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Carbon Footprints, Social Inclusion, and Inequality: Multidimensional Pathways to Sustainable Development Goals

Ślad węglowy, integracja społeczna i nierówności: wieopłaszczyznowe ścieżki do Celów zrównoważonego rozwoju

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Abstract

This study investigates the multidimensional pathways to sustainable development by modelling three key Sustainable Development Goals (SDGs): SDG 13 (Climate Action), SDG 5 (Gender Equality), and SDG 10 (Reduced Inequality) as dependent variables. Drawing on Sustainable Development Theory, the study analyses the influence of carbon emissions, female labour force participation, social inclusion indicators (vulnerable employment and employment-to-population ratio), GDP per capita, urbanization, and the COVID-19 pandemic as explanatory variables. Using unbalanced panel data for 65 countries (27 Sub-Saharan African and 38 OECD countries) spanning 2000–2022, the study captures the structural and regional variations across income levels and development contexts. The SDG 13 model reveals that carbon emissions significantly hinder climate action in both regions, more severely in OECD countries. Urbanization promotes climate resilience in OECD nations, while it remains insignificant in SSA. GDP per capita shows a negative association with climate action in both regions, underlining the growth–sustainability trade-off. In the SDG 5 model, female labour force participation enhances gender equality outcomes in OECD countries but weakens them in SSA, where informal and subsistence employment dominate. For SDG 10, high levels of vulnerable employment undermine inequality reduction efforts in SSA, while in OECD countries, the employment-to-population ratio negatively correlates with inclusive progress, reflecting the complexity of job quality and equity. The pandemic temporarily improved environmental outcomes, but the effect was not sustained. The study contributes to the growing body of knowledge on sustainable development by offering regional insights into how socio-economic and environmental variables shape climate action, gender equality, and reduced inequality. It underscores the need for region-specific, integrative policies that address environmental sustainability, gender empowerment, and social inclusion concurrently to advance transformative progress across the SDGs.

Key words: Sustainable Development Goals, SDG13- Climate action, SDG5- Gender equality, SDG10- Reduced inequalities, social inclusion, carbon emissions

Streszczenie

W tym artykule zbadano wielowymiarowe ścieżki do zrównoważonego rozwoju poprzez modelowanie trzech kluczowych Celów Zrównoważonego Rozwoju (SDG): SDG 13 (Działania na rzecz klimatu), SDG 5 (Równość płci) i SDG 10 (Zmniejszenie nierówności) jako zmiennych zależnych. Opierając się na teorii zrównoważonego rozwoju, badanie analizuje wpływ emisji dwutlenku węgla, uczestnictwa kobiet w rynku pracy, wskaźników włączenia społecznego (zatrudnienie zagrożone i stosunek zatrudnienia do populacji), PKB na mieszkańca, urbanizacji i pandemii COVID-19 jako zmiennych objaśniających. Korzystając z niezrównoważonych danych panelowych dla 65 krajów (27 krajów Afryki Subsaharyjskiej i 38 krajów OECD) obejmujących lata 2000–2022, badanie uchwyciło strukturalne i regionalne różnice w poziomach dochodów i kontekstach rozwoju. Model SDG 13 ujawnia, że emisje dwutlenku węgla znacznie utrudniają działania na rzecz klimatu w obu regionach, a w większym stopniu w krajach OECD. Urbanizacja promuje odporność na zmiany klimatu w krajach OECD, podczas gdy w Afryce Subsaharyjskiej pozostaje nieistotna. PKB na mieszkańca wykazuje negatywny związek z działaniami na rzecz klimatu w obu regionach, podkreślając kompromis między wzrostem a zrównoważonym rozwojem. W modelu SDG 5, udział kobiet w rynku pracy poprawia wyniki w zakresie równości płci w krajach OECD, ale osłabia je w Afryce Subsaharyjskiej, gdzie dominuje nieformalne i socjalne zatrudnienie. W przypadku SDG 10, wysoki poziom zatrudnienia zagrożonego podważa wysiłki na rzecz redukcji nierówności w Afryce Subsaharyjskiej, podczas gdy w krajach OECD stosunek zatrudnienia do populacji negatywnie koreluje z postępem inkluzywnym, odzwierciedlając złożoność jakości pracy i równości. Pandemia tymczasowo poprawiła wyniki środowiskowe, ale efekt ten nie był trwały. Badanie przyczynia się do rosnącej wiedzy na temat zrównoważonego rozwoju, oferując regionalne spostrzeżenia na temat tego, w jaki sposób zmienne społeczno-ekonomiczne i środowiskowe kształtują działania na rzecz klimatu, równość płci i zmniejszenie nierówności. Podkreśla to potrzebę wprowadzenia polityk regionalnych i integracyjnych, które będą uwzględniać kwestie zrównoważonego rozwoju środowiska, równouprawnienia płci i integracji społecznej, aby przyspieszyć transformacyjny postęp w zakresie realizacji Celów Zrównoważonego Rozwoju.

Słowa kluczowe: Cele Zrównoważonego Rozwoju (SDGs), SDG-13: Działania na rzecz klimatu, SDG-5: Równość płci, SDG-10: Zmniejszenie nierówności, włączenie społeczne, emisje dwutlenku węgla

1. Introduction

The adoption of the Sustainable Development Goals (SDGs) in 2015 marked a critical juncture in the global commitment to addressing interrelated challenges such as poverty, inequality, and environmental degradation. Encompassing 17 goals, 169 targets, and 231 indicators, the SDGs provide a comprehensive framework for promoting inclusive, equitable, and sustainable development (Bongaarts, 2020; Sachs, 2015). While the SDGs have catalysed efforts to integrate environmental and social objectives (Griggs et al., 2014), their implementation has been hindered by structural inequalities, uneven progress across regions, and persistent data limitations (Sachs et al., 2021). The COVID-19 pandemic has further exacerbated these challenges, disrupting progress across multiple goals and amplifying vulnerabilities, particularly in low-income countries (Elsamadony et al., 2022; Shulla et al., 2021)

A central concern in sustainable development discourse is the complex relationship between environmental sustainability and social inclusion. Although climate action (SDG 13) is often prioritized for its global urgency, its effective implementation is closely linked to reducing inequalities (SDG 10) and promoting gender equality (SDG 5) (Filho et al., 2023; Villavicencio Calzadilla, 2021). Carbon emissions, as a proxy for environmental stress, intersect with economic and social factors, creating both trade-offs and synergies. For instance, industrialization and trade may contribute to poverty reduction (SDG 1) but simultaneously hinder progress on SDG 13 due to increased ecological footprints (Khan et al., 2024; Moinuddin and Olsen, 2024). Similarly, global trade dynamics have displaced carbon-intensive activities to lower-income nations, complicating national sustainability assessments (Wiedmann and Lenzen, 2018).

Emerging evidence suggests that inequality in carbon footprints and access to environmental resources remains significant, particularly between and within countries. Studies reveal that higher-income groups disproportionately contribute to global emissions, while marginalized populations bear the brunt of climate impacts (Hubacek et al., 2017; López et al., 2020). Despite this, most sustainability analyses treat environmental, social, and economic dimensions in isolation, often overlooking how social inclusion mechanisms may enhance climate resilience or how inequality reduction can support ecological transitions (Hou et al., 2024; Roy et al., 2022).

This study addresses these limitations by examining the interconnected effects of carbon footprints and social inclusion on progress toward SDGs 5, 10, and 13. Using panel data from 40 countries – 20 from Sub-Saharan Africa and 20 from OECD economies – over the period 2000 to 2022, the study investigates how variations in environmental pressure and social equity influence the trajectory of sustainable development. The analysis pays particular attention to the COVID-19 pandemic (2020–2022) as a critical period that reshaped national capacities, fiscal space, and policy priorities related to sustainability.

The objectives of this research are threefold:

1. To investigate the impact of carbon footprints on the achievement of SDGs 5, 10, and 13;
2. To examine how social inclusion influences these SDGs across different income groups; and
3. To assess the moderating role of the pandemic period on the relationships between carbon emissions, social inclusion, and SDG progress.

By integrating environmental and social dimensions in a multidimensional analysis, this study contributes to a more nuanced understanding of sustainable development pathways. In doing so, it moves beyond aggregate assessments to provide policy-relevant insights that are both cross-national and temporally dynamic, aligning with the 2030 Agenda's call for transformative and inclusive development strategies.

2 Literature Review

2.1. Carbon Footprints and Climate Action (SDG 13)

Carbon footprints play a central role in the discourse on environmental sustainability and climate resilience. Efforts to reduce carbon emissions by over 50% by 2030 and eliminate them entirely by 2050 are widely recognized as crucial strategies to mitigate climate change and promote environmental sustainability. However, a singular focus on reducing carbon emissions can result in problem-shifting, wherein gains in carbon reductions may inadvertently intensify other environmental impacts (Laurent et al., 2012). This calls for a more integrated and multidimensional approach to climate action that considers not just carbon emissions, but the broader context of environmental sustainability.

One of the most significant factors influencing carbon footprints is income level. Higher-income households generally contribute more to emissions due to greater consumption patterns (Long et al., 2024; Moser and Kleinhückelkotten, 2018). Conversely, lower-income groups may have higher emissions in specific areas such as home energy use (Hardadi et al., 2021). While environmental self-identity can influence pro-environmental behaviour, its impact on actual emissions remains limited (Moser & Kleinhückelkotten, 2018). Income, therefore, remains the dominant determinant of carbon footprints, and inequality in carbon emissions persists even in relatively equal societies (Long et al., 2024). Addressing these disparities requires policy strategies that consider socioeconomic realities, such as revenue recycling from carbon taxes to buffer low-income households (Hardadi et al., 2021), and targeted support for middle-income groups who may be more amenable to personal decarbonization efforts Long et al., 2024).

Climate action (SDG 13) intersects closely with other Sustainable Development Goals. There are both synergies and trade-offs between climate mitigation and development objectives such as poverty reduction (SDG 1), income equality (SDG 10), and economic growth (SDG 8) (Barbier and Burgess, 2021; Filho et al., 2023; Khan et al., 2024). Reducing income inequality has been shown to facilitate the decoupling of economic growth from carbon emissions, particularly in wealthy countries (Hou et al., 2024). Nevertheless, in countries with higher material efficiency and population density, climate change mitigation efforts are often limited, while greater material footprints correspond to higher CO_2 emissions (Sardianou et al., 2023). Although rising CO_2 emissions entail environmental costs, global improvements in other SDG indicators often outweigh these losses, yielding a net welfare gain. However, low-income nations – despite declining CO_2 emissions – tend to experience smaller welfare improvements due to trade-offs with other development objectives (Barbier & Burgess, 2021).

Urbanization and trade further complicate the relationship between economic growth and climate action. Urban expansion influences CO_2 emissions in different ways, with some studies suggesting a reduction in emissions (Ahmed, 2016), while others indicate an increase due to concentrated energy consumption and industrial activities (Jiang et al., 2022). Trade globalization has displaced environmental and social costs from developed to developing nations, reinforcing the need to integrate footprint-based indicators into sustainability assessments to prevent hidden environmental liabilities (Wiedmann and Lenzen, 2018). Moreover, industrialization and trade contribute to global environmental degradation through carbon-intensive and energy-dependent structures (Jiang et al., 2022; Sarkodie et al., 2020). In many cases, emissions linked to manufacturing are outsourced beyond urban boundaries, thereby complicating mitigation efforts (Chen et al., 2019).

Beyond economic and structural drivers, social inclusion is increasingly recognized as a vital element in environmental resilience. Trade-offs between social inclusion goals—particularly SDGs 1, 5, and 10—and climate goals (SDG 13) indicate that industrialization and trade can enhance poverty alleviation and reduce inequality while exacerbating environmental harm (Khan et al., 2024). Progress on the SDGs is positively correlated with ecological footprints and international spillovers, suggesting that conventional growth models continue to hinder sustainability (Moinuddin & Olsen, 2024). Nevertheless, the synergy between SDGs 8, 10, and 13 becomes apparent when inequality is reduced in tandem with economic growth, as this can support decoupling and foster climate action (Hou et al., 2024).

The COVID-19 pandemic introduced another layer of complexity in achieving SDG 13. The crisis disrupted progress across multiple SDGs, with marked setbacks in gender equality (SDG 5), economic growth (SDG 8), sustainable cities (SDG 11), and responsible consumption (SDG 12) (Elsamadony et al., 2022). The pandemic's impact was more severe in low-income countries, underscoring the importance of climate action in fostering systemic resilience (Elsamadony et al., 2022). Education and climate sustainability were also significantly affected, although some positive long-term transitions, such as the potential shift toward a green economy, have emerged (Gulseven et al., 2020; Shulla et al., 2021). These developments point to the need for inclusive recovery strategies

that prioritize vulnerable populations and promote international collaboration (Elsamadony et al., 2022; Shulla et al., 2021; Wang & Huang, 2021).
Finally, innovation and technological advancement offer new pathways to reducing carbon footprints. Artificial intelligence has demonstrated potential in mitigating ecological degradation by enhancing energy efficiency and accelerating the transition to greener technologies (Wang et al., 2024). Nonetheless, its effectiveness is contingent on industry structure and trade openness, highlighting the need for context-sensitive approaches to climate policy. In the United States, while fossil fuel use and energy transitions have increased emissions, green innovation holds promise for long-term impact reduction (Abbasi et al., 2024). African countries continue to face challenges due to rising energy consumption and urbanization, which contribute significantly to environmental degradation (Nathaniel and Adeleye, 2021). Therefore, a holistic approach – incorporating technological, economic, social, and structural dimensions – is essential for advancing SDG 13 and achieving long-term environmental sustainability.

2.2. Gender Equality and Sustainability (SDG 5)

Gender equality plays a foundational role in advancing sustainable development, both as a standalone objective under SDG 5 and as a cross-cutting catalyst for achieving other Sustainable Development Goals (SDGs) (Leal Filho et al., 2022). The linkages between gender equality and sustainability extend beyond social justice to include multidimensional outcomes such as economic growth, environmental resilience, and institutional strength. As gender disparities are addressed, progress is observed in poverty alleviation, education, health, and broader development (Amulya Jeevanasai et al., 2023). The tourism sector exemplifies this interdependence, as its sustainability hinges on achieving gender balance and inclusivity (Alarcón & Cole, 2019). Frameworks like the Balanced Scorecard can support institutions in tracking gender progress while fostering sustainable outcomes (Blasi Valduga et al., 2023).
The synergy between gender equality and environmental sustainability is well-documented. Countries with higher political gender equality and national income levels tend to exhibit stronger pro-environmental behaviours, such as reduced meat consumption (De Boer and Aiking, 2023). Moreover, gender-diverse corporate boards are linked to stronger environmental practices (Kassinis et al., 2016), especially in politically stable and economically secure environments (Sraieb and Labadze, 2022). Feminist-oriented ecological communities provide further insight, integrating unpaid care work into sustainability models and offering alternatives that can inform policy (Bhatia, 2022). These findings underscore the mutual reinforcement between gender equality and environmental stewardship, where institutional and corporate gender inclusion drive ecological outcomes.
A growing body of research explores the intersection of gender equality and carbon emissions. Female representation in national parliaments and women's educational attainment contribute to lower carbon intensity of well-being (CIWB), though increased female labour force participation has the opposite effect (Ergas et al., 2021). The relationship between GDP and CO_2 emissions is moderated by gender equality—economies with greater gender parity show a weaker link between economic growth and environmental degradation (McGee et al., 2020). At the firm level, gender-diverse boards not only correlate with lower carbon emissions but also benefit from enhanced environmental innovation, especially in high-emission industries (Konadu et al., 2022; Rjiba and Thavaharan, 2022). These dynamics indicate that greater inclusion of women in governance and corporate decision-making can significantly influence carbon outcomes.
Cross-regional comparisons between OECD and Sub-Saharan African (SSA) countries reveal notable variations in how gender equality intersects with environmental and economic outcomes. In OECD countries, increasing female representation and education significantly reduce ecological degradation, although the effect of labour market equality on ecological footprint is non-linear and varies across income levels (Ergas et al., 2021; (Elish, 2022). Both ecofeminist and techno-centric approaches, including labour equality and innovation, have reduced environmental damage (Wani et al., 2023). Likewise, OECD firms with gender-diverse leadership show lower emissions (Rjiba & Thavaharan, 2022).
In contrast, the SSA context presents unique challenges. Environmental degradation undermines female economic inclusion, reinforcing cycles of inequality (Langnel et al., 2021). Women's participation in climate-resilient agricultural practices is uneven across countries due to cultural, regulatory, and social barriers (Perelli et al., 2024). Despite these constraints, local innovations and adaptive strategies among African women demonstrate significant potential for sustainability (Glazebrook and Opoku, 2020). These contrasts between SSA and OECD countries highlight the need for context-specific, intersectional policies that integrate gender into environmental planning.
The relationship between gender equality and economic growth is similarly complex across regions. In developing countries, gender parity in education contributes positively to economic expansion, with stronger effects observed in SSA (Altuzarra et al., 2021). However, the influence of women's political representation on growth is mixed, being beneficial globally but negatively associated with growth in SSA. Technological advancement positively affects growth in both OECD and SSA, though mobile telecommunications have a more pronounced impact in the latter (Myovella et al., 2020). Gender equality also affects youth employment, influenced by GDP, education, and globalization, with noticeable variations between North Africa and SSA (Anyanwu, 2016).

In OECD countries, closing the gender employment gap substantially reduces household income inequality (Azzollini et al., 2023). Gains in women's education have bolstered economic growth over several decades, with recent periods showing stronger effects (Thévenon and Del Pero, 2015). Moreover, gender gaps in health outcomes, such as mortality from neoplasms, affect national competitiveness (Gavurova et al., 2020). While the gender-math gap correlates with gender equality in low-income nations, this relationship is absent in OECD countries when country-specific factors are controlled (Anghel et al., 2020). These findings suggest that in more developed settings, structural factors may mediate the relationship between gender equality and human capital outcomes.

Decision-making power is another key vector in the gender-sustainability nexus. Female representation in parliaments is associated with environmentally progressive fiscal measures, including reduced fossil fuel subsidies and increased green taxation (Şimşek Kandemir et al., 2024). However, governance quality significantly affects the extent to which women's political presence translates into lower CO_2 emissions. Corporate gender diversity also enhances environmental performance (Kassinis et al., 2016)While in community-level natural resource governance, particularly in South Asia, women's inclusion has yielded positive conservation outcomes (Leisher et al., 2016). Though evidence from the SSA and OECD remains limited in this domain, the significance of women's leadership in environmental governance is evident across contexts.

The COVID-19 pandemic has further illuminated the vulnerabilities within gender equality, exacerbating existing disparities across both SSA and OECD countries. In SSA, women bore the brunt of job losses, increased unpaid care, mental health challenges, and gender-based violence (Ahinkorah et al., 2021; Casale and Posel, 2021; Jeawon, 2024). In OECD countries, women were more likely than men to lose jobs permanently, face income declines, and assume additional domestic responsibilities (Dang and Viet Nguyen, 2021; Kristal and Yaish, 2020; Reichelt et al., 2021). Despite evidence that women leaders managed the crisis more effectively, the pandemic widened gendered economic disparities (Profeta, 2020). These patterns suggest that systemic gender inequality compounds social and economic shocks and underscores the urgency for gender-responsive recovery policies.

In sum, the relationship between gender equality and sustainability is multifaceted and context-dependent, interlinking with carbon emissions, economic growth, trade, environmental resilience, and public health. While OECD countries exhibit structured institutional responses that leverage gender equality for sustainable gains, SSA countries face intersecting constraints of inequality, environmental vulnerability, and limited institutional capacity. However, evidence from both regions affirms that policies promoting gender inclusion—whether through education, leadership, or employment – can catalyse broader environmental and developmental benefits.

2.3. Social Inclusion and Inequality Reduction (SDG 10)

The pursuit of social inclusion is foundational to achieving Sustainable Development Goal 10, which aims to reduce inequality within and among countries. Defined as the process of improving the terms of participation in society for all people, particularly those who are disadvantaged, social inclusion ensures equitable access to resources, services, and opportunities (Van Niekerk, 2020). It addresses both income and non-income dimensions of inequality, making it an essential pillar of sustainable development (Cano-Hila, 2022). Across many low- and middle-income countries, particularly in Africa and Asia, the invisibility of marginalized groups in public service planning contributes to persistent exclusion, thereby exacerbating inequality and limiting life opportunities (Mir et al., 2024). Strategies aimed at improving inclusion – such as increasing the representation of disadvantaged communities in decision-making and transforming public service delivery systems to be more inclusive – have proven vital for fostering more equitable societies (Mir et al., 2024).

A dynamic relationship exists between social inclusion and inequality reduction, wherein inclusive practices promote equity, resilience, and economic participation. Empirical findings from Senegal and Mauritania reveal that individuals who perceive their communities as included in decision-making processes demonstrate stronger resilience capacities (d'Errico et al., 2018). Similarly, integrating economic inclusivity into business models, policy-making, and community development is pivotal for advancing SDG adoption and curbing global inequality (Van Niekerk, 2020). These insights highlight the bidirectional relationship between inclusive governance and societal well-being: as inclusion improves, inequality diminishes, and as inequality is addressed, more opportunities for inclusion emerge.

However, the effect of social inclusion on inequality reduction is not uniform; it is moderated by several contextual and structural factors. Financial inclusion emerges as a critical mechanism through which social inclusion reduces poverty and income inequality, particularly in developing countries (Omar and Inaba, 2020); Woldegiorgis, 2022). Yet, factors such as per capita income, internet penetration, inflation, age dependency, and population growth significantly shape the effectiveness of financial inclusion in narrowing inequality gaps (Omar & Inaba, 2020; Woldegiorgis, 2022). Additionally, inclusive educational policies can reduce disparities in youth well-being (Högberg, 2019). While healthcare access remains unequal, often favouring the wealthy, even in contexts of general improvement for disadvantaged groups (Heaton et al., 2016). The interplay between social inclusion and inequality is thus influenced by economic development levels, social redistribution, and sector-specific dynamics such as health and education.

A comparative perspective between Sub-Saharan Africa (SSA) and the Organisation for Economic Co-operation and Development (OECD) countries reveals both shared patterns and distinct pathways in the inclusion-inequality nexus. In SSA, social inclusion significantly reduces poverty and inequality, but this relationship may reverse beyond a certain threshold, suggesting a non-linear dynamic (Laryea et al., 2024). Furthermore, financial inclusion is linked to improved human capital and serves as a short-run moderator between inequality and economic growth, contradicting the classical Kuznets hypothesis (Menyelim et al., 2021). Income inequality, in turn, hampers poverty alleviation and inclusive growth, indicating that inequality itself undermines the benefits of inclusion unless deliberately addressed through redistributive and inclusive policies (Amponsah et al., 2023).

Conversely, in OECD countries, social investment (SI) policies are central to reducing inequality and poverty. The composition of social expenditures, such as parental leave, education funding, and active labour market policies plays a decisive role in determining the effectiveness of these investments (Bação et al., 2024; Sakamoto, 2021). Importantly, these SI policies yield the greatest equity gains when paired with redistributive measures, especially in social market economies, highlighting a complementary relationship between inclusion-focused programs and income redistribution (Sakamoto, 2023). The proposed international social inclusion index, which incorporates metrics such as education access, employment levels, and GDP growth, further reinforces the importance of multidimensional approaches to inclusion in OECD settings (Hassan et al., 2022).

In conclusion, while social inclusion generally facilitates inequality reduction, its impact is contingent upon several moderating factors, including financial access, educational equity, healthcare accessibility, and economic development. The SSA and OECD experiences underscore the context-specific nature of inclusion policies and their differential outcomes. In SSA, inclusion must be strategically scaled to avoid reversal effects, while in OECD countries, balanced policy mixes combining inclusion with redistribution offer the most sustainable path toward equity. These insights affirm the critical role of tailored, multi-sectoral interventions in advancing SDG 10 and fostering inclusive, equitable societies.

2. Empirical Review

The link between financial inclusion and environmental quality has been extensively explored in the literature, with inconclusive results on its effect on Carbon dioxide emissions. Studies offer diverse insights into sustainability, innovation, and social development. Hong et al. (2024) link time allocation to family well-being, while Fang et al. (2025) advance remote sensing for water quality. Li et al. (2024) explore wind power innovation networks, and Li & Li (2023) show how AI reduces 5G-related emissions. Cai et al. (2025) emphasize circular economy spill-overs. Luo et al. (2024) introduce "culturomics" for cultural analysis. Gao et al. (2025) examine gender's role in eldercare, and Ren and Zhu (2025) highlight ecological risks of a growing middle class. Li et al. (2021) address rural special education disparities. Liu et al. (2022) explored the impact of financial inclusion on environmental quality in sub-Saharan Africa, which indicates that financial inclusion increases Carbon dioxide emissions. More specifically, the findings of Adedoyin et al. (2022) indicated a correlation between financial development in the SSA region and higher CO_2 emissions, underscoring the importance of institutional frameworks in forging a balance between environmental sustainability and financial inclusion.

The role of clean energy transition in reducing CO_2 emissions in sub-Saharan Africa was examined by Maji (2019). The study found that a higher renewable energy consumption significantly reduces Carbon dioxide emissions in sub-Saharan Africa. This is corroborated by the findings of Lin & Agyeman (2020), who identified clean energy diffusion as a key factor in mitigating CO_2 emissions in both the short and long term, and Adedoyin et al. (2022), who emphasised that increased renewable energy consumption can effectively curb environmental degradation.

Langnel et al. (2021) examined the impact of environmental degradation on the economic inclusion of women in sub-Saharan Africa. The result of the study shows that CO_2 emissions have a negative effect on the labour force participation of women in SSA, which invariably, will slow down progress toward the Sustainable Development Goal 5 (SDG 5). This is a significant discovery in the exploration of the link between environmental sustainability and social inclusion, emphasizing the importance of gender-sensitive environmental policy.

Thresholds in the economic growth, CO_2 emission, and inclusive development linkages have also been empirically of some interest. CO_2 emission thresholds beyond which inclusive human development deteriorates were determined by Asongu & Odhiambo (2019) for sub-Saharan Africa, and were claimed to lie within the range of policy-making and hence ought to inform an evidence-informed response. Similarly, Abdulqadir (2023) provided evidence for the Kuznets curve on the relationship between urbanization, economic growth, renewable energy, trade, and CO_2 emissions. Economic growth and urbanization tipping points were identified by the study that, once reached, endanger environmental sustainability.

Skare et al. (2024) pointed out the significance of digitalisation in achieving the Sustainable Development Goals (SDGs). The findings of their study showed that digitalization has a positive impact on sustainable development. The study also showed that enhancing green total factor productivity is significantly crucial in achieving the 2030 SDGs. Ecological footprints across different industries and countries showed slow convergence. Additionally, sectoral studies on carbon footprint have provided valuable insights into targeted mitigation strategies. Karwacka et al. (2020) examined sustainable development in the agri-food sector, and according to their study, the sector's carbon footprint is a significant element of sustainability. The result of their study further indicated that animal-origin products have significantly higher carbon footprints than plant products, emphasizing the need for sustainable agriculture.

Ma et al. (2023) analysed trends in university carbon footprint research, which indicated rising academic literature on sustainability practices at the university level. More literature proves that economic development in most African countries is typically at the cost of rising carbon footprints, primarily due to energy use and resource extraction. For instance, Adeleye et al. (2021) recognized energy use and rising per capita income as drivers of Carbon dioxide emissions in African countries, characterizing developing economies' economic-environmental trade-offs. Institutional quality emerges as a guiding pillar of green growth.

Degbedji et al. (2024) showed that green economic growth in the West African Economic and Monetary Union is significantly boosted by strong institutions, which suggests that sound governance structures are essential to the success of green policies. This is consistent with findings by Guo et al. (2025), who emphasized the mediating effect of political institutions in the resource curse and in advancing sustainable development, even outside Africa. Osabohien et al. (2025a) also emphasise this by examining the post-COVID-19 era and revealing that the use of clean energy is supreme in building sustainable resilience in African economies. Similarly, renewable energy was found by Osabohien et al. (2025b) and Zheng et al. (2023) to have a positive and stable impact on sustainable development in Africa.

These studies emphasize the imperatives of investment in renewable infrastructure for decoupling economic growth from environmental degradation. This is reasserted in Imeokparia et al. (2023), where they found that African oil-producing countries must reinvest extractive revenue into sustainable and inclusive development if they are not to exacerbate poverty and environmental degradation. At the organizational and behavioural levels, Sahan et al. (2025) illustrated that green human resource management practices encourage pro-environmental behaviour and enhance environmental performance, emphasizing the micro-foundations of sustainability.

Urhie et al. (2020) determined that economic growth is negatively correlated with air pollution and human well-being, urging a balance between growth and human health. Several studies (Zhao et al., 2024; Xu et al.,2023; and Ma et al., 2024) have determined that digitalization, smart city policies, urban waste management systems, and AI-driven innovations can reduce carbon footprints and improve environmental governance. Specifically, Zhao et al. (2024) demonstrated that manufacturing technological upgrading reduces pollution significantly. Liu and Zhou (2025) applied extended input-output analysis to analyse prominent drivers of transport emissions and gave SSA a useful template to transition to.

Lin et al. (2024) investigate the dynamic impact of energy-related driving factors on carbon dioxide (CO_2) emissions and its future trend in SSA. The result showed that agricultural biodegradable mulching can both increase yields and lower emissions at the same time.

3. Methodology and Theoretical Framework

This sustainable development theory, is at the core of this study. It helps us to evaluates progress across three SDGs (5, 10, and 13), with a focus on inclusive growth, environmental sustainability, and inequality reduction. Sustainable Development Theory underscores the interdependence of economic growth, social inclusion, and environmental preservation, all of which are central components of this study.

This study utilizes an unbalanced panel dataset comprising 65 countries consisting of 27 Sub-Saharan Africa which were selected across four regions viz; Central Africa: Angola, Cameroon, Central African Republic, Chad, Congo (Democratic Republic), Congo (Republic), and Gabon. East Africa: Burundi, Kenya, Madagascar, Malawi, Mauritius, Rwanda, Seychelles, Tanzania, Uganda. Southern Africa: Botswana, Lesotho, Namibia, South Africa. West Africa: Burkina Faso, Cabo Verde, Ghana, Guinea, Liberia, Niger, Nigeria, Togo. and 38 OECD member states, which were also selected across five regions viz; East Asia & Pacific: Australia, Japan, Korea Republic, and New Zealand. Europe & Central Asia: Austria, Belgium, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Türkiye and United Kingdom. Latin America & Caribbean: Chile, Colombia, Costa Rica and Mexico. Middle East and North Africa: Israel. North America: Canada and United States of America. The selection reflects diverse developmental trajectories and policy responses to sustainability challenges and purely based on availability of required data. Data were obtained from the UN Sustainable Development Goal Global Database (SDR) and World Bank World Development Indicators (WDI) covering the period from 2000 – 2022. The data description and measure are shown in Table 1.

To empirically examine the multifaceted pathways to sustainable development, three panel regression models are specified, each aligned with a specific Sustainable Development Goal (SDG): SDG13 (Climate Action), SDG5 (Gender Equality), and SDG10 (Reduced Inequality). These models incorporate a set of theoretically and empirically pertinent regressors, including carbon emissions ($lnCO_2$_emission), female labour force participation (lnFem_lab_part), employment to population ration (Emp_Pop_Ratio) Vulnerable employment as a percentage of total employment (Vulnerable_Emp), urbanization (lnUrban), GDP per capita (lnGDP_pc), and a pandemic dummy variable. These variables are selected to reflect the study's core dimensions: environmental impact, social inclusion, and economic disparity. Their inclusion facilitates the examination of how structural factors and external shocks interact to influence progress across the selected SDGs. This approach allows for a nuanced understanding of sustainability that transcends aggregate metrics to explore cross-national and temporal variations in development outcomes. Furthermore, given the cross-country nature of Sub-Saharan Africa (SSA) and Organisation for Economic Co-operation and Development (OECD) economies, this study employs a multivariate panel time series model. Three-panel regression models are estimated to capture the relationships between the explanatory variables and each SDG outcome. The log-linear models are specified below: Model 1 captures SDG-5 – Gender Inequality, Model 2 captures SDG10 – Inequality, and Model 3 captures SDG13 – Climate Action.

Table 1. Variables Description, Expectations and Sources, source: Authors' compilations

Variables	Measurements	Source
SDG13	Climate Action	SDR Data
SDG5	Gender Equality	SDR Data
SDG10	Social Inclusion	SDR Data
CO_2	Carbon dioxide emission (Carbon Footprint)	WDI
FEM_LAB_PART	Ratio of female to male labour force participation (A proxy for gender equality)	WDI
EMP_POP_RATIO	Proportion of a country's population that is employed	WDI
VULNERABLE_EMP	Vulnerable employment as a percentage of total employment.	WDI
PANDEMIC	A time dummy variable for 2020–2022 was introduced to capture the impact of the COVID-19 pandemic on sustainability efforts.	WDI
REC	Share of renewable energy in total final energy consumption.	WDI
GDP_PC	GDP per capita is gross domestic product at current U.S. dollars.	WDI
URBAN	Urban population (% of total population)	WDI

$$lnSDG5_{it} = a_0 + \alpha_1 \text{lnCO2\_emission}_{it} + \alpha_2 \text{lnFem\_lab\_part}_{it} + \alpha_3 \text{lnemp\_pop\_ratio} + \alpha_4 \text{lnvunerable\_emp\_} + \alpha_5 Pandemic_{it} + \alpha_6 \text{lnGDP\_pc}_{it} + \alpha_7 lnUrban_{it} + \varepsilon_{it} \quad (1)$$

$$lnSDG10_{it} = a_0 + \alpha_1 \text{lnCO2\_emission}_{it} + \alpha_2 \text{lnFem\_lab\_part}_{it} + \alpha_3 \text{lnemp\_pop\_ratio} + \alpha_4 \text{lnvunerable\_emp\_} + \alpha_5 Pandemic_{it} + \alpha_6 \text{lnGDP\_pc}_{it} + \alpha_7 lnUrban_{it} + \varepsilon_{it} \quad (2)$$

$$lnSDG13_{it} = a_0 + \alpha_1 \text{lnCO2\_emission}_{it} + \alpha_2 \text{lnFem\_lab\_part}_{it} + \alpha_3 \text{lnemp\_pop\_ratio} + \alpha_4 \text{lnvunerable\_emp\_} + \alpha_5 Pandemic_{it} + \alpha_6 \text{lnGDP\_pc}_{it} + \alpha_7 lnUrban_{it} + \varepsilon_{it} \quad (3)$$

where *i* and *t*. denote country and year, respectively, α_0 is the constant term, while α_1 – α_8 are the estimated coefficients. ε_{it} is the error term,

By employing consistent regressors across all models, this study facilitates a comparative analysis of the interactions between carbon emissions and inclusion variables with various sustainability goals. This methodological approach is particularly effective in addressing Objective 1 (the impact of carbon footprints), Objective 2 (social inclusion across income groups), and Objective 3 (the moderating role of the pandemic). Moreover, the methodology adopted in this research embodies a systems-thinking approach to Sustainable Development Goals (SDG) research, focusing not only on outcomes but also on the underlying drivers and constraints that influence sustainable development. The inclusion of a pandemic moderator is both timely and pertinent, situating the study within ongoing global discussions on resilience and recovery in response to systemic shocks. Additionally, the utilization of cross-national panel data with temporal variation enhances the analytical depth of the study, allowing for the generation of policy-relevant insights that can assist both national and international stakeholders in formulating targeted and adaptive development interventions.

4. Results and Discussion

4.1. Descriptive Statistics and Correlation Analysis

This section delineates the results of the principal characteristics of the variables within the dataset, as derived from the descriptive statistics presented in Table 2. The Sustainable Development Goal 13 (SDG13) exhibits an average value of 79.57 with a standard deviation of 19.40 for the full sample, indicating high levels of climate action performance with moderate variation across the countries examined. This high level of climate action performance and variability for the full sample is quite similar across the sub-regions, with the SSA, having the highest (96.00) average sustainable development goal 13 performance and a standard deviation of 5.29 indicating a minimal variability among the countries that make up the region while OECDE has a mean score of 67.88 and a standard deviation of 17.18, also indicating dispersion in the series.

For SDG10 (Social Inclusion), the mean score for the full sample was 61.21, indicating modest effort in improving social inclusion among the selected countries. In evaluating the performance of SSA and OECD towards enhancing social inclusion in the regions, the OECD countries (77.21) have a higher mean value compared to the SSA countries (38.69). However, significant variations exist among the selected countries. For the full sample, the standard deviation of 29.85 indicates a very high level of deviation from the true mean. This is similar for the SSA (22.25) and OECD (23.58) countries, with SSA having the highest variable in terms of social inclusion. Gender equality (SDG5) records an average value of 61.11 with a standard deviation of 18.59, demonstrating significant variability in gender equality across countries. Sub-Saharan Africa has the lowest mean value for gender equality (46.74) and a high level of variability. The OECD has a high level of gender equality and a moderate level of variability among the countries that make up the organisation. The average value for CO_2 emission for the full sample was 208.08, and the standard deviation of 684.49, indicating a very high level of variability among the countries. A further examination indicates that the OECD countries have the highest mean CO2 emission value (338.36) while the SSA has the least mean carbon emission (24.72). Both regions show a high level of variability.

Table 2. Descriptive Statistics, *source: Authors' computation*

Variable	Full Sample		SSA		OECD	
	Mean (SD)	**Min (Max)**	**Mean (SD)**	**Min (Max)**	**Mean (SD)**	**Min (Max)**
sdg13	79.57	13.63	96.0091	78.41	67.88794	13.63
	(19.40)	99.80	5.29762	99.8	17.18229	93.49
sdg10	61.21	0.00	38.6939	0	77.21109	6.06
	(29.85)	100.00	22.2552	91.76	23.58704	100
sdg5	61.11	17.92	46.7465	17.92	71.30995	24.99
	(18.59)	94.12	16.8747	87.36	11.74888	94.12
CO_2_emission	208.08	0.15	24.7249	0.15	338.3602	2.85
	(684.49)	5928.97	84.2707	487.91	869.4055	5928.97
fem_lab_part	79.92	33.02	83.7546	46.12	77.18928	33.02
	(11.25)	104.01	10.447	104.01	11.01466	95.77
emp_pop_ratio	59.12	36.80	63.25	36.80	56.18	37.29
	(10.02)	85.84	12.43	85.84	6.42	76.26
vulnerable_emp	67.14	0.10	64.09	8.83	98.88	3.57
	(42.26)	100.00	24.75	94.13	3.61	48.95
gdp_pc	20890.03	111.41	3638.31	111.41	33147.83	533.59
	(24086.04)	133712.00	9352.55	68190.7	23844.4	133712
urban	61.29	8.25	40.4982	8.25	76.05892	50.09
	(23.49)	98.15	20.2148	90.74	11.32562	98.15

Table 3. Correlation Matrix for SSA, *source:* Authors' computation

	sdg13	**sdg10**	**sdg5**	**CO_2_ emission**	**fem_lab _part**	**emp_pop _ratio**	**Vulnerable _Emp**	**gdp_pc**	**urban**
sdg13	1.000								
sdg10	0.392	1.000							
sdg5	-0.463	-0.451	1.000						
CO_2_emission	-0.525	-0.272	0.329	1.000					
fem_lab_part	0.366	0.001	0.038	-0.086	1.000				
emp_pop_ratio	0.693	0.440	-0.379	-0.245	0.551	1.000			
vulnerable_Emp	0.720	0.413	-0.683	-0.408	0.507	0.720	1.000		
pandemic	0.023	0.098	0.158	0.008	-0.019	-0.099	-0.029		
gdp_pc	-0.345	-0.135	0.097	0.086	-0.144	-0.151	-0.195	1.000	
urban	-0.693	-0.282	0.183	0.250	-0.212	-0.488	-0.386	0.550	1.000

The female labour participation, with an average value of 79.92 and a standard deviation of 11.25, exhibits modest fluctuation. This is similar across the SSA and OECD regions, with SSA having the highest level of female labour participation (83.75) while OECD has the least level (77.18). The employment-to-labour ratio shows a mean value of 59.12 and a standard deviation of 10.02, reflecting mild dispersion. The same trend is recorded in SSA and OECD, with Sub-Saharan Africa having a higher mean value of employment to labour ratio than the OECD. The OECD has the highest mean value of vulnerable employment (98.88) with a standard deviation of 3.61, reflecting an insignificant fluctuation. However, the OECD with a mean of 64.09 for vulnerable employment a high level of variability. Furthermore, the sampled countries exhibit an average per capita Gross Domestic Product of 20890.03, indicating modest economic levels, with a standard deviation of 24086.04, signifying high variability among the countries.

Table 4. Correlation Matrix for OECD, source: Authors' computation

	sdg13	sdg10	sdg5	CO_2_ emission	fem_lab _part	emp_pop _ratio	Vul-nera-ble _Emp	gdp_pc	urban
sdg13	1.000								
sdg10	-0.463	1.000							
sdg5	-0.367	0.394	1.000						
CO_2_emission	-0.117	-0.172	-0.090	1.000					
fem_lab_part	-0.520	0.610	0.711	-0.011	1.000				
emp_pop_ratio	-0.455	0.087	0.512	0.083	0.476	1.000			
vulnerable_Emp	0.499	-0.671	-0.522	-0.172	-0.681	-0.248	1.000		
pandemic	0.094	0.040	0.209	-0.016	0.124	0.056	-0.042		
gdp_pc	-0.513	0.412	0.408	0.096	0.425	0.370	-0.459	1.000	
urban	-0.143	-0.078	0.198	0.105	0.087	0.264	-0.080	0.408	1.000

The OECD (33147.83) has the highest level of per capita Gross Domestic Product, while SSA (33147.83) has the lowest level of Gross Domestic Product per capita. The mean value for urbanisation is 61.29 for the full sample while it was 40.4982 for SSA and 76.058 for OECD, indicating that the OCED has the highest average level of urbanisation.

4.2. Cross-Sectional Dependence, Stationarity, and Cointegration Tests

This study examines how carbon footprints, social inclusion, and inequality jointly influence the progress toward SDGs 5 (Gender Equality), 10 (Reduced Inequality), and 13 (Climate Action) in selected SSA and OECD countries between 2000 and 2022. Since there can be interdependence among countries, based on geographic closeness or shared socio-economic features, it is pertinent to begin by testing for cross-sectional dependence (CSD), which, if not controlled, can lead to spurious estimates. To determine this, this study implemented the Pesaran (2004, 2007) CD test, which is suitable for both large and small panels. Failure to reject the null hypothesis would indicate that CSD is present. The result of the CSD test score of 50.036, with a probability of 0.0000, indicates the presence of cross-sectional dependence. This study, therefore, employed second-generation unit root tests to ensure strong estimation. The Cross-Sectional Augmented Im, Pesaran, and Shin (CIPS) test and the Cross-Sectionally Augmented Dickey-Fuller (CADF) test are utilized in specific contexts. These tests control for interdependencies across countries through the inclusion of cross-sectional averages, thus producing more reliable stationarity tests in panels with correlated units. The result of the unit root test reported in Table 5 indicates that all the variables are stationary at first difference at the 1% level of significance, except for female labour participation, which is integrated of order one I(0) at the 10% level of significance for the CIPS test.

The examination of cointegration among the variables underscores the long-term equilibrium relationship suggested by macroeconomic models. Consequently, to explore potential cross-sectional interdependence, the Pedroni cointegration test was employed. The Pedroni test is designed for heterogeneous panels, allowing for cross-sectional dependence and varying slopes across units. The findings in Table 6 indicate that a cointegrating relationship exists between the SDG indicators and the included regressors in the three models. Therefore, the Random Effect (RE) and Fixed Effect (FE) estimation techniques can be engaged to examine the effects of the explanatory variables on the outcome variables (SDG13, SDG5, and SDG10).

Table 5. Stationarities of the Variables, source: Authors' computation

Variable	CIPS		CADF	
	I(0)	I(1)	I(0)	I(1)
SDG13	-2.419	-4.552***	-2.291	-4.359***
SDG10	-2.269	-4.641***	-2.230	-4.569***
SDG5	-2.397	-4.184***	-2.374	-4.263***
CO2_emission	-2.475	-4.525***	-2.344	-4.548***
Fem_Lab_Part	-2.525*	-3.992***	-2.306	-3.984***
Emp_Pop_Ratio	-1.997	-3.228***	-1.668	-3.155***
Vulnerable_Emp	-1.823	-3.932***	-1.732	-3.925***
GDP_PC	-2.190	-3.493***	-1.942	-3.493***
Urban	-1.636	-3.739***	-1.456	-3.571***

Note: ***, ** and * illustrate the 1 %, 5 % and 10 % significance levels, respectively.

Table 6. Pedroni Panel cointegration test results, source: Authors' computation

Test statistics	MODEL 1: SDG13		MODEL 2: SDG5		MODEL 3: SDG10	
	SSA	OECD	SSA	OECD	SSA	OECD
	1	2	3	4	5	6
Modified Phillips–Perron t	3.6481***	5.0126***	5.4495***	4.6646***	5.2163***	5.5949***
Phillips–Perron t	-6.2733***	-5.9572***	-2.7146***	-5.9527***	-2.8095***	-7.3475***
Augmented Dickey–Fuller t	-7.9905***	-6.3304***	-3.5041***	-6.0644***	-2.9444***	-6.9288***

Note: ***, **, and * illustrate the 1 %, 5 %, and 10 % significance levels, respectively.

4.3. Fixed Effect Result and Regional Estimate

For unobserved heterogeneity, the study employs either the Fixed-Effects (FE) or Random-Effects (RE) model, based on the outcome of the Hausman test. The Hausman test evaluates whether the fixed-effects model is preferred by testing the null hypothesis that the random-effects model is consistent. If the null hypothesis is rejected, the fixed-effects model is selected, as it controls for time-invariant characteristics unique to each entity, thereby mitigating omitted variable bias. The result of the Hausman test reported in Table 7 indicates that the *p_value* of the chi2 for the three models is less than 0.05. We therefore reject the null hypothesis and estimate the fixed effect model

Model 1: Gender Equality (SDG 5)

The findings from Model 2 (columns 3 and 4) underscore the pivotal role of female labour force participation (lnFem_Lab_Partt) in promoting gender equality across both Sub-Saharan Africa (SSA) and the Organisation for Economic Co-operation and Development (OECD) regions. The variable demonstrates a strong, positive, and statistically significant influence on gender equality outcomes, with coefficients of 0.468 in SSA and 0.879 in the OECD. These results reaffirm the notion that women's economic participation is not merely a developmental goal in itself but a critical enabler of broader gender equity, particularly in the context of Sustainable Development Goal 5 (SDG 5).

Despite these gains, other indicators of social inclusion, such as the employment-to-population ratio and vulnerable employment, yield contrasting outcomes, particularly within SSA. The employment-to-population ratio exerts a negative effect on gender equality (-0.380), as does vulnerable employment (-0.317), suggesting that high employment levels, in the absence of job quality and social protections, may entrench rather than alleviate gender disparities. This dynamic reflects the structural weaknesses in SSA labour markets, where a substantial share of employment remains informal, low-paying, and devoid of social security conditions under which women are disproportionately represented. These findings highlight the need for African policymakers to adopt comprehensive labour market reforms that prioritize the formalization of work, the extension of gender-responsive social protection systems, and the enforcement of labour rights, especially in sectors dominated by female workers.

In the OECD context, vulnerable employment also negatively impacts gender equality (-0.103), albeit to a lesser extent. This finding signal that even in high-income settings, job insecurity – manifested through part-time, temporary, or gig work – can erode the progress made in gender equity. Thus, policy efforts in OECD countries must include targeted strategies to strengthen employment protections for women in precarious job categories, including enhanced parental leave, wage parity laws, and pathways to permanent employment.

Interestingly, CO_2 emissions are positively associated with gender equality in SSA (coefficient = 0.116). This counterintuitive result may reflect the demographic and occupational realities of SSA economies, where women are significantly engaged in high-emission sectors such as agriculture, charcoal production, and informal trading. In contrast, the relationship is slightly negative in OECD countries (-0.024), where female labour tends to be concentrated in low-carbon sectors such as health, education, and social services. These divergent trends highlight the intersection of gender and environmental outcomes, suggesting that the green transition must be designed with equity considerations. For SSA, the implication is clear: climate policies must aim to transition women into green and climate-resilient sectors through skills training, inclusive access to green financing, and affirmative policies supporting women-led sustainable enterprises. In OECD countries, the mainstreaming of gender perspectives into environmental governance and climate finance frameworks is essential to ensure a just and inclusive transition.

The variable capturing the COVID-19 pandemic demonstrates a small but positive influence on gender equality in both SSA (0.024) and the OECD (0.026). This may reflect the heightened visibility and participation of women in care work, health services, and community-level responses during the crisis. However, these gains may prove ephemeral without sustained institutionalization. It is therefore imperative that post-pandemic recovery strategies include gender-responsive budgeting, participatory policy planning, and structural investments in the care economy to consolidate and expand the gender-equity dividends of crisis response efforts.

Finally, both urbanization (0.285) and GDP per capita (0.064) are positively associated with gender equality in SSA. These findings suggest that modernization and economic expansion can contribute to gender parity when aligned with inclusive and equitable policies. Urban environments, in particular, may offer women greater access to education, formal employment, healthcare, and political participation. However, the quality of urban growth matters; without proactive policies to address urban gender disparities, such gains may be unevenly distributed.

Thus, integrated urban planning and inclusive growth strategies are essential to ensure that the benefits of modernization are equitably shared across gender lines.

Model 2: Reduced Inequality (SDG10)

The results from Model 3 (columns 5 and 6) reveal notable regional heterogeneity between Sub-Saharan Africa (SSA) and the Organisation for Economic Co-operation and Development (OECD) countries, reflecting divergent structural, institutional, and developmental contexts.

In SSA, carbon emissions (lnCO_2_emission) are positively associated with inequality (coefficient = 0.120), although this relationship is statistically insignificant. This suggests that rising emissions – typically a byproduct of industrial and economic activity – have not translated into broad-based gains or inclusive employment, possibly due to weak regulatory frameworks, limited value-chain integration, and the dominance of extractive industries with low employment elasticity. In contrast, the OECD shows a significant positive relationship (coefficient = 0.140), potentially indicating that environmentally intensive industries are more likely to generate employment opportunities and reduce income disparities, possibly through formal labour markets and inclusive industrial policies. These contrasting dynamics emphasize the need for green industrial policies in SSA that link environmental performance with equitable economic outcomes.

Female labour force participation (lnFem_Lab_Partt) yields divergent results across regions. In SSA, it is negatively associated with inequality (-0.181), suggesting that increased participation does not necessarily equate to empowerment or equitable outcomes. This may be attributed to the concentration of women in informal, low-wage, and insecure employment, reinforcing existing gender hierarchies. Conversely, the significantly positive coefficient in OECD countries (0.331) implies that higher female participation contributes to reduced inequality, likely due to stronger institutional support for gender equality, higher female educational attainment, and better access to quality jobs. Policy interventions in SSA must therefore go beyond labour force participation to focus on enhancing the quality of women's employment, including access to education, legal protections, and social safety nets.

Vulnerable employment is strongly associated with increased inequality in both regions, albeit with greater intensity in SSA (coefficient = -0.678) compared to the OECD (-0.103). This finding highlights the developmental cost of informality and underemployment, particularly in low-income settings where labour protections are weak and social insurance is limited. The stark effect in SSA calls for urgent labour market reforms, including the formalization of informal enterprises, investment in decent work, and improved social protection systems.

The employment-to-population ratio (lnEmp_Pop_Ratio) exerts a significant equalizing effect in SSA (coefficient = 0.521), indicating that broader labour market inclusion can support redistributive outcomes and poverty reduction. This underscores the importance of employment-intensive growth strategies in the region. In contrast, the effect is muted in OECD countries, possibly due to already high baseline levels of employment and comprehensive redistributive systems that buffer inequality through other channels.

The impact of the COVID-19 pandemic exhibits a positive but modest coefficient in both regions (0.131 in SSA; 0.043 in OECD), suggesting that emergency fiscal interventions and social assistance programs may have temporarily mitigated inequality. However, the durability of these effects remains uncertain and highlights the need for sustained social protection mechanisms, particularly in SSA, where such systems are often fragmented and under-resourced.

GDP per capita shows a positive association with inequality in both regions (0.053 in SSA; 0.033 in OECD), though the effect is weaker in SSA. This suggests that while economic growth has the potential to reduce poverty, it may not automatically translate into reduced inequality without deliberate redistributive policies. The weaker effect in SSA reinforces concerns about growth patterns that are exclusionary and spatially uneven, driven by capital-intensive sectors with limited employment linkages.

Finally, urbanization does not exhibit a statistically significant impact on inequality in either region (0.077 in OECD), pointing to the complex and context-specific nature of urban development. In SSA, this may reflect the prevalence of slum urbanization, infrastructural deficits, and spatial inequality, while in OECD countries, urbanization's benefits may be counterbalanced by rising housing costs and labour market segmentation.

Model 3: Climate Action (SDG13)

Based on the regression analysis examining the multidimensional pathways to Sustainable Development Goals (SDGs) through the lenses of carbon footprints, social inclusion, and inequality, the results reveal important insights for both Sub-Saharan Africa (SSA) and OECD countries. Table 7 presents the estimates obtained from the fixed effect estimation for the three models. The findings indicate that, in Model 1 (SDG13 – Climate Action) in columns 1 and 2, carbon footprint (lnCO_2_emission) exert a statistically significant negative effect on climate action in both regions, with a coefficient of -0.004 in SSA and a much larger -0.218 in OECD. This suggests that a 1% increase in carbon footprint may result in approximately a -0.004% and -0.22% decrease in achieving sustainable development goal 13 in both the Sub-Saharan Africa (SSA) and OECD countries. This confirms that increased emissions undermine climate resilience, particularly in more industrialized economies. The negative impact of carbon dioxide emissions on sustainable development (SDG13) in SSA and OECD countries indicates a substantial reliance on fossil fuels and carbon-emitting industries. This is contrary with the research of Wang et al. (2024), ho identified a positive relationship between CO_2 emissions and sustainable development in SSA. These results underscore the urgent need for SSA and OECD countries to transition towards sustainable industrialization, invest in renewable energy, and adopt low-carbon technologies to decouple economic growth from environmental degradation and also highlights the region's challenges in balancing industrial growth with environmental protection, necessitating stronger policies and regulations to promote sustainable development while mitigating climate change impacts (Wang et al., 2024; Asongu & Odhiambo, 2019).

The findings reveal a stark contrast in the level and structure of gender equality proxied by female labour force participation (lnFem_Lab_Partt) between SSA and OECD countries, with significant implications for both female labour force participation and its impact on climate action (SDG 13). In SSA, the negative relationship between female labour force participation and climate action (-0.013) suggests that gender equality remains limited in terms of access to quality, sustainable employment. Women in SSA are often confined to informal, low-wage, and environmentally harmful sectors like agriculture and informal services, which hampers their potential to contribute to climate resilience and sustainable development. This reflects the structural challenges in SSA, where gender equality is not yet fully integrated into the labour market, and women's economic roles are often undervalued and restricted to sectors with minimal environmental sustainability practices.

In contrast, OECD countries show a positive and significant relationship between female labour force participation and climate action (0.337), indicating that gender equality in the workforce is more advanced. Here, women's inclusion is linked to progressive environmental policies, technological innovation, and sustainable sectors, where gender-inclusive strategies can actively drive climate resilience. This suggests that gender equality in OECD countries has evolved, where women's participation in the labour market contributes meaningfully to environmental sustainability, which is underpinned by stronger labour protections and inclusive policies. To foster beneficial outcomes, particularly in SSA, the focus must be on advancing gender equality by providing women with greater access to secure, green jobs, particularly in renewable energy and eco-friendly industries. Gender-sensitive environmental policies, alongside initiatives for skills development in green technologies, can empower women in SSA, enabling them to play a pivotal role in advancing both gender equality and climate resilience.

Vulnerable employment (lnVulnerable_Emp) significantly hampers climate performance in SSA (-0.043) at the 1% level of significance, reinforcing the role of labour precarity in weakening environmental governance. However, in OECD (0.03) its effect was positive and weakly significant at the 10% level. This implies that the effect of vulnerable employment hampers climate performance in Sub-Saharan Africa (SSA), reflecting the prevalence of insecure, informal jobs in resource-exploitative sectors. The result highlights that the level and structure of social inclusion in Sub-Saharan Africa (SSA) are characterized by a significant presence of vulnerable employment, which negatively impacts climate performance. This finding indicates that a large portion of the workforce in SSA is engaged in insecure, informal jobs, often in environmentally exploitative sectors. These precarious jobs limit workers' ability to participate in sustainable practices, leading to weak environmental governance and hindering efforts to achieve SDG 13 (Climate Action). This reflects a broader structural challenge in SSA, where labour market insecurity and lack of labour protections contribute to social exclusion, further exacerbating the region's vulnerability to climate change. For meaningful social inclusion and improved environmental resilience, SSA must focus on securing livelihoods through formal, sustainable, and green job creation, alongside strengthening labour rights and protections.

In contrast, the result suggests that OECD countries exhibit a higher level of social inclusion in the labour market, characterized by stronger labour protections that help mitigate the negative impacts of vulnerable employment on climate performance. The positive coefficient of 0.03 indicates that, in these countries, even vulnerable employment has a relatively weaker but beneficial effect on climate outcomes. This can be attributed to the more secure, formal, and often environmentally conscious nature of jobs in the OECD, where labour rights are better protected, and workers are more likely to be involved in climate-positive policies and practices. The structure of social inclusion in the OECD promotes resilience through inclusive economic policies, stronger labour regulations, and a focus on sustainability, which together support both social equity and environmental sustainability.

Employment-to-population ratio (lnEmp_Pop_Ratio) had a negative and insignificant effect on Climate performance in SSA, while its performance in OECD was negative and statistically significant at the 1% level of significance.

The employment-to-population ratio (lnEmp_Pop_Ratio) reveals differing implications for climate action across regions. In Sub-Saharan Africa (SSA), its negative but statistically insignificant effect suggests that general employment levels do not strongly influence climate outcomes, likely due to the dominance of low-productivity, informal, and resource-intensive sectors. These sectors neither promote green practices nor contribute meaningfully to environmental governance.

In contrast, the significantly negative effect observed in OECD countries (at the 1% level) implies that higher employment levels, under current economic structures, may exacerbate environmental pressures. This could be attributed to labour-intensive industries with high carbon footprints, highlighting the challenge of decoupling job creation from environmental degradation. To improve climate performance, both regions must align employment strategies with sustainability goals. SSA should focus on formalizing the labour market and investing in eco-friendly industries, while OECD countries must accelerate the transition to green jobs and adopt cleaner technologies that support both employment and environmental resilience.

The pandemic variable exhibits a small but significant positive coefficient (0.006 in SSA; 0.049 in OECD), likely reflecting temporary emission reductions during lockdowns. The findings suggest that the COVID-19 pandemic had a modest positive impact on climate action in both SSA and OECD countries, though more pronounced in OECD. The positive coefficients (0.006 in SSA; 0.049 in OECD) likely reflect temporary reductions in carbon emissions due to lockdowns and reduced industrial activity. This underscores how structural shifts in economic activity can influence climate outcomes. For lasting climate gains, both regions must transition from reactive, crisis-driven reductions to deliberate, sustainable environmental policies and green economic reforms.

The result indicates that GDP per capita (lnGDP_PC) has a detrimental effect on SDG13 - climate action scores (-0.008 SSA; -0.059 OECD). The negative relationship between GDP per capita and climate action scores in both SSA (-0.008) and OECD (-0.059) highlights a critical environmental paradox: economic growth, as presently structured, is still largely dependent on carbon-intensive sectors. In Sub-Saharan Africa, this may stem from a reliance on extractive industries, rapid urbanization, and infrastructural development that often neglect sustainable practices. In OECD countries, despite advanced technologies, high consumption patterns and continued dependence on fossil fuels in transportation, manufacturing, and energy generation contribute to this decoupling failure.

These findings suggest that neither region has successfully decoupled economic growth from environmental degradation. To reverse this trend, both the SSA and the OECD must adopt green growth strategies. SSA should focus on leapfrogging to clean technologies, investing in renewable energy, and embedding sustainability in national development plans. OECD countries must strengthen regulatory frameworks, incentivize green innovation, and reduce carbon dependency through circular economy models, carbon pricing, and sustainable consumption initiatives. A deliberate shift toward inclusive, low-carbon economies is essential to reconcile economic development with SDG 13 targets.

Table 6. Estimates from the Fixed Effect (FE) and regional analysis, source: Authors' Estimation

	MODEL 1: SDG13		MODEL 2: SDG5		MODEL 3: SDG10	
Variables	SSA	OECD	SSA	OECD	SSA	OECD
	1	2	3	4	5	6
lnCO2_emission	-0.004***	-0.218***	0.116***	-0.024**	0.120**	0.140***
	(0.0014)	(0.0159)	(0.016)	(0.012)	(0.052)	(0.024)
	[-2.97]	[-13.7]	[7.02]	[-1.98]	[2.32]	[5.95]
lnFem_Lab_Partt	-0.013*	0.337***	0.468***	0.879***	-0.181	0.331***
	(0.0076)	(0.0456)	(0.087)	(0.035)	(0.287)	(0.068)
	[-1.7]	[7.4]	[5.37]	[24.95]	[-0.63]	[4.91]
lnEmp_Pop_Ratio	-0.005	-0.173***	-0.380***	0.097**	0.521*	0.072
	(0.008)	(0.0491)	(0.092)	(0.038)	(0.307)	(0.073)
	[-0.68]	[-3.52]	[-4.12]	[2.56]	[1.69]	[1.00]
lnVulnerable_Emp	-0.043***	0.030*	-0.317***	-0.103***	-0.678**	0.008
	(0.0066)	(0.0179)	(0.075)	(0.014)	(0.309)	(0.026)
	[-6.49]	[1.67]	[-4.21]	[-7.48]	[-2.19]	[0.3]
pandemic	0.006***	0.049***	0.024*	0.026***	0.131***	0.043***
	(0.0011)	(0.0067)	(0.013)	(0.005)	(0.04)	(0.01)
	[5.65]	[7.31]	[1.85]	[4.99]	[3.32]	[4.34]
lnGDP_PC	-0.008***	-0.059***	0.064***	0.038***	0.053	0.033***
	(0.0012)	(0.0071)	(0.014)	(0.006)	(0.046)	(0.011)
	[-6.15]	[-8.29]	[4.43]	[6.84]	[1.17]	[3.09]
lnurban	0.008	0.490***	0.285***	0.213***	0.057	0.077
	(0.0055)	(0.0749)	(0.063)	(0.058)	(0.205)	(0.111)
	[1.48]	[6.55]	[4.53]	[3.68]	[0.28]	[0.7]
_cons	4.845***	2.791***	2.937***	-0.884***	4.240**	1.210**
	(0.0443)	(0.3684)	0.508	0.285	2.095	0.545
	[109.31]	[7.58]	[5.78]	[-3.11]	[2.02]	[2.22]

***, **, * denotes significance levels at 1%, 5%, and 10% respectively. The dependent variable here are 3 sustainable development goals, measured SDG13, SDG5 and SDG10. The independent variables explaining sustainable development goals are carbon footprints measure by CO_2 emission, female labour participation, employment to labour ratio, vulnerable employment, Covid-19 pandemic, gross domestic product per capita, and urbanisation. The standard errors are in parentheses while the t-statistics are in braces.

Urbanization (lnurban) shows an insignificant 0.008 in SSA but a significant 0.490 in OECD, implying that only advanced urban systems contribute positively to climate goals. To harness urbanization for climate resilience, SSA must prioritize sustainable urban planning, invest in green infrastructure, and integrate climate considerations into city development. Enhancing institutional capacity, enforcing urban environmental regulations, and promoting inclusive city governance are also crucial steps toward making urban growth a driver of climate action in the region.

4.4. COVID-19 and Sustainable Development: A Comparative Analysis of Gender Equality, Employment Vulnerability, and Climate Action in OECD and Sub-Saharan Africa

4.4.1. Assessing Regional Progress on Gender Equality, Inequality Reduction, and Climate Action Before and After COVID-19: A Comparative Analysis of SDG Performance in Africa and OECD Countries

The graph presents a comparative analysis of the average scores for SDG 5 (Gender Equality), SDG 10 (Reduced Inequality), and SDG 13 (Climate Action) across five regions—Central Africa, East Africa, Southern Africa, West Africa, and OECD countries—before COVID-19 (≤2018) and during/after COVID-19 (≥2019).

In terms of SDG 5, OECD countries consistently recorded the highest scores both before and during/after the pandemic, ranging between 70 and 78. Southern Africa maintained similarly high scores, closely following the OECD, with slight improvements noted post-pandemic. East Africa exhibited marked progress, with its score rising from approximately 52 to 63. Although Central Africa and West Africa initially recorded the lowest scores, both regions showed moderate improvement after COVID-19, with Central Africa increasing from around 37 to 43 and West Africa from about 34 to 41. Overall, COVID-19 did not cause major distortions in gender equality outcomes, as most regions, particularly within Africa, experienced slight improvements.

Regarding SDG 10, OECD countries again led with scores improving marginally from approximately 81 to 84. Notably, West Africa achieved significant progress, rising from around 49 to nearly 59, while East Africa also recorded moderate gains. Central Africa experienced a slight increase from about 33 to 36. Southern Africa, however, remained persistently low, with only a modest improvement from approximately 7 to 12, highlighting continued challenges in addressing inequality. The impact of COVID-19 on inequality was thus moderate, with positive trajectories in West and East Africa but continued concerns in Southern Africa.

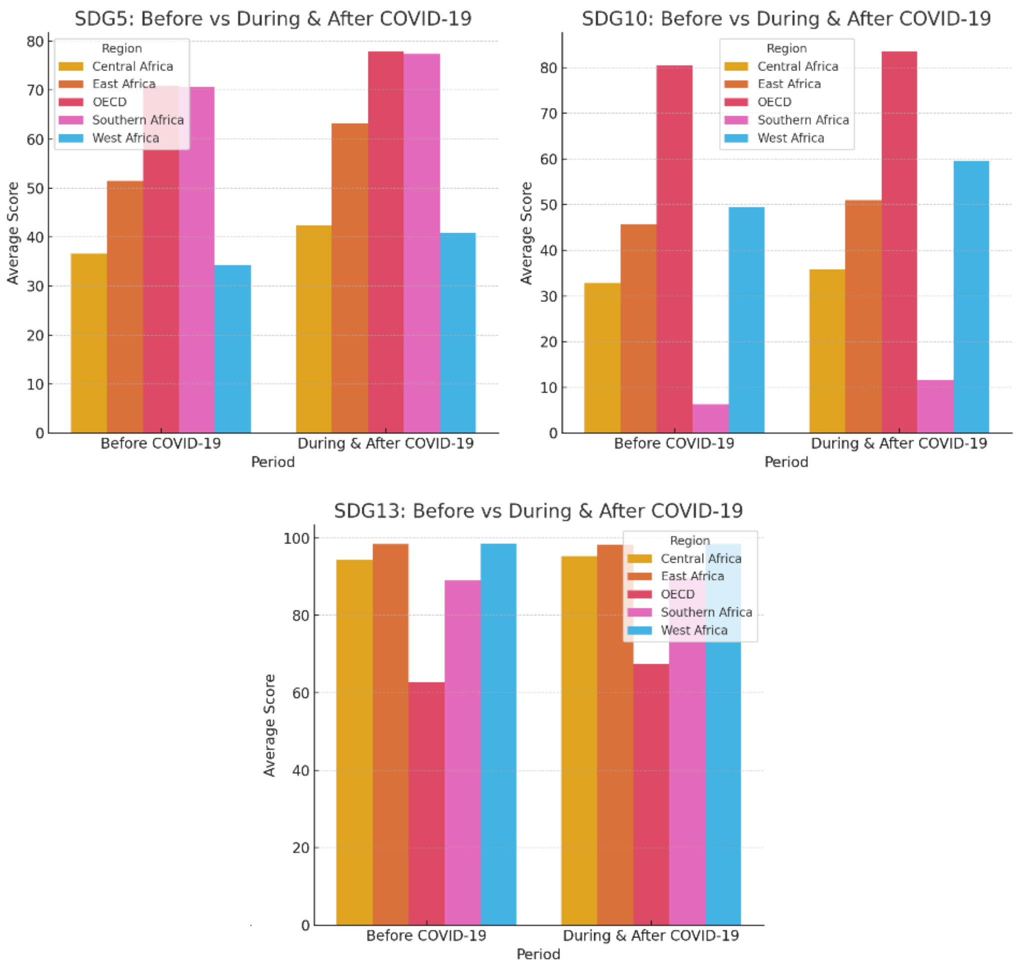

Figure 1. Comparison of SDG 5. 10 and 13 between OECD and SSA: Before vs During and After COVID-19

In terms of SDG 13, West Africa and OECD countries emerged as top performers, maintaining scores between 99 and 100, and demonstrating resilience to pandemic-related disruptions. East Africa showed slight improvements, Central Africa remained stable at around 94–95, while Southern Africa, although comparatively lower, improved modestly from approximately 63 to 67. Climate action efforts thus appeared largely resilient across regions during the pandemic.

In summary, no significant distortions or sharp declines in SDG progress were observed following COVID-19. Instead, improvements were evident in Central, East, and West Africa regarding gender equality and inequality reduction, while OECD countries consistently maintained their leading position. Although Southern Africa struggled, particularly with inequality (SDG 10), minor improvements were noted. Climate action (SDG 13) proved the most resilient globally, underscoring the capacity of many regions to sustain environmental commitments even amid global crises.

4.4.2. Temporal Dynamics of Female Labor Force Participation During the COVID-19 Pandemic: A Comparative Analysis of OECD and Sub-Saharan Africa

An analysis of female labour force participation across the COVID-19 pandemic periods reveals divergent trends between OECD countries and Sub-Saharan African (SSA) subregions. OECD nations exhibited a relatively consistent level of female labour force participation, maintaining figures around the low 80 percent range throughout the pre-pandemic, pandemic, and post-pandemic phases, indicating a degree of resilience within these advanced economies. In contrast, SSA subregions displayed greater heterogeneity. Central and East Africa experienced a marginal decline in female labour force participation during the pandemic, followed by a return to pre-crisis levels in the subsequent period. West Africa demonstrated a similar pattern of a slight decrease and subsequent recovery, potentially even surpassing pre-pandemic engagement. However, Southern Africa experienced a more substantial contraction in female labour force participation during the pandemic, with the recovery in the after COVID-19 period appearing incomplete, suggesting potentially enduring structural impacts on female employment in this subregion. These observations indicate significant distortions within SSA, particularly the protracted negative effect observed in Southern Africa, while the temporary disruptions in Central, East, and West Africa suggest differing capacities for labour market adaptation and recovery across the continent. Further investigation is warranted to elucidate the underlying socio-economic factors contributing to these distinct trajectories in female labour force participation.

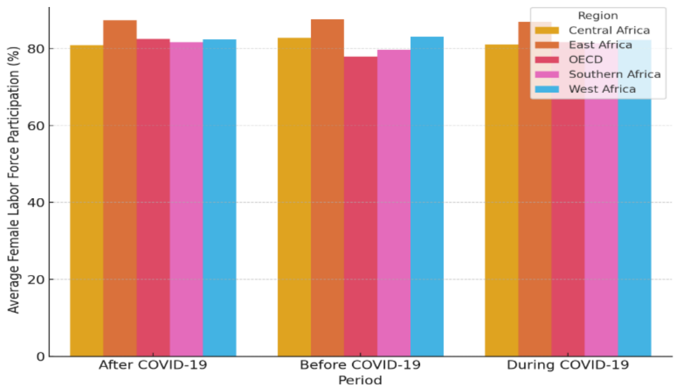

Figure 3. Female Labour Participation Across COVID-19 Periods (OECD vs SSA)

4.4.3. Differential Impacts of the COVID-19 Pandemic on Vulnerable Employment: A Comparison of OECD and Sub-Saharan Africa

Vulnerable employment, characterized by a higher proportion of own-account and contributing family workers associated with job insecurity, lower earnings, and limited social protection, exhibited differential patterns across OECD countries and Sub-Saharan Africa (SSA) during the COVID-19 pandemic. OECD nations consistently demonstrated the lowest levels of vulnerable employment, maintaining relative stability with a minor, temporary increase during the pandemic that subsequently receded to near pre-crisis levels. This suggests a labour market structure characterized by greater formality and job security. Conversely, SSA subregions generally presented significantly higher rates of vulnerable employment. Central and East Africa experienced a modest increase during the pandemic, with a partial decline thereafter, though remaining above pre-pandemic figures. Notably, Southern and West Africa witnessed substantial increases in vulnerable employment during the pandemic, and these elevated levels persisted into the post-pandemic period. This suggests a potential structural shift towards more precarious forms of employment in these subregions, possibly driven by formal sector job losses and a resultant increase in own-account work as a coping mechanism during economic disruptions. The comparatively resilient performance of OECD countries, with a minimal and transient rise in vulnerable employment, underscores the strength of their social safety nets and the prevalence of formal employment structures, contrasting with the more pronounced and enduring impacts observed across much of Sub-Saharan Africa. These trends highlight the heterogeneous effects of the pandemic on labour market vulnerability, contingent on the prevailing levels of economic formality and social protection mechanisms.

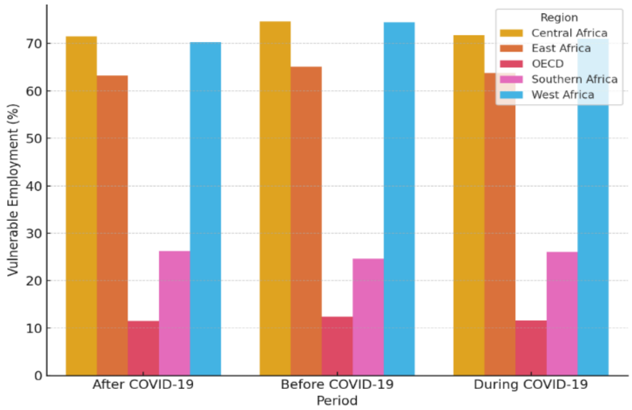

Figure 3. Average Vulnerable Employment: Before, During and After COVID-19 Periods (OECD vs SSA)

4.4.4. Employment-to-Population Ratio Trends During COVID-19: A Comparative Analysis of OECD and Sub-Saharan Africa

The employment-to-population ratio, a crucial indicator of labour market health reflecting an economy's capacity for job generation and workforce absorption, exhibited distinct patterns across OECD countries and Sub-Saharan Africa (SSA) during the COVID-19 pandemic. OECD nations demonstrated a relatively stable ratio across the examined periods, experiencing a minor contraction during the pandemic, followed by a substantial recovery to near pre-crisis levels, suggesting a resilient labour market capable of rebounding from economic shocks. Conversely, SSA presented a consistently higher employment-to-population ratio compared to the OECD throughout the observed timeframe. While SSA also experienced a temporary decrease in this ratio during the pandemic and a subsequent recovery, the aggregated nature of this data for the entire SSA region potentially obscures more significant heterogeneities observed at the sub-regional level in other labour market indicators such as female labour force participation and vulnerable employment. The broadly similar trends of a temporary dip and recovery in the employment-to-population ratio for both OECD and SSA at this aggregate level suggest a widespread impact of the pandemic on employment. However, the persistently higher ratio in SSA likely reflects structural economic differences, including a larger informal sector, necessitating greater participation for livelihood security. Consequently, the apparent stability at the aggregated SSA level may mask considerable intra-regional variations and shifts in the quality and security of employment, underscoring the necessity of disaggregated analysis for a comprehensive understanding of the pandemic's labour market consequences.

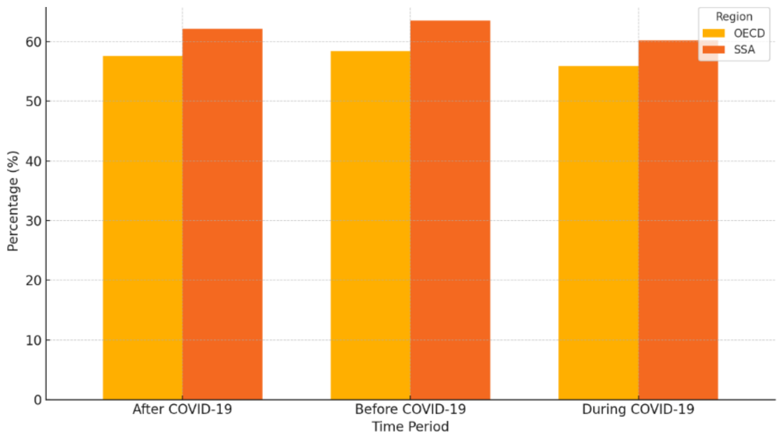

Figure 4. Employment to population ratio Across Regions: Before, During and After COVID-19 Periods (OECD vs SSA)

5. Conclusion and Policy Implications

This study has explored the multidimensional pathways toward achieving the Sustainable Development Goals (SDGs), focusing particularly on SDG 5 (Gender Equality), SDG 10 (Reduced Inequality), and SDG 13 (Climate Action), through the lenses of carbon emissions, labour market dynamics, and social inclusion across OECD and

Sub-Saharan African (SSA) countries. The empirical findings reveal significant structural and regional disparities that influence the pace and character of progress toward these global goals.

The gender dimension, particularly SDG 5, exhibited nuanced dynamics. Although female labour force participation improved modestly across most SSA regions during and after COVID-19, with notable resilience in East and West Africa. Southern Africa experienced a marked and lingering contraction. OECD countries maintained consistently high levels of participation, reflecting stronger institutional support. The divergent outcomes reflect differing capacities for labour market adaptation and underscore the structural barriers facing women in SSA, where informal and subsistence-level employment predominates. This context may partly explain why increased female labour participation in SSA was associated with weaker climate action outcomes, in contrast to the positive association found in OECD countries. Therefore, gender-sensitive climate policies, promotion of formal green jobs, and inclusive governance structures are essential to ensure that women's economic empowerment translates into sustainable development.

Concerning SDG 10, inequality remains a formidable barrier, especially in SSA, where vulnerable employment increased significantly during the pandemic and remained elevated in Southern and West Africa thereafter. This trend highlights a concerning shift toward precarious forms of employment, exacerbated by weak social protection systems and informal labour market structures. In contrast, OECD countries demonstrated relatively stable and low levels of vulnerable employment, thanks to more robust safety nets and formal labour systems. The employment-to-population ratio trends further illuminate these disparities. Although SSA consistently maintained higher ratios than OECD countries, this likely reflects economic necessity rather than labour market robustness, driven by informal sector dominance. The analysis suggests that not all employment contributes positively to climate goals; in fact, some forms may be environmentally detrimental. Thus, there is a need for SSA to invest in formalization, equitable job creation, and targeted social interventions to transform vulnerable employment into green and decent work opportunities, while OECD countries should align employment expansion with sustainability imperatives.

In terms of climate action (SDG 13), carbon emissions continue to pose a major challenge in both regions, albeit with greater intensity in OECD countries, where industrialized economies remain tethered to carbon-intensive growth. SSA, though contributing less to global emissions, faces increasing environmental stress due to urbanization, inefficient energy systems, and limited infrastructure. While the pandemic offered temporary environmental relief, the modest improvements observed in SDG 13 scores, especially in West Africa and OECD regions, underscore the resilience of climate commitments during crises. Nevertheless, sustained progress requires the institutionalization of green policies – SSA must leapfrog to clean technologies and enhance energy efficiency, while OECD countries should deepen transitions to circular economies and low-carbon production systems.

The negative association of GDP per capita with SDG 13 across both regions reinforces the tension between economic growth and environmental sustainability, suggesting the urgent need to redefine growth paradigms that prioritize ecological resilience. Urbanization, which enhanced climate action in OECD countries through effective planning and infrastructure, remains a missed opportunity in SSA, where unregulated expansion undermines sustainability efforts. Integrated urban strategies and smart infrastructure development are therefore essential for SSA to harness urbanization as a catalyst for climate resilience. Ultimately, the COVID-19 pandemic exposed both vulnerabilities and resilience in the pursuit of sustainable development. While some temporary gains were observed – particularly in climate action – these are unlikely to persist without structural transformations. This study underscores the imperative of adopting holistic, context-specific policy frameworks that simultaneously advance gender equality, reduce inequality, and promote environmental sustainability. Such integrated approaches are necessary to achieve transformative progress toward the SDGs in both OECD and Sub-Saharan African regions.

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