the concepts and propositions put forth by these two influential authors. The findings of the first model are as follows:

- Gross capital formation (investment) positively contributes to economic growth;
- The labor force has a negative impact on economic activity;
- Workers with advanced education negatively affect the economy, implying that an overemphasis on highly educated workers may have adverse effects on economic performance;
- Workers with intermediate education have a positive impact on the economy;
- Instability or political uncertainty is likely to negatively affect economic growth, highlighting the importance of political stability and predictability for economic development;

- The use of a renewable energy matrix positively contributes to economic growth, emphasizing the benefits of sustainable energy sources in fostering economic expansion;
- Oil consumption has a negative impact on economic growth, suggesting that heavy reliance on oil can hinder the economy.

The second model introduced in the study incorporated an open economy framework, taking into consideration the impacts of globalization on economic growth. This approach sought to account for the effects of globalization in the context of economic growth dynamics. The findings of the second model are as follows:

- Energy consumption, both renewable and non-renewable, contributes to economic growth with a "U-shaped" pattern;
- There is a positive relationship between globalization and economic growth, indicating that increased globalization is associated with higher economic growth.

Challenges – Economic Growth analyses:

The primary metric for assessing economic growth is Gross Domestic Product (GDP), whether in total or per capita terms. However, it is important to note that GDP only captures what is produced within a specific economy during a given time period. As such, it provides an approach that predominantly addresses the production aspects of the economy, while omitting consideration of intricate institutional factors, such as cultural elements, which are challenging to measure and compute. Consequently, the relationships that attempt to elucidate the factors influencing economic growth are numerous and intricate. It is worth noting that the results obtained in this study, which pertain to economic growth, serve as examples. This is due to the fact that the samples used for each economic growth model were not uniform or consistent, further highlighting the complexity and variability in the analysis of economic growth.

Despite the variations in the samples used, a consistent conclusion can be drawn that the consumption of renewable energies has a positive impact on economic growth. This positive effect may be attributed to several factors. Firstly, renewable energies are often produced domestically and are influenced by geographical and natural conditions, which contribute to local production. In contrast, fossil fuels like oil, natural gas, and coal are often associated with the exploitation of finite natural resource reserves and are susceptible to price fluctuations in the international market. This natural resource dependency can make renewable energy consumption less vulnerable to external market shocks.

Furthermore, the evolution of renewable energy technology is an ongoing process, with the expectation that its implementation costs will decrease and efficiency will increase over time. This trend makes the adoption of renewable energy sources increasingly attractive and cost-effective. As a result, it is reasonable to anticipate that in the near future, the positive impact of renewable energy consumption on economic growth will become even more pronounced, contributing to sustained economic development, since the economic growth depends on energy consumption, and consumption requires either production or purchase.

A significant challenge in achieving economic growth relates to the workforce, and it may seem counterintuitive that a negative relationship has been observed between workers and their contribution to economic growth. However, a more in-depth analysis, particularly when considering the level of education, provides revealing insights. This analysis indicates that only workers with intermediate training make a positive contribution to growth.

Workers with basic education do not contribute to growth, which can be rationalized by their typically lower performance and productivity levels, falling below the desired standards. On the other hand, workers with higher education levels also do not positively contribute, which is unexpected since higher education should theoretically enhance an individual's productive capacity.

To address this issue, an analysis suggests that the costs associated with training highly educated individuals and the wages they demand are high to the extent that, in the end, their overall contribution becomes negative within the economic aggregate. Therefore, a key challenge for achieving economic growth in relation to the workforce is to invest in more technical training that aligns with the demands of the labor market. This includes encouraging individuals with basic education to seek additional technical training, thereby fostering their ability to make a positive contribution to economic growth.

The stability of the political economy is of paramount importance for fostering economic growth. This stability allows economic agents to anticipate and plan for the government's actions regarding fiscal, monetary, and exchange rate policies. Predictability in government behavior and strategies creates a favorable environment for economic agents to make informed investment decisions, which, in turn, is crucial for expanding the economy.

Therefore, achieving economic growth presents a significant challenge, as it necessitates transparency and a seamless transition between economic policies during changes of leadership. In this context, for growth to be sustainable, it is imperative that markets can comprehend and foresee the actions that policymakers will take. This predictability enables businesses and individuals to adapt and invest with confidence, contributing to the long-term sustainability of economic growth.

Opportunities – Economic Growth analyses

In the realm of energy, renewable sources have demonstrated a positive impact on economic growth. Given the fundamental role of energy infrastructure in driving growth, a gradual transition to renewable energies is crucial for achieving sustainable economic growth and concurrently mitigating environmental degradation. This transition aligns with the need to balance economic progress with environmental responsibility.

Regarding the workforce, the education of the population plays a pivotal role. It is incumbent upon governments to assess the specific demands of the domestic labor market and encourage the development of more technical training programs. This can be achieved through the creation of educational initiatives or by providing incentives to educational institutions, with a focus on aligning training programs with contemporary job market demands.

The stability of economic policies is another critical factor in promoting economic growth. Policymakers should work to develop legal mechanisms that enhance the transparency and efficiency of macroeconomic strategies. This not only fosters predictability for economic agents but also helps reduce information asymmetry, ultimately stimulating increased investments that contribute to economic growth.

Globalization, while potentially beneficial for economic growth through increased trade relations, also exposes the economy to international fluctuations. To address this challenge, it is advisable to foster deeper partnerships beyond mere trade relations. These partnerships can encompass collaborative research efforts, including technology exchanges that yield mutual benefits. Additionally, collaborations involving the exchange of researchers can promote knowledge expansion among all stakeholders, all with the shared goal of improving both the economy and society at large. These multidimensional partnerships can help buffer the potential vulnerabilities associated with increased globalization.

Suggestions for Economic Growth Worldwide

- Elaboration of agreements along the lines of the Kyoto Protocol, but with a focus on the energy transition to a renewable matrix:

  Creating international agreements akin to the Kyoto Protocol but with a specific emphasis on transitioning to renewable energy sources is a proactive step toward addressing global energy and climate challenges. These agreements should establish clear targets, commitments, and mechanisms for countries to shift from fossil fuels to renewables. By setting emission reduction goals and providing incentives for the adoption of clean energy technologies, such agreements can facilitate the transition to a sustainable and low-carbon energy matrix on a global scale and enhances the economic growth worldwide.

- Global targets for the uptake of renewable energy:

  Setting global targets for the adoption of renewable energy is an effective means to accelerate the transition to clean energy sources. These targets should specify the percentage of energy that countries aim to derive from renewables within a defined timeframe. Such global targets can encourage countries to invest in renewable energy infrastructure, incentivize technological advancements, and promote international collaboration in achieving a more sustainable energy future.

- Expansion of the OECD and/or creation of new groups to study and suggest guidelines for greater clarity in economic policies:

To enhance the clarity and effectiveness of economic policies on a global scale, the expansion of existing organizations like the Organization for Economic Co-operation and Development (OECD) or the establishment of new international groups can be instrumental. These organizations can bring together policymakers, experts, and representatives from various countries to conduct in-depth analyses of economic policies. Their role would be to provide recommendations and guidelines that promote transparency, efficiency, and consistency in economic decision-making, fostering a more stable and conducive environment for investment and growth.

- Supporting Poor Economies to Achieve Sustainable and Growth Goals:

Addressing the challenges faced by economically disadvantaged nations is essential for global economic development. International efforts should focus on supporting these countries in their pursuit of sustainable and inclusive growth. This support can take various forms, including financial assistance, technology transfer, capacity building, and trade agreements that facilitate access to global markets. By helping poor economies meet their development goals, we can contribute to a more equitable and prosperous world while also fostering stability and cooperation on a global scale.

7.2. Socio-Economic Development

This thesis also delved into the realm of socio-economic development by employing a regional development model that incorporated key pillars such as population, employment, and energy. As part of this research, the model was expanded to encompass corruption, technical progress, carbon dioxide emission and access to electricity as additional drivers that can significantly impact socio-economic development. The contributions and findings stemming from this expanded model include:

- Population growth tends to have a negative impact on socio-economic development;
- Real job growth has a positive effect on socio-economic development;
- Energy consumption negatively affects socio-economic development in rural areas but contributes to development in urban areas;
- Access to electricity exhibits an inverse relationship with socio-economic development;
- Corruption has a detrimental effect on development;
- Carbon dioxide emissions contribute to improved socio-economic development.

Challenges – Socioeconomic Development analyses:

The Human Development Index (HDI) served as the metric for analyzing socioeconomic development in this study. Population growth exhibits varying trends across different regions of the globe, with some areas experiencing population decreases. Consequently, the challenge in fostering socioeconomic development is to tailor policies to the unique needs of each region to ensure a consistent and continuous improvement in living standards.

While job creation has traditionally been a key driver of development, the increasingly dynamic and automated economy presents new challenges. The automation of jobs and the changing structure of the labor market may lead to a loss of employment opportunities. Therefore, a significant challenge in achieving socioeconomic development lies in the ability to adapt and create new professions in alignment with these labor market changes. Workforce training and education become critical factors in addressing this challenge.

The surprising positive impact of carbon dioxide emissions on development is likely linked to industrialization and economic activity. Nevertheless, the great challenge lies in transitioning to a more sustainable form of economic growth that minimizes environmental degradation without compromising overall social well-being. Balancing economic progress with environmental responsibility is crucial for achieving sustainable and inclusive development in the long term.

Opportunities – Socioeconomic Development analyses:

Opportunities for advancing socioeconomic development are contingent upon the formulation of strategies aimed at mitigating job displacement in the context of an economy characterized by escalating automation. Simultaneously, efforts must be directed toward curtailing carbon emissions, thereby fostering a more sustainable economic framework, all the while avoiding any adverse consequences on economic activity that might impede the course of socioeconomic development.

Suggestions for Socio Economic Development Worldwide

- The training of the workforce should be aligned with market demands to prevent an escalation in the unemployment rate. This entails ensuring that individuals are equipped with the skills and qualifications that are sought after by employers, thus bolstering their employability.
- In regions experiencing an uptick in birth rates, it is imperative to enhance access to education, healthcare, and employment opportunities. Public policies should be tailored to the unique context of these regions, addressing the specific needs and challenges presented by increased population growth.

7.3. Limitations and Future Research’s

The primary limitation associated with this analysis pertains to data availability. Specifically, a more comprehensive dataset is required, particularly concerning the workforce and broader coverage of the Global Economic Policy Uncertainty (GEPU) index. Furthermore, it is important to recognize the inherent limitations of using an index as analytical tool. While indices are frequently employed in academic research, they may not fully capture the nuanced and multifaceted nature of real-world situations.

From our perspective, having more detailed information on the workforce, including age group breakdowns for each educational level, is of paramount importance. This limitation constrains the methodologies and analyses, necessitating the adoption of panel data analysis, which estimates results for a broad spectrum of countries. Having more extensive data availability would be ideal for conducting individualized analyses, enabling specific diagnoses for distinct situations and thereby enhancing the effectiveness of policy recommendations.

Consequently, the continuation of research stemming from this thesis entails replicating studies on an individual or more homogeneous group basis, if the data is available, with the aim of obtaining results and conclusions that are more tailored to specific countries or regional clusters. This approach will enable a deeper and more precise understanding of the unique dynamics and challenges faced by each country or group of countries.

Appendix

Chapter 3

A.1 Search Protocol some details

The search protocol is dated, which is a work limiter. The Scopus database updates its article base very frequently, so it becomes impossible to replicate and analyze all the work in it.

On the Scopus (https://www.scopus.com) search page, which is restricted access, requiring a login, we researched the three key words used in our research (Renewable Energy, Economic Growth and Development Economic), obtaining a total of 2836 documents. However, articles published in Biochemistry, Genetics and Molecular Biology, Medicine, Physics and Astronomy, Immunology and Microbiology, Pharmacology, Toxicology and Pharmaceutics, Arts and Humanities, Psychology, Health Professions and Veterinary. Below can be seen the final research protocol, which resulted in a sample of 291 documents, which later, went through another screening stage that culminated in the 199 articles analyzed in this study.

Search Protocol

TITLE-ABS-
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) OR EXCLUDE (SUBJAREA , "AGRI") OR EXCLUDE (SUBJAREA , "MATH") OR EXCLUDE (
SUBJAREA , "BIOC") OR EXCLUDE (SUBJAREA , "MATE") OR EXCLUDE (SUBJAREA , "CO
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"CHEM") OR EXCLUDE (SUBJAREA , "IMMU") OR EXCLUDE (SUBJAREA , "ARTS") OR EX
CLUDE (SUBJAREA , "DECI") OR EXCLUDE (SUBJAREA , "HEAL") OR EXCLUDE (SUBJARE
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Source: prepared by the authors with data from Scopus.

A.2. Renewable and Non-Renewable Energy Consumption, Economic Growth and Economic Development

Fonseca, J. M., et al. (2020); Le, H. P., & Sarkodie, S. A. (2020); Gasmi, S., et al. (2020); Maneejuk, T., et al. (2020); Baba, M., & Amfo, T. (2021); Singh, N., et al. (2019); Krakauer, N. (2014); Tawiah, V., et al. (2021); Pereira, D., et al. (2021); Asafu-Adjaye, J., et al. (2016); Khan, R., & Kong, X. (2020); Hassan, S., & Nosheen, S. (2019); Al Mamun, M. A., et al. (2018); Soukiazis, E., et al. (2019); Cerqueira, P., et al.

(2020); Balsalobre-Lorente, D., et al. (2020); Alam, M. R., & Murad, M. (2020); Aye, G. C., & Edoja, I. E. (2017); Abdollahi, M. (2020); Yilanci, V., et al. (2021); Tsaurai, K. (2020); Gosens, J. (2020); Kutan, A. M., et al. (2018); Yu, Z., et al. (2019); Adedoyin, F. F., et al. (2020); Simas, A. B., & Pacca, A. C. (2013); Hdom, K., & Fuinhas, J. A. (2020); Magazzino, C., et al. (2021); Lisin, I., et al. (2016); Johansson, B., et al. (2015); Liu, W., et al. (2016); Qu, H., et al. (2017); Yuan, Z., et al. (2017); Zhao, X., et al. (2018); Sarkodie, S. A., et al. (2020); Cui, L., et al. (2021); Liu, W., et al. (2021); Qin, X., et al. (2020); Tseng, L. (2019); Muhammed, A., & Tekbiyik-Ersoy, F. (2020); Zhang, W., et al. (2014); Wang, X., et al. (2019); Alola, A. A., et al. (2019); Melas, D., et al. (2017); Chovancová, J., & Vavrek, R. (2020); Adedoyin, F. (2020); Radmehr, H., et al. (2021); Simionescu, M. (2017); Madsen, J. B., & Hansen, J. (2019); Bilan, Y., et al. (2019); Busu, T. (2019); Adedoyin, F. F., et al. (2020); Xie, Y., et al. (2020); Azretbergenova, G., et al. (2021); Alsaleh, A., et al. (2021); Shahbaz, M., et al. (2017); Silva, E. M., et al. (2012); Kravtsiv, O., et al. (2017); Pryshliak, I., & Tokarchuk, L. (2020); Dinç, M., & Akdoğan, T. (2019); Ertay, T., et al. (2013); Safta, M., et al. (2013); Štreimikienė, D., & Mikalauskienė, A. (2016); Bere, A., et al. (2017); Raszkowski, A., & Bartniczak, B. (2019); Stadniczeńko, D. (2020); Miskinis, K., et al. (2019); Allan, G., et al. (2008); Tishkov, A., et al. (2020); Koengkan, S., et al. (2019); Ben Jebli, M., et al. (2019a); Le, H. P., & Bao, X. (2020); Zeeshan, M., et al. (2020); Pansera, M. (2013); Pinzón, J. A. (2018a); Robalino-López, A., et al. (2014); Belloumi, M., & Alshehry, A. (2015); Hosseini, S. M., et al. (2019); Nosheen, S., et al. (2021); Murshed, M., & Dao, M. (2020); Arshad, M., et al. (2020); Rauf, A., et al. (2018); He, J., et al. (2021); Bakar, M. A., et al. (2019); Baek, J., et al. (2015); Huq, R. (2018); Sulaiman, C., & Abdul-Rahim, S. (2017); Ridzuan, M. S., et al. (2020); Sinaga, H., et al. (2019); Roespinoedji, D., et al. (2019); Daryono, M., et al. (2019); Surya, I., et al. (2021); Sugiawan, D., & Managi, S. (2016); Prastiyo, D., et al. (2020); Saudi, M., et al. (2019); Nguyen, H. M., et al. (2019); Hong, X., & Yen, C. (2019); Chandio, A., et al. (2019); Abbasi, A., et al. (2020); Khan, M. K., et al. (2020); Bano, S., et al. (2021); Shabbir, M., et al. (2020); Hasanov, F., et al. (2019); Zhanseitov, T., et al. (2020); Ike, L., et al. (2020); Asongu, S. A., et al. (2020); Imasiku, M., et al. (2020); Rutebuka, D., et al. (2018); Njoke, A., et al. (2019); Riti, S., & Shu, H. (2016); Tenaw, T. (2021); Ben Jebli, M., et al. (2015); Chambers, J., et al. (2018); Sovacool, B. K., & Walter, L. (2019); Carfora, V., & Scandurra, G. (2019); Waheed, M., et al. (2019); Moraru, M. (2015); Marolin, P., et al. (2020); Barrett, A., et al. (2008); Han, J., et al. (2009); Chen, G. C., & Lees, F. (2016); Warner, R., & Jones, M. (2019); Laila, N., et al. (2021); Karim, M. A., et al. (2019); Hadiwijoyo, S., et al. (2013); Katina, P., et al. (2018).

A.3. Transition to a Low-Carbon Economy/ Energy Efficiency

Rahman, M. M., et al. (2016); Gielen, D., et al. (2019); Taghizadeh-Hesary, F., & Rasoulinezhad, E. (2020); Murshed, M. (2020); Twum, E. A., et al. (2021); van der Zwaan, B., et al. (2018); Qi, Y., et al. (2014); Ou, X., et al. (2017); Zhang, H., et al. (2020); Sarangi, S., et al. (2019); Ortega-Ruiz, M., et al. (2020); Aized, M., et al. (2018); Urban, F., et al. (2018); Jianzhong, Z., et al. (2018); Gao, S., et al. (2020); O'Mahony, J., et al. (2012); Atis, T., et al. (2014); Oteman, M., et al. (2017); MacKinnon, J. G., et al. (2019); Hodson, M., et al. (2018); Rehan, M., et al. (2016); Monasterolo, I., & Raberto, M. (2019); Bollino, C. A., et al. (2017); Wysokińska, Z. (2013); Haas, W., et al. (2015); Zhang, Z. (2010); Odgaard,

S. (2015); Lanshina, T., & Barinova, S. (2017); Henrysson, M., & Hendrickson, C. (2021); Adewuyi, A. O., et al. (2020).

A.4. Environmental Degradation

Nazeer, A., et al. (2016); Cheng, C., et al. (2019); Sarkodie, S. A. (2020); Adebayo, T., et al. (2021); Eyuboglu, K., & Uzar, U. (2020); Pham, T. T., et al. (2020); Akyol, S., & Uçar, H. (2021); Yuksel, A. (2008); Roespinoedji, R., et al. (2020); Huong, H. T., et al. (2021); Liu, C. H., et al. (2012); Lawson, S. (2020); Asumadu-Sarkodie, S., & Owusu, P. A. (2017); van Vuuren, D., et al. (2017); Odeku, K. O. (2017); Abam, F. I., et al. (2014).

A.5. Others

Xu, X., & Liu, H. (2019); Ari, A., & Koc, M. (2021); Mrówczyńska, M., et al. (2021); Wang, T., et al. (2021); Režný, J., & Bureš, J. (2019); Cucui, G., et al. (2018); Caruso, G., et al. (2020); Gaynanov, T., et al. (2015); Bhuiyan, M. A., et al. (2021); Mousavian, M., et al. (2020); Wang, P., et al. (2021); Siciliano, G., et al. (2015); Baumli, F., & Jamasb, T. (2020); Vidican, G. (2009); Khandekar, G., et al. (2015); Pretel, G., et al. (2015); Tu, J., et al. (2020); Marques, A. C., et al. (2020); Makarov, V., et al. (2021); Liu, J., et al. (2019); Zanuttigh, B., et al. (2015); Mijakovski, V., et al. (2018); Chen, X., et al. (2020); Hao, X., et al. (2020); Zhang, F., & Wu, Y. (2021); Singh, R. P., et al. (2020).zz (R. P. Singh et al., 2020).

Chapter 5

A1 – KOF GLOBALIZATION INDEX METRICS

To conduct a robust and coherent debate on the KOF Globalization Index, de facto, it is essential to comprehend the variables considered in formulating each indicator. The Globalization Index comprises three main dimensions, namely Economic Globalization, Social Globalization, and Political Globalization, which are assessed based on empirical evidence. Economic Globalization is divided into two categories, Trade Globalization and Financial Globalization. The former evaluates a country's commercial capacity by examining its trade in goods, number of trading partners, and trade in services. The latter category analyzes foreign direct investment, investment portfolio, foreign debt, foreign currency reserves, and international income payments (2018 KOF Globalisation Index: Structure, Variables and Weights Globalisation Index, de Facto, 2018).

Social Globalization comprises three groups, namely Interpersonal Globalization, Informational Globalization, and Cultural Globalization. The Interpersonal Globalization group examines variables that measure people's relationships with foreign nations, including migration, international voice traffic, international tourism, and transfers. The Informational Globalization group evaluates the dissemination of knowledge and technology across borders, including the number of patents, international students, and the export of high technology. The Cultural Globalization group assesses the diffusion of cultural values and norms, such as the number of McDonald's restaurants and IKEA stores, trademark applications, trade in personal services, and trade in cultural goods (2018 KOF Globalisation Index: Structure, Variables and Weights Globalisation Index, de Facto, 2018).

Finally, Political Globalization evaluates the extent to which countries engage in international relations through diplomatic and humanitarian efforts. It includes only three items in its calculation: the number of embassies, the number of non-governmental organizations (NGOs), and the number of United Nations (UN) peacekeeping missions. (2018 KOF Globalisation Index: Structure, Variables and Weights Globalisation Index, de Facto, 2018).

In addition to the KOF Globalization Index de facto, there is also the KOF Globalization Index de jure, which briefly considers each country's legal structures and regulations. The de jure Economic Globalization dimension is also divided into the same two groups as the de facto dimension: Trade Globalization and Financial Globalization. Trade Globalization examines trade regulations, trade taxes, and tariffs, while Financial Globalization considers the restrictions on investments and capital accounts 1 and 2 (2018 KOF Globalisation Index: Structure, Variables and Weights Globalisation Index, de Facto, 2018).

The Social Globalization dimension de jure shares the same categories as the de facto dimension. The former considers telephone subscriptions, freedom to visit, and international airports for the Interpersonal Globalization group. The Informational Globalization group includes variables such as televisions, internet users, press freedom, and internet bandwidth, while the Cultural Globalization group is based on gender parity, education spending, and civil liberties (2018 KOF Globalisation Index: Structure, Variables and Weights Globalisation Index, de Facto, 2018).

Finally, the de jure Political Globalization dimension includes variables such as the number of international treaties a country belongs to, the number of international organizations it participates in, and the number of international partners in investment treaties (2018 KOF Globalisation Index: Structure, Variables and Weights Globalisation Index, de Facto, 2018).