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ACHIEVING SUSTAINABLE GROWTH: INTEGRATING ENVIRONMENTAL SOCIAL AND GOVERNANCE FACTORS INTO THE COMPANY'S FINANCIAL STRATEGY

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Abstract
The increasing economic and social development of societies is widely acknowledged to have resulted in a number of ecological problems. Thus, the purpose of this study is to analyze the impact of natural resources, social inequality, human development, and institutional quality on trade-adjusted material footprints in G10 countries from 1992-2022. The long-run and short-run relationships have been examined via the cross-sectionally augmented autoregressive distributed lags (CS-ARDL) model, which takes into account the importance of cross-sectional dependence, the absence of slope homogeneity, the stationarity characteristics, and the panel cointegration between the variables. Empirical findings point a positive long-and short-term environmental impacts (i.e., low material footprints) as a consequence of investments in human capital and high-quality institutions. Environmental sustainability is being threatened by increased material footprints brought about by increasing demands on finite natural resources, social inequity (economic inequality), and urbanization. The findings show that improved human development and high-quality institutions are necessary for efficient management of natural resources and for achieving ecological sustainability.

Keywords: Natural Resources; Environmental Integrity; Social Inequity; Human Development; CS-ARDL model

1.Introduction
Increasing production and consumption are directly responsible for the deterioration of the environment, and reversing this trend is widely seen as one of the most pressing challenges that must be met to achieve the sustainable development objectives set for 2030. Human consumption of numerous natural resources has reached record highs due to escalating economic and social demands far beyond the planet's capacity to support such usage. Consequently, many of these resources have been depleted. Climate change, environmental degradation, soil erosion, biocapacity loss, and other pollution-related difficulties all verify this argument's central premise. In recent years, ecological overshoot has come to the forefront of the public's mind, and it now affects around 85 percent of the global population. Environmental excess occurs when resource use outstrips the rate at which resources can be replenished, for example, by increasing farmable land or decreasing carbon emissions from fossil fuels.
A large number of studies have been conducted on the topic of environmental sustainability. Still, most of them have ignored the impact of resource use in favor of a single metric: carbon emissions produced by businesses and the logistics sector. Recent research has shown that the material footprint is the best indicator of whether or not an initiative to cut greenhouse gas footprints by decreasing resources and materials used would be successful (Tian et al. 2021). All data presented here were compiled by the World Resources Institute of the UN Environment Programme. Rapid economic growth and structural changes have the unintended consequence of increasing resource use and undermining environmental protection efforts. This has repercussions for environmental protection efforts. The aim of this study is to examine what factors impact the G10 countries'

resources footprint. Ten countries with comparable political structures and economic priorities comprise the Group of Ten (G10). These countries collaborate to achieve global financial and economic success by aligning their fiscal and monetary policies (Friedl and Getzner 2003).

Global issues like overconsumption of goods and environmental degradation are rooted in the unequal allocation of financial opportunities between various groups and communities worldwide (Muganyi et al. 2021). There is mounting evidence that economic inequality is a societal problem that may have both beneficial and harmful consequences on ecosystems (Soundarrajan and Vivek 2016). Prioritizing research on carbon dioxide emissions may have made sense at one time, but today human actions such as excessive production and consumption are the leading cause of environmental degradation (Li et al. 2018). However, it needs to be clarified how much socioeconomic disparities impact resource or material use. When tracking the historical evolution of environmental degradation or climatic change, it is essential to account for ecosystem services, organic acreage, and waste production.

There are presently several serious discussions centered on whether human capital liberates the world's natural systems and ecosystems. In its conventional definition, human capital refers to an individual's skill set, aptitudes, and willingness to learn and grow in the workplace (Le et al. 2021). Investment in education is one of the most excellent methods to increase people's acceptance of renewable energy and other environmentally friendly practices (Broten 2017). Many also think that if we invest in people, they will be more likely to perform environmentally friendly actions like cutting down on carbon emissions, improving energy efficiency, minimizing the use of precious natural resources, and increase recycling (Arafat et al. 2012).

Studies have yet to compare natural resources with environmental proxies and discovered contradictory results (Casey et al. 2015; Pan et al. 2019; Jin et al. 2021). Experts believe that abundant and low-cost natural resources, including fossil fuels, are responsible for this issue. However, according to (Charoensukmongkol and Moqbel 2014), overabundance of coal and other environmental assets harms the ecosystem. An oversaturated market for natural resources is a direct result of rising economic growth, urbanization, and industrialization (Kadlec and Gabrys 2009). The International Resource Panel estimates that using natural resources is responsible for more than half of the world's manufactured greenhouse gas emissions. This was uncovered during the process of mining for the necessary minerals. Furthermore, these extractions are responsible for the loss of water resources and the degradation of biodiversity.

This study aims to fill a gap in the literature by analyzing the long-term ecological responsibility of the G10 nations over the previous three decades, focusing on the effects of socioeconomic inequality, resource scarcity, human capital, and weak institutions.

- To begin with, this is the first study (to the best our knowledge) to examine how economic disparity has affected the physical legacy of the G10 countries.
- The study estimated the environmental impact of using biomass, fossil fuels, metal ores, and non-metal ores by determining the amount of carbon dioxide (CO2), water, land, and ice required to produce a given amount of those resources. We did this by looking at how various resource types affected the ecosystem.
- Cross-sectionally enhanced autoregressive distributed lags are used in the regression analysis (CARADL). They developed long-term dynamics using a dynamic common correlation estimator.

This method also enabled us to account for confounding variables, such as "cross-sectional dependency and slope heterogeneity," leading to more accurate results. However, the G10's material footprint is anticipated to grow due to rising social inequality, depletion of natural resources, and increased urbanization. Building human capital and strong institutions has been shown to reduce the G10's physical footprint. The findings support the creation of a policy framework to encourage sustainable economic growth.

The following is a synopsis of the article's five sections. Section 2 provides a description of the links between the variables; Section 3 presents a discussion of applicable research; Section 4 outlines the discussion the findings (including an empirical comparison); and Section 5 presents conclusion the work.

2. Literature Review

2.1.Human Capital Index and Natural Resources

How much new born in the modern day can give to society by the time they are eighteen is measured by Human Capital Index (HCI). The quality of healthcare and schooling in a country are included in this ranking. The Health-Centric Index (HCI) is calculated using a formula that considers several facets of a person's life, such as education, lifespan, and health (Deng et al. 2019). The first of its kind, this indicator measures the positive impact that rising health and education levels have on individual productivity and economic growth. This is because this index is the first of its type to make use of novel micro-econometric analysis.

A country's material footprint is the total amount of resources used in producing goods sold and consumed exclusively inside its borders. All metal and non-metal parts, as well as the non-metal particles, fossil fuels, and biomass, may be added together to get the total quantity of material foot print. Using cutting-edge research techniques, (Dong et al. 2023) delves into the fundamentals of the G10 countries. They examine the impact of high-throughput computers and biocapacity on estimates of material usage, which constitutes an ecological footprint. Because people in a growing population are more likely to be accountable for their material consumption, the proposed method yields unique results for each country. Findings suggest that HCI may have immediate and long-term impacts on lowering MFP. The data from this study lends credence to the idea that a feedback loop connects HCI with MFP. Sometimes, policymakers in underdeveloped economies get specialized economic advice. Utilizing data collected between 1985 and 2018 and a unique application of the dynamic ARDL technique, (Bithas and Latinopoulos 2021) discovered a connection between HCI and China's ecological footprint. The research showed that HCI has a far more significant negative impact on sustainability and material footprint (as measured by resource utilization) than was previously thought. Environmental Kuznets Curves were useful when conducting a more comprehensive data analysis for all of China's provinces (Halis and Halis 2016).

Community members and HC employees from a wide range of fields would benefit from workshops emphasizing the importance of sustainability and demonstrating how to use scarce resources better (Ouertani et al. 2018). Given the scarce resources, these steps must prioritize minimizing waste whenever possible. If China's economy is going to succeed in reaching Sustainable Development Goals, all of these factors must be considered simultaneously (Kadlec and Gabrys 2009). (Soundarrajan and Vivek 2016)'s study explores the connections between human-computer interaction and environmental sustainability in various parts of China. As mentioned earlier, cointegration analysis employs the set of variables using the bootstrap casualty method. According to the results, HCI can help lessen environmental degradation over time. HCl's unexpectedly positive response to progress suggests it might play a moderating role in expanding sustainable development. This estimate shows a connection between resource use and ecological footprint; it was calculated using the bootstrap causality technique (Sun et al. 2021).

2.2.The measures of wealth disparity and natural resources

The Gini Coefficient is a statistical measure of a country's degree of income inequality. When the GINI index increases, the income gap between the rich and the poor grows. If the GINI index is high, the wealthiest people in a population can keep a disproportionate amount of their earnings (Seroka-Stolka and Ociepa-Kubicka 2019). (Zhang et al. 2021a) argue that the elite stand to gain the most from environmental degradation since they are able to cope with the consequences of such change. People who are rich and influential in society are more prone to make decisions that are harmful to the environment, as stated by the power-weighted choice rule. It proves that influential organizations will continue to exploit natural resources even if doing so harms society after they control such resources (Wang and Huang 2021). This outcome may be traced back to the stepped-up use of resources. The governing partnership is more likely to gain from environmental rules, at the cost of the general public, due to the unequal distribution of financial management and money in society. This is due to the unequal distribution of economic power and resources. As a result of their fast economic development, the BRICS nations now face widespread pollution and rising income disparity. This is a natural consequence of the thriving economy of the nation (Stiglitz 2021). Various challenges prevent the BRICS countries from achieving their sustainable development goals and improving ecological integrity (Bracco et al. 2018). Interactions between income disparity and environmental consequences are now the focus of state-of-the-art nonlinear empirical research based on the agent-based random dynamical system (ARDL) methodology.

Contrary to popular belief, research from China, Brazil, and Russia suggests that countries with lower income inequality also tend to have more productive labor forces. In contrast, rising income inequality reduces total MFP in India, Brazil, and Russia in short to medium run. There can be no question that BRICS government officials are interested in the outcome. (Tian et al. 2021) used panel data from 25 economies between 1970 and 2016 to conclude the relationship between income inequality and global environmental sustainability. The research articles published between 1970 and 2016 serve as the basis for their analysis and findings. Quantile regression is employed here to analyze the panel data. Findings show that the environmental effect rises between the tenth and twenty-fifth percentiles of the economic gap index. We demonstrated this using data from the 10th and 25th percentiles. According to the study's authors, economic inequality may be mitigated by green technology investment(Jiang et al. 2008).

(Jin et al. 2021) examine G20 income disparity and carbon dioxide emissions. The evidence suggests that as income is distributed more fairly in developing countries, CO2 emissions decrease per person. Using the ARDL model, (Yi et al. 2023) show that economic disparity in Indonesia significantly affects the country's CO2 emissions. (Li et al. 2016b) found that the widening gap in economic development across nations in Sub-Saharan Africa was correlated with a rise in global carbon dioxide levels. They determined that the rising poverty in Sub-Saharan Africa significantly impacts pollution. Disputes about who should pay for cleaning up the air in Japan's shopping and residential areas have been connected to (Deng et al. 2019) use the RICE model to assess the effects of alternative policies on environmental quality, with an eye on reducing the effects of climate change and economic inequality. It also looks at whether the discrepancy in GDP between developing and industrialized countries is responsible for divergent environmental consequences. Attempts to simultaneously improve environmental conditions, increase social justice, and grow the economy inevitably leads to tensions. In their research on low-and middle-income nations between 1980 and 2008, (Soundarrajan and Vivek 2016) discovered an inverse relationship between economic disparity and ecological footprint.

2.3. Natural resources rent

Natural resources rent encompasses a wide variety of rental income sources, such as gas, oil, minerals, coal, and forests (NRR). The net return on investment (NRI) is calculated as the profit margin, or the amount left over after deducting the average production cost from the selling price. This can be accomplished by adding up the prices of all the raw materials and then subtracting an estimate for the expenses associated with extracting and processing those materials (Chomistek et al. 2015). By multiplying unit rents by the amount taken or harvested, the National Resource Return (NRR) for each commodity may be calculated as a percentage of GDP (Jiang et al. 2020). To gauge the scope of the income gap, this study categorizes the BRI economies into several income brackets. In this case, the authors look at the upper, middle, and lower classes. The study uses the Augmented mean group (AMG) estimator and the cointegration method to calculate the degree of association between variables. Based on an analysis of panel data from 1998-2016, the authors conclude that NRR has a double-edged effect on the environment, hastening its degradation while raising material and labor productivity. All income brackets in BRI countries saw the same effects. That association between NRR and MFP is supported by ecological Kuznets curves. In recent years, sustainability and NRRs have received more attention from policymakers and academics. Using data from 1984 to 2016, (Salinas et al. 2014) analyzed the connection between NRR and ecological footprint in twenty-two developing nations. The increase in population between those years is a critical indicator in their study, suggesting that these countries are making progress.

(Salmerón et al. 2018) study of NRR and ecological footprints in the context of the BRICS countries adds to the existing scholarly literature. Using a panel data estimator known as the Fully modified Ordinary Least Squares (FMOLS) method, this study analyzed information collected between 1992 and 2016. (Chang et al. 2015) The report highlights crucial policy concerns to further the BRICS nations' sustainable development. In their 2020 study, (Yang et al. 2012) examine how NRR and MFP are cointegrated in low-income countries. Data from 1984-2016 is analyzed by using second order cointegration methods. The findings show that sustainable management of natural resources is related to MFP over the long term. The results of the CS-ARDL approach are consistent with a positive relationship between the two variables. (Marin-Garcia and Tomas 2016) analyze the impact of NRR on the United States' material footprint and sustainable ecology. Furthermore, the authors establish a bidirectional causal relationship between the variables. These studies show that protecting natural resources while following all applicable regulations is crucial to ensuring environmental sustainability and minimizing individual impacts.

2.4. Institutions and natural resources

Institutional Quality Index, is a real-time metric used to assess the quality of institutions worldwide. Governance, corruption, regulation, social engagement, and law enforcement are the five pillars on which the IQI may be built. One of the biggest obstacles to long-term economic growth in emerging nations is poor management of their natural resources. Sarkodie and Adams revised the spontaneous sustainable growth model to analyze total factor productivity improvements brought about by the environmental regulatory process due to reduction activities. Panel data from 66 emerging nations between 1984 and 2019 is analyzed using generalized system methodology and the fixed effects method. IQI contributes positively to environmental sustainability in the long run. The impact of intelligence on lower-middle-income nations' long-term economic growth is more significant and more robust than its impact on low-poverty countries' economic development. According to the findings, low-middle-income countries are more relevant than low-poverty countries for elucidating the differential influence of IQ factors. This is what we learn when comparing the two nation's GDPs.

According to the empirical study, there are two significant policy implications. To begin constructing efficient and effective natural resource management laws, legislative support in the form of organizational regulation is essential. Moreover, while formulating regulations to safeguard natural capital, it is vital to consider the variety of organizational structures. Using data gathered between 1992 and 2015, (Scott et al. 2015) analyze the effects of IQ on ecological footprints in the context of the G7 economies. In this study, they employ the CEMG and AMG estimators to measure the degree of association between two sets of data. Increases in IQ were shown to reduce an organization's ecological footprint across the board, although having varying effects on E7 economies. The research shows that IQ has a role in decreasing the quantity of waste produced in countries like Indonesia, China, Russia, and India.

Using data collected between 1984 and 2017, (Emrouznejad and Yang 2018) add to the existing body of literature by investigating the correlation between intelligence and environmental sustainability in underdeveloped countries. Short-term and long-term effects were evaluated using sophisticated economic analysis tools like the CS-ARDL estimator. Results showed that in developing countries, increased IQ contributed to ecological sustainability by decreasing MFP. In addition, the provided variables are found to have an inverted U-shaped relationship. Separately, (Liu 2023) examine the role that intelligence plays in the capacity of Sub-Saharan African nations to maintain a sustainable environment. Panel data from 2005-2014 are analyzed using Moments' in-depth method. The research found that most realistic models have less of an impact on the environment as intelligence develops. In their research, (Emrouznejad and Yang 2018) examine how a country's level of intellect affects its ability to protect its natural resources. The study also delves into the human capital index to examine the impact of economic growth on EF. The impact of intelligence on the relationship between economic growth and ecological damage is also explored.

Using panel data collected between 1984 and 2017, researchers (Begum et al. 2023) applied the CS-ARDL method to conduct short-and long-term empirical studies. The empirical evidence suggests that the decline in ecological integrity brought on by monetary integration is due to higher MFP. According to the results of this study, higher IQ is associated with lower MFP. The rise in human capital that accompanies economic growth is the direct cause of the rise in average IQ linked to this phenomenon. Ecological footprints (EFs) are a proxy for a country's commitment to environmental sustainability. Another study (Li et al. 2016a) aims to add to the existing data by analyzing EFs in BRICS countries that have implemented environmental technologies. In this study, they apply the environmental Kuznets curve (EKC) hypothesis as a theoretical framework to investigate the connection between intelligence and the ecological viability of a region. The authors use many different types of analytic approaches, such as the Augmented mean group (AMG) estimator, the Common correlated effect analysis of variance in repeated measures (ARDL), and the Common correlated effect mean group estimate, to determine the existence and strength of both extended-and short-term associations. Using these methods, the authors examine data from 2001-2020 and identify either type of association. Second-generation macroeconomic approaches find that higher intelligence correlates with smaller ecological footprints, which may indicate that environmental degradation is slowing.

2.5 Urbanization and natural resources

The material footprint and environmental sustainability of the G10 economies are affected by urbanization. The process by which a society adjusts to the challenges posed by a rapidly growing population is reflected in the term urbanization, which describes the movement of people from rural to urban areas. New technologies, especially environmentally friendly ones, flourish in urban areas (Li and Umair 2023; Wang et al. 2023). As more people move into cities, there may be a greater need for eco-friendly utilities and services. In the long run, ecologically friendly technology, machines, transportation, and supplies will decide the success of a green economy (Liu et al. 2023; Pan et al. 2023).

In order to demonstrate a long-term connection between the factors, the research (Chang et al. 2023b) looks at data from 1990 to 2017. The research uses the Mean Group (MG) and Westerlund Cointegration methods to analyze the relationship between urbanization and EF over the short and long term. In this research, the robustness is assessed using the Augmented Mean Group (AMG) method. A similar positive and strong relationship exists between the industrialization index and the EF. However, in the case of industrialized economies, the services sector has a negative correlation with environmental effect. It means that the service industry helps to improve environmental conditions over time. Increases in population and urbanization are good for the environment. The problems that the G7 nations have to deal with include increased urbanization, worsening ecological consequences, and declining biocapacity. In many countries, industrial production and consumer consumption are concentrated in urban areas. Based on this, (Chang et al. 2023a) research examines the effects of urbanization on the EF within the framework of the G7 nations. For the provided data from 1971 to 2014, the research used effective estimators for panel data analysis, such as CUP-BC and CUP-FM. As the population of a certain region (or metropolitan area) grows, so does the demand for natural resources, as shown by the study's conclusions. The causality tests used in this research establish a one-way relationship between urbanization and the human capital index. However, it is estimated that urbanization and ecological impact are causative in both directions.

In addition, (Zhang et al. 2023) study examines the impact of urbanization in the context of ASEAN countries using panel data from 1990 to 2016. The cross-sectional dependency is explored by means of the first and second unit root tests. The study's findings show that as the population of ASEAN countries grows, so does their ecological footprint and their material consumption in metropolitan areas. Urbanization is the primary factor in the improvement of regional social and economic conditions.

However, industrialization in this area has caused considerable damage to the fragile natural environment that formerly existed here. (Gong et al. 2023) improve upon the conventional EF model and introduce the concept of local EF to investigate the ecological stress brought on by urbanization in China's central region. From 2005 to 2020, the updated model was used to evaluate the ecological and environmental stress brought on by China's rapid urbanization in the region's center. The results show that environmental pressure in China increased consistently between 2005 and 2014. Using data collected between 1998 and 2017, (Chen et al. 2023) analyze the link between Eastern Europe's rapid urbanization and its material footprint. The research uses the Dumitrescu Hurlin causality and VAFD unit root test to examine the link between the specified variables. The results show that urbanization has a long-term, unidirectional effect on ecological footprint. The research has policy implications that might help lessen our environmental impact and strengthen urbanization laws.

3. Data and Methodology

The variables and their meanings are shown in table1. The period of study is from 1990 to 2018.

Abbreviations	Variable	Nature	Measure	Data Source
MFP	Impact on resources	DV	Material imprint based on human consumption	GMF
HCI	Human capital	IV	Human Capital Measurement	PWT
GIN	inequality in incomes	IV	GINI index	SWIID
NRR	Renewable income from natural resources	IV	%of GDP	WDI
INQ	Competence of Institutions	IV	Polity2 Index	Polity dataset
URB	Urbanizations	Control	a share of the total populace in cities	WDI

A cross-sectional dependency analysis on panel data is necessary to determine whether the different cross-sectional units of observation are related across time. However, erroneous conclusions may be drawn from the research if similar patterns in the data are ignored in the later stages of the examination. Therefore, the Pesaran (2015) test was used. In addition, the cross-sectional dependency analysis produces a by-product that verifies the data's stationarity. Testing procedures developed by (Chen et al. 2014) used to verify that the findings of the study were accurate.

The second aspect of this research was analysis of the slope heterogeneity in the data. The results and discussion of this research included both the null and alternative hypotheses for slope heterogeneity. After that, we looked at the findings of an experiment on panel cointegration. Lastly, the long-term and short-term connections between the relevant variables were investigated using the cross-sectional autoregressive distributed lags model. In our research, material perceptions were the most important endogenous variable. However, factors like income inequality, the human capital index, natural resources, and the quality of institutions have elevated social disparity to an important explanatory variable. This is because these indicators have brought attention to the relevance of economic inequality. In conclusion, the equation suggests that the level of urbanization is being used as a variable to control in this study (1).

$$MFT_{,i,t} = f(HCI_{i,t}, GIN_{i,t}, NRR_{i,t}, INQ_{i,t}, URB_{i,t}) \quad (1)$$

t shows the time, and i represents the cross-section. Regression is shown in equation 2.

$$MFP_{it} = \beta_{1it} + \beta_{2it}HCI_{it} + \beta_{3it}GIN_{it} + \beta_{4it}NRR_{it} + \beta_{4it}INQ_{it} + \beta_{4it}URB_{it} + \alpha_i + \delta_{it} (2)$$

The third equation shows the ARDL model.

$$W_{i,t} = \sum_{i=0}^{pw} \varphi_{i,t}W_{i,t-1} + \sum_{i=0}^{pz} \gamma_{i,t}Z_{i,t-1} + \varepsilon_{i,t} \quad (3)$$

The modified form of equation 3 is as in equation 4.

$$W_{it} = \sum_{i=0}^{pw} \varphi_{i,t}W_{i,t-1} + \sum_{i=0}^{pz} \gamma_{i,t}Z_{i,t-1} + \sum_{i=0}^{px} \alpha_i\tilde{\bar{X}}_{t-1} + \varepsilon_{i,t} \quad (4)$$

The long-run coefficient and long run estimators are shown in equation 5.

$$\grave{\pi}_{CD-AR\ ,i} = \frac{\sum_{I=0}^{pz} \grave{\gamma}_{Ii}}{1=\Sigma_{I=0}} \grave{\varphi}_{I,t} \quad (5)$$

Group mean is as…

$$\grave{\bar{\pi}}_{MG} = \frac{1}{N}\sum_{i=1}^{N} \grave{\pi}_i \quad (6)$$

Short term coefficients are as…

$$\Delta W_{it} = \vartheta_i[W_{i,t-1} - \pi_i Z_{i,t-1}] - \sum_{i=0}^{pw-1} \varphi_{i,t}\Delta_i W_{i,t-1} + \sum_{i=0}^{pz} \gamma_{i,t}\Delta_i Z_{i,t-1} + \sum_{i=0}^{px} \alpha_i\tilde{\bar{X}}_t + \varepsilon_{i,t} (7)$$

Here

$$\Delta_i = t - (t-1)$$

$$\grave{\tau}_i = -(1 - \sum_{i=0}^{pw} \grave{\varphi}_{i,t}) \quad (8)$$

$$\grave{\pi}_i = \frac{\sum_{i=0}^{pz} \grave{\gamma}_{i,t}}{\grave{\tau}_i} \quad (9)$$

$$\grave{\bar{\pi}}_{MG} = \frac{1}{N}\sum_{i=1}^{N} \grave{\pi}_i \quad (10)$$

4. Results and discussions

Table 2 displays the descriptive analysis findings for the examined variables. According to the statistics, the average value of the institution's physical footprint is the highest, while the average value of the institution's quality is the lowest. The human capital variable has the lowest standard deviation, while the material footprint variable has the highest. From this, we might deduce that the material imprint is the more enigmatic of the two. However, the Human Capital Index has a far narrower range of possible values.

Table 2. Statistics of input data

Description	Variables					
	MFP	**HCI**	**GIN**	**NRR**	**INQ**	**URB**
Mean	5.885	2.463	3.152	2.654	2.115	2.332
Median	4.542	2.365	3.254	2.297	1.456	2.553
Max	22.489	2.126	4.456	2.423	2.785	2.126
Min	2.463	2.255	2.596	2.568	1.678	1.621
Std. Dev.	4.247	1.268	2.234	1.287	1.278	2.489

Throughout this investigation, we have relied on the “Breusch-Pagan LM, Pesaran Scaled LM, and Pesaran CD tests” to get reliable results. Table 3 shows the cross-sectional dependence results of the variables. Based on the data, a shock to the economy of one G10 member may trigger a domino effect on the economies of the other members of the group. This indicates the extent to which the selected nations rely on one another in several contexts.

Table 3. Cross sectional dependence analysisone member of the G10 economies may reflect a spill-over effect in other member states.

Table 3. Cross-sectional dependence.

Test	**Statistic**	**Probability**
Breusch-Pagan LM	278.65	0
Pesaran Scaled LM	22.3746	0
Pesaran CD	7.234	0

Table 4 also displays unit root test results with and without the incorporation of structural failures. After figuring out whether the data show cross-sectional dependence, the next stage is looking at the stationarity or unit root qualities. Table 4 contains results of unit root test. The results of the study indicate that both tests were unable to reject the null hypothesis, thereby accepting the absence of stationarity at a certain level.

Table 4 Unit root test

	Level I(0)			First Difference I(1)		
Variables	CIPS	M − CIPS			CIPS	M − CIPS
MFP	−1.992 ***	−4.221 **			−	−
HCI	−2.576 ***	−4.208 **			−	−
GIN	−4.121 ***	−4.185 **			−	−
NRR	−4.279 ***	−2.296 **			−	−
INQ	−6.205 ***	−5.252 **			−	−
URB	−3.882 ***	−6.327 **				
		Carrion and Bai test				
	Z	Pm	P	Z	Pm	P
MFP	1.221	1.385	20.127	− − 6.201 ***	6.257 ***	85.101 ***
HCI	1.218	1.275	11.185	− − 5.875 ***	4.239 ***	71.182 ***
GIN	1.317	1.112	20.182	−5.423 ***	6.258 ***	68.796 ***
NRR	1.207	1.262	23.535	−4.188 ***	4.117 ***	62.237 ***
INQ	1.178	1.257	18.62	−5.330 ***	5.220 ***	73.615 ***
URB	1.252	1.217	20.307	−2.428 ***	−7.257 ***	49.216 ***

To preserve the consistent nature of the data, we looked at the first-order difference alongside the implication of $Bai\ and\ Carrion - I - Silvestre$. According to our analysis, the data have either reached static properties or do not contain any unit root problems connected to the cross-sectional dependency. The lack of associations in the data corroborates both of these hypotheses. This is clearly seen in Table 4. The hypothesis predicts that if enough time has elapsed, all factors will intersect or incorporate into a single state.

Table 5 displays the findings of a comparison that looked for variations and distinctions in the slopes. In this case, the null hypothesis proposes that all slopes are identical or that all that varies is the slope's coefficient. Slope heterogeneity may be tested for, as stated by the alternative hypothesis H1, which refutes the null hypothesis. As can be seen in Table 5, numerous observations provide credence to the null hypothesis (H0); hence, the slope coefficients exhibit a wide range of potential values. As a result, the present study has provided sufficient data to show the existence of CD, stationarity features, and variability in the slope coefficients, all indicative of a workable strategy for producing credible results in the next stage. The present study has also shown slope coefficient variation, indicating a workable strategy. Keeping the slope coefficients stable was the key to achieving this goal, and this was finally accomplished thanks to the method that proved to be the most successful.

Table 5: Analysis of slope heterogeneity

Statistics	Test value (P − value)
Delta tilde	62.467(0)
Delta tilde Adjusted	66.587(0)

Data from a panel cointegration analysis of the most important findings by Westerlund and Edgerton are shown in Table 6. The null hypothesis (H0) rejects H1, the existence of cointegration, and states that the alternative (H1) is correct. This is valid in various contexts, not simply panel cointegration. If we choose the 1% significance threshold, as shown in Table 6, we must accept H1 in all three test cases. There are three possible outcomes: "no break, mean shift, and regime change." Understanding that panel cointegration happens in the examined variables is crucial when discussing the significance of a physical footprint's involvement in a study.

Table 6: Outcome of cointegration analysis

Test	No break	Mean shift	Regime shift
Zφ(N)	−7.215	−8.245	−5.899
Pvalue	0	0	0
Zτ(N)	−5.2545	−4.215	−6.2147
Pvalue	0	0	0

Table 7 summarizes the study's findings on the long-term impact of intellectual resources, $GINE$, environmental assets, institutional quality, and urbanization on material footprints. An increase of only one unit in the HCI would reduce the G10 nations' carbon footprints by 23.9%, given the coefficient of human capital is -0.239. If the G10 nations invested more in their people, their environmental impact would greatly diminish, and so would their material footprints. Investigating the ties that bind them, People with more education tend to have a better understanding of environmental issues and are more likely to take action to slow down or stop environmental damage. This link highlights the significance of the human resources index as an indicator of residents' level of education. The concerns of environmental sustainability and human-computer interaction have garnered the attention of academics from various economic sectors.

Table 7: CSARDL Findings in long run

Variable	Co. efficient	t_stats	p value
HCI	−0.564	−3.2545	0
GIN	0.2545	5.2156	0
NRR	0.5454	5.2458	0
INQ	−0.3569	−3.454	0
URB	0.2455	5.3569	0

As the human capital index coefficient shows a negative result, increasing the amount of human capital available significantly improves environmental quality by lowering material footprints. The fact that the coefficient is negative demonstrates the conclusion. The ecological footprints of a selection of G7 countries are used in (Dong et al. 2023) research on the connection between HCI and environmental pollution. Based on these findings, HCI may reduce the EFP and provide a long-term, workable solution to the problem of how human population growth affects the natural world. In addition to (Henseler and Sarstedt 2013) provide policy relevance for human capital development in the service of enhanced environmental outcomes.

The data in Table 7 shows a positive relationship between material footprints and GIN inequality. This holds if economic inequality among the G10 causes a rapid depletion of natural resources. With a p-value of 1%, the $GIN\ model$ predicts a 0.358% shift in the material footprint overall. When considering the environmental effects, such as the evaluation of MFP using GIN, it is clear that the G10 countries' wealth must be redistributed immediately. There is evidence in favor of and against the hypothesis that GIN is linked to tangible traces of its use in the past. In addition, (Piwowar-Sulej 2020) argue that income disparity significantly affects air quality in Japan's major cities. In addition, (Bithas and Latinopoulos 2021) analyzed the United States on a state-by-state level between 1997 and 2012. The trend of rising carbon emissions in the top ten wealthiest states may be inferred from the available data. However, increased energy use and carbon emissions are inevitable outcomes of a fairer and efficient distribution of wealth.

Table 7's numbers reveal, in addition to what has already been said, that natural resources impact the material footprint, with a coefficient value of 0.118. When this coefficient is positive, it indicates a direct and proportionate relationship between a rise in MFP and a rise in natural resources. The $t-test$ shows that the correlation between $NRR\ and\ MFP$ is significant at the 1% level. If these hypotheses hold, the earth's natural resources are adding to climate change by leaving more tangible traces of human activity. Likewise, if these assumptions are false, then the reverse is true. To be more specific, when NRR grows by 1% worldwide, an MFP of 11.8 is employed to promote climate change. Coal, oil, and other minerals may be found in several G10 countries. Therefore, the fundamental cause of the overexploitation of these natural resources is unsustainable practices, which also contribute to other issues like material footprints.

The relationship between natural resources and ecological footprints is studied by (Emrouznejad and Yang 2018) using nonlinear estimating methods. The data suggests there is a positive link between the two factors. The effects of human capital and natural resources on ecological footprints in a cross-section $of\ ECOWAS$ member states are investigated by (Zhang et al. 2021b). Research shows that NRR reduces environmental quality by increasing energy-for-production. (Chen et al. 2013) of China employ the $BARDL\ technique$ to look at $NRR\ and\ EFP$. It is clear from the results that NRR has a significant detrimental effect on China's ecosystem. In contrast, (Jin et al. 2021) argued that our findings were incorrect since NRR actually reduces EFP in the BRICS region.

Quality initiatives by G10 institutions are shown to support sustainable approaches in Table 7, column 2. The less amount of waste produced by the research lends credence to the eco-friendly method. The INQ coefficient demonstrates that G10 states have smaller material footprints due to increased environmental sustainability education and awareness among citizens, corporations, and other stakeholders. The G10 nations are using less material. The overall operational capabilities of all sectors, including public, and corporate governance, benefit from improved regulatory frameworks, increasing institutional quality. Scientific studies have shown that improved institutional quality reduces pollution and boosts economic growth in all countries. (Ritzén and Sandström 2017) conclude that effective institutions in South Asia are responsible for a cleaner environment. (Kirchherr et al. 2017) used a second-generation panel survey to show that weak institutional frameworks lead to environmental decline. According to (Bithas and Latinopoulos 2021), the quality of an organization may be gauged by its carbon footprint . Institutional quality has been shown to have a direct and modest effect on climate change.

Studies were done to investigate the link between urbanization and material footprints. From value of URB coefficient, we can conclude that environmental pollution indicates dangerously high levels of urbanization, as shown in Table 7. Moreover, at 1% significance, the given coefficient demonstrates that increasing urbanization is associated with increasing MFP and vice versa. Multiple studies in the existing body of information reach the same conclusion concerning the direct role that URB plays in the progression of environmental pollution. Urbanization has a detrimental effect on the environment since it increases our ecological footprint. They argue that EFP is not a measure of natural environment productivity since it increases as urbanization increases. (Nashihin 2014) discovered that urbanization reduces EFP in the natural environment of the BRICS area, the only location where the validity of EKC can be established, so they dispute the concept that urbanization leads to environmental pollution.

Table 8 shows possible inferences based on the nature of the interplay between the factors mentioned above. The results support that improvements in institutional quality and HCI are causal factors in MFP's persistent long-term reduction. However, increasing urban centers and income gaps contribute to environmental degradation. Substantial negative values for the error correction term provide more evidence for the system's long-run approach to stable equilibration at an adjustments rate of 62.7%. (ECT).

Table 8: CSARDL Findings in short run

Variable	Co − efficient	t_stats	p − value
HCI	−0.6569	−4.1585	0
GIN	0.2154	3.58678	0.101
NRR	0.265	3.2489	0.0254
INQ	−0.10214	−4.2658	0
URB	0.10211	4.1545	0
ECT	−0.21015	−5.2145	0

Note: MFP is a dependent variable

4.1. Robustness Evaluation

A robustness evaluation was conducted using the analysis as mentioned earlier in combination with the AMG $method.$ Table 9 displays the AMG test findings confirming the empirical conclusion of CS ADRL linking to variables in this study for the $G10$ countries. As a result, the trajectory of the connection is preserved, even if the correlation's significance changes over time.

Table 9: Robustness check

Variable	Co − efficient	t stats
HCI	−0.6598	−3.997

GIN	0.5458	5.87/8
NRR	0.241	6.548
INQ	−0.01254	−5.4568
URB	0.13024	4.0365

5. Conclusion and Policy Implications

While research on the link between inequality and climate change has increased, the treatment of the empirical evidence for such a link needs to be more consistent. In recent years, researchers have paid a lot of attention to two different types of capital: natural resources and human capital, especially in the G10 nations. With these considerations in mind, this research identified the factors (such as human capital, economic disparity, natural resources, and institutional quality) that most significantly affect material footprints. One of the most reliable indicators of environmental damage is the "material footprint." The impact of urbanization on the $MFP\ of\ G10$ countries from 1995 to 2022 is also analyzed in the model as a control variable. Empirical studies have shown that improvements in human capital and institutional quality are the only two variables that do not lead to smaller ecological footprints. Despite this, other variables, such as the region's natural resources, wealth inequality, and urbanization, may account for its greater MFP. The results, as mentioned earlier, are supported by recent empirical research, and any counterexamples may be analyzed logically. Recent empirical research corroborates conclusions.

Several policy recommendations have been made in light of the empirical results and discussions. Rising economic growth is linked to broader social inequalities and deteriorating environmental conditions, demonstrating the delicate balancing act that this progress entails. Officials from the G10 nations are tasked with prioritizing ecologically responsible and sustainable development alongside maintaining adequate and continuous economic growth. As a nation's standard of living improves, its citizens move toward greener pursuits. Meanwhile, it has been suggested that affluent people be singled out for particular scrutiny to get them to do more to stop environmental degradation. Reducing the country's dependence on traditional fuels like coal, natural gas, and crude oil should, on the other hand, be a primary focus for the government. These regulations and policies can potentially limit resource extraction, which would benefit the environment by producing less waste. Meanwhile, if human capital development and the quality of institutions are continuously and sustainably reviewed, the community and other stakeholders could benefit from a productive setting.

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