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Balancing Employment and Environmental Goals: Evidence from BRICS and Other Emerging Economies, 1991–2020

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Abstract

This paper examines how emerging markets balance the seemingly conflicting objectives of higher employment generation and improved environmental quality, with particular attention to the pivotal roles of trade openness and natural resource endowments. Utilizing a balanced panel dataset from 20 emerging economies that include all BRICS nations (except Ethiopia) and 10 other major emerging economies such as Mexico, Malaysia and Thailand spanning 1991–2020, the analysis applies the cross-section augmented autoregressive distributed lag (CS-ARDL) model to estimate both short- and long-run relationships. The findings indicate that increased trade openness and greater natural resource rents do not intensify the employment–environment trade-off; instead, they may facilitate simultaneous improvements in both areas, resulting in a win–win scenario. The results show that effective trade and resource management policies can reduce conflicts between unemployment and environmental issues, benefiting both the economy and the environment. This study also highlights the importance of integrated policies that connect trade liberalization, resource governance, and sustainability, offering useful guidance for emerging economies aiming for the Sustainable Development Goals (SDGs).

Keywords: natural resource rent; environmental Phillips curve; environmental unemployment curve; unemployment; renewable energy; CO₂ emissions



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1. Introduction

The escalating threat of environmental degradation, largely driven by rising CO₂ emissions in emerging economies, has intensified the urgency to examine the underlying factors that link economic development to ecological harm. Emerging economies such as Brazil, Russia, and India rank among the world’s largest carbon emitters, highlighting the scale of the challenge [1]. These trends underscore the need for policy frameworks that simultaneously address environmental deterioration and support inclusive growth. The issue is particularly acute given that economic expansion in developing nations often relies heavily on energy-intensive production, natural resource extraction, and trade-driven industrialization, all of which have direct implications for sustainability.

Researchers examining the nexus between environmental quality and macroeconomic variables have been particularly concerned with balancing employment generation and

environmental sustainability. Recent studies provide both theoretical and empirical evidence of a potential conflict between these two goals. This tension arises because efforts to reduce unemployment often depend on policies that stimulate industrial activity, which can, in turn, increase pollution and carbon emissions. The trade-off has been conceptualized through the Environmental Phillips Curve (EPC) [2]. While the conventional Phillips Curve captures the short-run inverse relationship between unemployment and inflation, the EPC reflects a long-run structural trade-off between employment generation and environmental quality [3].

Parallel to this theoretical development, the policy landscape has been shaped by the United Nations Sustainable Development Goals (SDGs), which explicitly call for job creation (SDG 8), environmental action (SDG 13), and responsible resource management (SDG 12). These targets highlight the need for an integrated policy approach in emerging economies, particularly those endowed with substantial natural resources. The role of natural resource rents (NRR), revenues from the extraction and sale of oil, minerals, and timber has received heightened attention in this regard. While resource wealth has the potential to accelerate growth, evidence suggests it often comes with significant drawbacks, including environmental degradation [4–6]. Resource dependency tends to amplify emissions, delay the transition to renewable energy, and exacerbate ecological pressures, especially in labor-abundant economies with weaker institutional capacities [7]. Thus, the governance of natural resources becomes a pivotal factor in determining whether they serve as a blessing or a curse for both economic and environmental outcomes.

Another critical dimension shaping the employment generation and environmental quality is trade openness. The relationship between trade and the environment has long been debated, with scholars pointing to three principal channels of influence [8,9]. The scale effect suggests that trade expansion, by boosting output, increases emissions. The technology effect highlights the diffusion of cleaner and more efficient production methods through international trade, which can mitigate environmental harm. The composition effect reflects structural changes in production and trade patterns, which may either favor environmentally sustainable goods or exacerbate ecological damage [10–14]. The net outcome depends on the relative strength of these channels, making the trade–environment–employment relationship highly context-dependent.

This paper seeks to contribute to this ongoing debate by investigating the evolving interrelationship between employment generation, environmental sustainability, and macroeconomic policy in emerging markets. Specifically, it examines how trade openness and natural resource rents interact to shape the unemployment–environment trade-off across 20 emerging economies. Unlike prior studies that have analyzed growth, trade, or natural resources in isolation, this study adopts a more integrated approach by explicitly situating these variables within the Environmental Phillips Curve framework. The novelty of this research lies in exploring how trade-oriented growth strategies, when combined with resource endowments, alter the dynamics of the employment–environment nexus.

Accordingly, the present work is set out as follows: Section 2 discusses the theoretical background and empirical literature on the environment, employment, trade and growth links. The data and methodologies utilized in the investigation are elaborated in Section 3. The discussion of results and policy implications are presented in Section 4, and Section 5 concludes the study.

2. Theoretical Background and Empirical Literature on the Environment, Employment, Trade and Growth Links

The interlinkages between employment generation, environmental quality (EQ), trade openness (TO), natural resource rents (NRR), and economic growth have long been debated

in both theoretical and empirical research. While the individual relationships among these variables are well documented, the literature remains divided on the joint effects they produce when analyzed together. One of the most established findings in macroeconomics is the inverse relationship between economic growth and unemployment, often captured by Okun's law, which posits that unemployment falls during economic expansions and rises during contractions. However, this traditional growth–employment nexus largely overlooks environmental constraints, assuming resource availability and ecological capacity as given. In reality, sustained economic growth is frequently accompanied by energy-intensive industrialization that undermines environmental sustainability, thus generating a tension between unemployment reduction and environmental preservation.

Trade openness adds another dimension to this debate, as it shapes the growth–employment relationship by expanding market size, enhancing specialization, and improving resource allocation. Many studies find that more open economies tend to experience higher growth and lower unemployment [15–19]. However, other evidence highlights trade liberalization's potentially adverse effects on employment when domestic industries lack competitiveness, especially in labor-abundant economies [20,21]. Empirical findings reveal strong heterogeneity depending on factor endowments, industrial structures, and labor market flexibility. For instance, some studies show that trade openness reduces unemployment in lower-income OIC countries but contributes to rising unemployment in higher-income counterparts [22,23]. Similarly, others emphasize the importance of flexible labor markets in ensuring that openness generates employment. These mixed findings underscore that trade's employment effects are far from universal [24].

The literature on trade openness and environmental quality is equally inconclusive. Some works conceptualize three channels: scale, technology, and composition effects through which trade liberalization influences environmental outcomes [8,25]. Depending on which effect dominates, trade can either worsen or improve environmental sustainability. Much of the empirical evidence points toward adverse consequences, with studies showing that liberalization increases carbon emissions in BRICS, Pakistan, the United States, and emerging economies more broadly [10,26–31]. However, others suggest that in capital-intensive economies, openness may facilitate emissions reduction [32]. These findings collectively suggest that the trade–environment nexus is mediated by institutional quality, energy structures, and industrial specialization.

Natural resource rents represent another important factor influencing the employment–environment–growth nexus. Defined as revenues from extracting and selling natural resources [33], NRR can reduce unemployment by creating jobs in extraction industries [34], but may simultaneously trigger “Dutch disease” by appreciating exchange rates and harming non-resource sectors such as manufacturing and agriculture. Empirical findings again reveal mixed outcomes. Some find both positive and negative effects of NRR on growth in developing economies [35], while others famously argue that resource dependence often results in a “resource curse,” slowing long-term development [36]. Later work emphasizes the role of institutional quality, showing that resource rents promote growth only in strong institutional settings [37,38]. Evidence on employment is also inconsistent: while some observe a negative relationship between NRR and unemployment in Pakistan [34], others find a positive association in OPEC countries, highlighting the role of structural and regional differences [24].

The environmental implications of NRR further complicate the picture. Resource-dependent economies often experience higher emissions and ecological degradation [39], particularly when resource windfalls discourage investment in renewable alternatives. Empirical findings are diverse: some report that NRR worsen ecological footprints in Asian economies [40], while others find that rents combined with renewable energy improve

sustainability in OECD nations [41]. Similarly, some observe positive links between NRR and environmental quality in BRICS [42], whereas others report such outcomes only in industrialized countries [43]. These mixed results suggest that the resource–environment relationship is heavily conditioned by institutional quality, policy frameworks, and energy mix.

A more recent contribution to this literature is the Environmental Phillips Curve (EPC), developed by Kashem and Rahman [2]. Drawing from the classical Phillips Curve, which reflects the unemployment–inflation trade-off, the EPC posits a negative relationship between unemployment and environmental quality. Lower unemployment achieved through economic expansion, according to this framework, often comes at the cost of higher emissions and environmental degradation. Empirical evidence across diverse contexts including OECD, NICs, BRICST, and South Asian countries—generally supports this hypothesis [2,44–49]. These findings highlight the pressing challenge for policymakers: fostering job creation while maintaining environmental sustainability.

Despite the growing body of literature, several gaps remain. Findings on employment–environment linkages are inconsistent, varying by income levels, resource dependence, and labor market structures. Research on the direct relationship between NRR and employment is limited, with most studies focusing primarily on growth outcomes. Moreover, while the EPC framework has gained empirical traction, few studies have integrated the roles of trade openness and natural resource rents into this relationship. Finally, emerging economies where these dynamics are often most pronounced remain underrepresented in the existing literature.

3. Data and Methodology

This paper utilizes a panel dataset comprising 30 years of data from 1991 to 2020, gathered from 20 emerging nations and the data is gathered from two primary sources: World Development Indicators (WDI) generated from the World Bank and the Financial Development (FD) statistics from the International Monetary Fund (IMF) database. We employ the IMF World Economic Outlook Classification [50] to define emerging economies, namely Argentina, Brazil, Chile, China, Colombia, Egypt, Hungary, India, Indonesia, Iran, Malaysia, Mexico, Philippines, Poland, Russia, Saudi Arabia, South Africa, Thailand, Turkey, and the United Arab Emirates.

As outlined in the introduction, this study examines the interrelationships between unemployment, CO₂ emissions, trade openness (TO), and natural resource rents (NRR) across 20 selected emerging economies over a 30-year period. Figure 1 displays the trend lines corresponding to the mean values of these variables. As indicated, trade openness (TO), carbon dioxide (CO₂) emissions, and total net reproduction rate (NRR) have demonstrated a consistent upward trajectory, whereas unemployment rates have steadily decreased across the selected emerging economies over the past three decades. These patterns highlight the challenge faced by such nations: as they strive to strengthen their global presence, they must carefully balance sustainable growth with employment generation, placing particular emphasis on the efficient use of natural resources.

To further illustrate the preliminary interrelationships among these variables in our dataset, Figure 2 demonstrates the association between unemployment and environmental quality, while Figure 3 illustrates the linkage between natural resource rents and CO₂ emissions within emerging economies. Figure 2 indicates that economic growth in these regions is often associated with reductions in unemployment rates, leading to increased energy consumption and higher CO₂ emission levels. Conversely, Figure 3 demonstrates a potential positive correlation between natural resource rents and CO₂ emissions in emerging economies. Greater dependence on resources such as oil, gas, coal, and minerals

generates substantial rents, but also accelerates fossil fuel extraction, energy use, and industrial activity, all of which contribute to elevated emission levels.

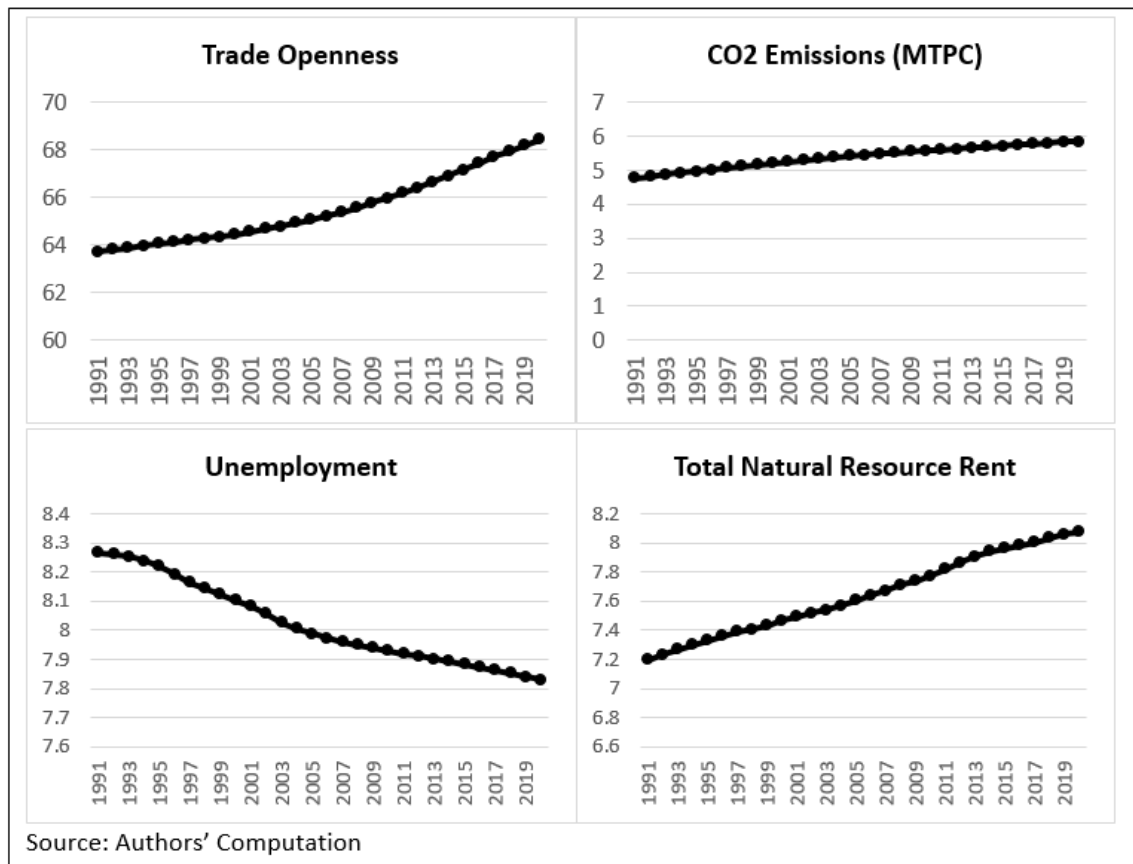


Figure 1. Mean values of KEY variables in Emerging Economies, 1991–2019.

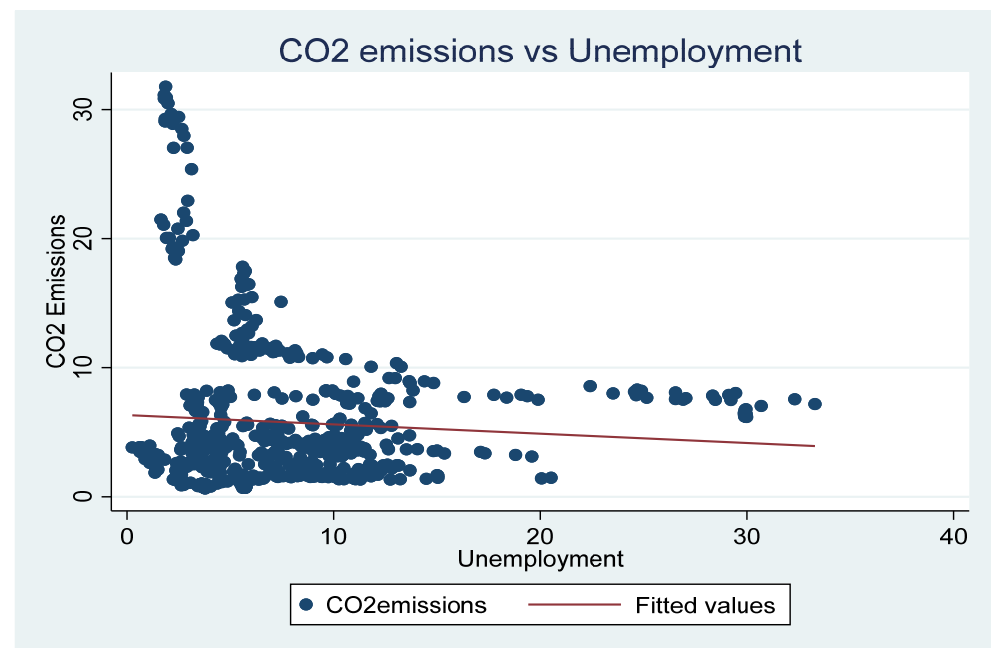


Figure 2. CO₂ Emissions and Unemployment in Emerging Economies.

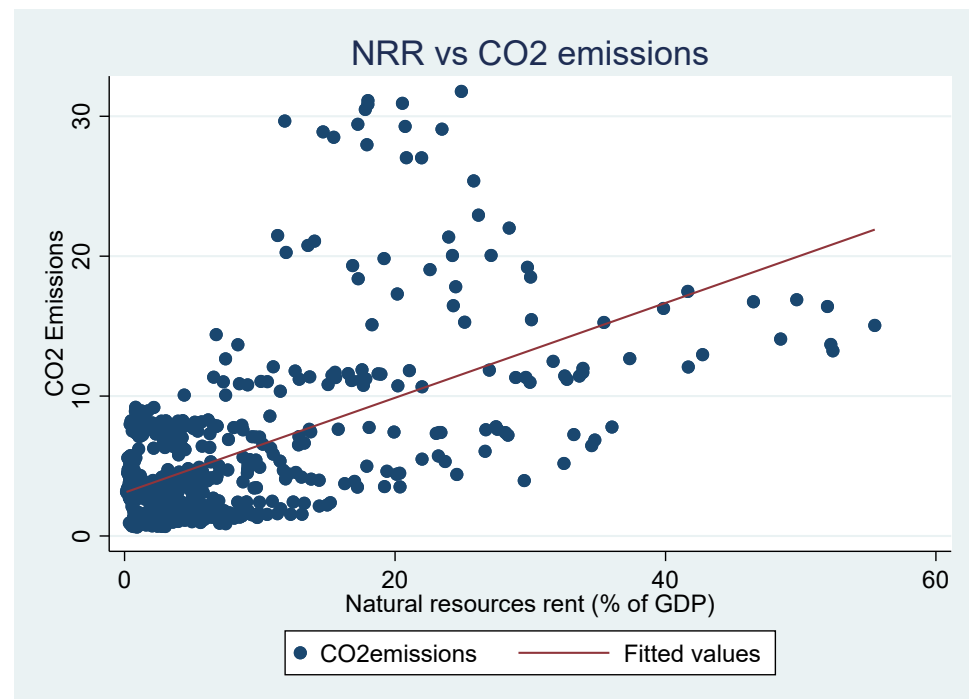


Figure 3. NRR and CO₂ Emissions in Emerging Economies.

This study conducts a systematic analysis of the impact of trade openness and natural resource rents on two United Nations Sustainable Development Goals: employment generation (SDG 8) and environmental quality (SDG 13) within emerging economies. To rigorously explore the intricate relationships among these factors and establish a foundation for empirical investigation, three distinct econometric models are employed and briefly outlined below.

Model 1 investigates the effect of unemployment on CO₂ emissions, focusing on the potential trade-off between labor market outcomes and environmental sustainability. This specification essentially tests the validity of the Environmental Phillips Curve (EPC) in the context of emerging economies. The dependent variable is CO₂ emissions, while the key explanatory variable is the unemployment rate. Several control variables are included, namely GDP, renewable energy consumption (REC), population growth, and foreign direct investment (FDI). The literature suggests that these factors exhibit noteworthy associations with CO₂ emissions. For example, economic growth is generally linked to higher emissions due to increased industrial activity, whereas renewable energy mitigates this effect by substituting fossil fuels [51–54]. Similarly, population growth—locally or due to tourism—heightens energy and resource demand, thereby contributing to higher emissions [55–57]. Foreign direct investment may enhance environmental quality through the transfer of cleaner technologies; however, it can also exacerbate emissions if investment flows gravitate toward countries with weaker environmental regulations [58].

Model 2 considers unemployment as the dependent variable, with trade openness (TO), natural resource rents (NRR), GDP per capita, and inflation included as explanatory variables. The literature identifies multiple, and at times contradictory, channels through which NRR influences unemployment. On one hand, an increase in NRR may trigger the so-called “Dutch Disease,” whereby resources shift from tradable to non-tradable sectors, leading to de-industrialization and subsequent job losses [59]. On the other hand, resource-led job creation in extraction and related industries may help to reduce unemployment [60,61]. Similarly, trade openness generally improves resource allocation and promotes technology transfer, thereby lowering unemployment. However, in capital-abundant economies, trade

openness may raise the demand for capital relative to labor, potentially leading to higher unemployment [19].

Model 3 represents the core specification of this study. It employs CO₂ emissions as the dependent variable, with unemployment, natural resource rents (NRR), and trade openness (TO) as the principal explanatory variables, thereby providing a comprehensive assessment of their joint impact on environmental outcomes. Theoretical and empirical evidence suggests that the relationship between these factors and environmental quality is multifaceted. Consistent with endogenous growth theory, technological innovation may simultaneously foster economic performance and reduce environmental degradation through efficiency gains and cleaner production processes [62–64]. However, innovation can also exacerbate emissions by stimulating industrial expansion and resource-intensive activities [65,66]. Institutional quality and emerging technologies further condition this relationship. For instance, some demonstrate that stronger corruption control influences energy structures in favor of sustainability [67], while others emphasize the role of financial technologies in accelerating the transition toward clean energy [68]. Similarly, financial development has heterogeneous effects across Sub-Saharan Africa, underscoring the importance of policy frameworks that reconcile economic growth objectives with environmental sustainability [69].

The three models that we have discussed are represented in the following form

$$lCO2_{it} = \beta_0 + \beta_1 lunemp_{it} + \beta_2 lgdppc_{it} + \beta_3 lrec_{it} + \beta_4 PG_{it} + \beta_5 FDI_{it} + \varepsilon_{it} \quad (1)$$

$$lunemp_{it} = \beta_0 + \beta_1 lgdppc_{it} + \beta_2 ltnrr_{it} + \beta_3 ltrade_{it} + \beta_4 linflation_{it} + \varepsilon_{it} \quad (2)$$

$$lCO2_{it} = \beta_0 + \beta_1 lunemp_{it} + \beta_2 lgdppc_{it} + \beta_3 lrec_{it} + \beta_4 ltrade_{it} + \beta_5 ltnrr_{it} + \beta_6 FD_{it} + \beta_7 linnov_{it} + \varepsilon_{it} \quad (3)$$

All these variables, except for population growth (PG), foreign direct investment (FDI), and financial development (FD) have been transformed using a logarithm. Hence, the prefix ‘l’ in these variables indicates the logarithmic transformation. Table 1 presents a description of each variable and the data source.

Table 1. Variables’ definition and data sources.

Terminology	Parameter Name	Scale of Measurement	Data Extracted
lCO ₂	Growth in CO ₂ emissions	Per person carbon dioxide emissions (metric tons)	World Development Indicators (WDI), World Bank
lunemp	Unemployment Rate	The labor force that is not finding work but is available for and are job seekers (in percentage)	
ltnrr	Total natural resource rent	Total revenue generated from extracting natural resources as a share of Gross Domestic Product	
ltrade	Trade openness	Summation of exports and imports of goods and services as a proportion of Gross Domestic Product	
lgdppc	Economic growth	Growth in per head gross domestic product (constant 2010 USD)	
lrec	Use of renewable energy	Proportion of renewable energy in aggregate final energy consumption	
linnov	Innovation	Research and development expenditure (% of GDP)	
PG	Population growth	Yearly percentage	
FDI	Foreign direct investment	FDI net inflows (BoP, current US dollars)	
linflation	Inflation	GDP deflator (yearly percentage)	International Monetary Fund (IMF)
FD	Financial development	The relative ranking of countries based on access, depth, and efficiency of their financial institutions and financial markets is the Financial Development Index.	

Panel data models are typically estimated using either fixed effects or random effects methods, both of which assume slope homogeneity across cross-sections. While this assumption simplifies estimation, prior studies highlight that if slope heterogeneity exists, estimators based on homogeneity may yield biased and inconsistent results, leading to unreliable inferences [70]. To address this concern, the study first applied slope homogeneity and cross-sectional dependence (CSD) tests. The results, reported in Tables 2 and 3, indicate significant cross-sectional heterogeneity in the dataset.

Table 2. Empirical results of slope homogeneity test.

	Delta	Delta adj.	p-Value
Model 1	23.759 ***	27.162 ***	0.000
Model 2	17.576 ***	19.659 ***	0.000
Model 3	19.307 ***	23.332 ***	0.000

Source: authors' computation. Note: *** presents a significance level at 1 percent.

Table 3. Empirical results of cross-section dependence test.

Variables	CD-Test	p-Value
lCO ₂	20.36 ***	0.000
lunemp	4.93 ***	0.000
lgdppc	53.26 ***	0.000
ltnrr	40.04 ***	0.000
ltrade	24.79 ***	0.000
lrec	16.23 ***	0.000
FD	39.26 ***	0.000
linnov	25.49 ***	0.000
PG	30.99 ***	0.000
FDI	7.51 ***	0.000
linflation	23.49 ***	0.000

Source: authors' computation. Note: *** presents a significance level at 1 percent.

Given these findings, the study employed the Cross-Sectionally Augmented Autoregressive Distributed Lag (CS-ARDL) model developed by Chudik and Pesaran [70]. This approach offers distinct advantages over traditional panel methods such as Pedroni [71], Kao [72], and Johansen's system-based techniques. In particular, the CS-ARDL framework accommodates cross-sectional dependence by accounting for unobserved common factors such as energy price shocks which are especially relevant for resource-rich emerging economies. Additionally, CS-ARDL is flexible with respect to variable integration orders, handling both I(0) and I(1) series, provided none are I(2). Unlike conventional VAR or VECM approaches, CS-ARDL permits heterogeneous short-run dynamics and long-run relationships, making it more suitable for diverse panels.

Before estimating the three specified models, it is also essential to test the stationarity of the panel data, as the CS-ARDL methodology requires that none of the variables be integrated of order two. The results, reported in Table 4, indicate a mix of I(0) and I(1) processes across the variables.

Table 4. CADF stationarity test results.

Variables	At Level	First Difference
lCO ₂	−1.716	−4.316 ***
lunemp	−1.529	−3.860 ***
lgdppc	−1.794	−3.434 ***
ltnrr	−1.876	−5.357 ***
ltrade	−2.056 *	
lrec	−2.305 ***	
FD	−2.635 ***	
linnov	−2.789 ***	
PG	−1.992	−2.642 ***
FDI	−2.642 ***	
linflation	−3.523 ***	

Source: authors' computation. Note: ***, * presents significance levels at 1 and 10 percentages, respectively.

The diagnostic test results indicate that the cross-section autoregressive distributed lag (CS-ARDL) approach is suitable for estimating both short-run and long-run relationships [71]. Nonetheless, it should be acknowledged that the CS-ARDL framework relies on the assumption of weak exogeneity, which limits its capacity to fully address issues of potential endogeneity among variables. To address this limitation, future research could employ panel structural vector autoregression (SVAR) models or simultaneous equation techniques, which are better suited to capturing feedback effects and disentangling causal mechanisms among the variables.

4. Discussion of Results and Policy Implications

4.1. Discussion of Results

As outlined earlier, the empirical analysis is based on three econometric models. Model 1 specifies CO₂ emissions as the dependent variable, with unemployment as the key explanatory factor. Model 2 considers unemployment as the dependent variable, with natural resource rents and trade openness as the main regressors. Model 3 integrates the insights from the first two models by examining the determinants of CO₂ emissions, with unemployment, natural resource rents, and trade openness serving as the principal explanatory variables. The estimated short-run and long-run coefficients for these models are presented in Tables 5 and 6, respectively.

Model 1: Employment–Environment Trade-Off

The estimation results from Model 1 reveal intriguing dynamics. In the short run, the unemployment coefficient is negative and significant at the 10% level. This provides moderate statistical evidence that higher unemployment is associated with reduced CO₂ emissions in the short run. The interpretation is intuitive: during periods of elevated unemployment, economic activity slows, resulting in lower industrial output, decreased energy consumption, and, consequently, fewer emissions.

More striking is the long-run effect. The coefficient of unemployment is larger in magnitude and highly statistically significant, suggesting that persistently higher unemployment contributes to an even greater reduction in emissions over time. This long-term relationship likely reflects structural changes: prolonged joblessness dampens industrial activity, suppresses aggregate demand, and discourages energy-intensive investments, resulting in consistently lower emissions.

Table 5. CS-ARDL: Short-run coefficients.

Parameters	Model 1 (lCO ₂)	Model 2 (lunemp)	Model 3 (lCO ₂)
lunemp	−0.035 * (0.019)		0.059 ** (0.024)
lgdppc	0.356 *** (0.106)	−1.112 ** (0.456)	0.250 ** (0.117)
lrec	−0.284 *** (0.060)		−0.363 *** (0.070)
PG	−0.032 (0.040)		
FDI	0.000 (0.002)		
ltnrr		0.006 * (0.049)	−0.002 * (0.023)
ltrade		−0.329 *** (0.076)	−0.027 * (0.035)
linflation		−0.034 (0.047)	
FD			0.068 (0.128)
linnov			−0.009 (0.014)
ECT(−1)	−0.866 *** (0.038)	−0.665 *** (0.147)	−0.821 *** (0.041)

Source: authors' own computation. Note: *, **, and *** show 10, 5, and 1 percent levels of significance, respectively; Numbers in parentheses indicate the standard errors.

Table 6. CS-ARDL: Long-run coefficients.

Variables	Model 1 (lCO ₂)	Model 2 (lunemp)	Model 3 (lCO ₂)
lunemp	−0.044 * (0.023)		−0.082 ** (0.036)
lgdppc	0.389 *** (0.129)	−3.412 ** (1.471)	0.282 ** (0.129)
lLrec	−0.330 *** (0.075)		−0.499 *** (0.142)
PG	−0.039 (0.050)		
FDI	0.000 (0.002)		
ltnrr		−0.074 * (0.094)	−0.019 * (0.034)
ltrade		−0.388 ** (0.155)	−0.040 * (0.062)
linflation		0.088 (0.140)	
FD			0.139 (0.170)
linnov			−0.015 (0.018)

Source: authors' computation. Note: Numbers in parentheses indicate the standard errors. *, **, and *** show significance levels at 10, 5 and 1 percent, respectively.

From a policy perspective, this evidence underscores a classical employment–environment trade-off. While reducing unemployment is crucial for social welfare and economic development, doing so without environmental safeguards risks higher carbon emissions. These findings resonate with the conclusions of Kashem and Rahman [2] and Shastri et al. [73], who similarly document that labor market improvements, unless paired with green technologies or regulatory oversight, tend to elevate environmental pressures.

Model 2: Employment, Resource Dependence, and Trade Openness

Model 2 examines the impact of natural resource rents and trade openness on employment. The short-run coefficient for natural resource rents is positive and moderately significant, indicating that an increase in resource rents may initially result in higher unemployment. While this finding might seem counterintuitive since resource booms are typically associated with job creation, it is consistent with the “Dutch disease” phenomenon. A sudden influx of resource revenues can lead to currency appreciation, reducing the competitiveness of non-resource exports and consequently lowering employment in those sectors. Additionally, labour markets may encounter short-term frictions as workers transition between industries. These transitional dynamics help explain why unemployment may rise temporarily following an increase in resource rents.

In contrast, the long-run coefficient of natural resource rent is negative and significant. Over time, resource rents contribute to lower unemployment, suggesting that once economies adjust, resource revenues are harnessed to create employment opportunities. Governments may use these revenues to finance infrastructure, expand public services, or develop downstream industries, all of which create jobs. This finding aligns with Fattah [74], who finds beneficial long-run effects of resource wealth on employment.

Trade openness significantly reduces unemployment in both the short and long term. In the short run, increased openness quickly lowers unemployment, likely due to export growth and greater efficiency from global integration. Over time, a 1% rise in openness cuts unemployment by nearly 0.4%, supporting structural improvements in labour markets. These findings align with classical trade theory and studies like Carere et al. [75] showing that global integration fosters sustained employment growth.

Model 3: Determinants of Environmental Degradation

The third model integrates the insights of Models 1 and 2, taking CO₂ emissions as the dependent variable while including unemployment, resource rents, and trade openness as main explanatory variables. Results from the model suggest that the short-run impacts of unemployment on CO₂ emissions positive and statistically significant. This is interesting and one plausible explanation is that during times of high unemployment, governments may relax environmental regulations or prioritize stimulus programs, often relying on energy-intensive projects, to boost job creation leading to increased emissions. Over the long run, however, the relationship reverses indicating that persistently high unemployment reduces CO₂ emissions. This shift in signs between short- and long-run estimates underscores the complexity of labor market–environment linkages.

For natural resource rents, both short-run (−0.002) and long-run (−0.019) coefficients are negative and moderately significant. This suggests that higher resource rents are associated with lower emissions, albeit modestly. This relationship could arise because resource revenues enhance government capacity to invest in cleaner technologies, promote renewable energy, or enforce environmental standards. However, the small magnitude indicates that these effects are highly dependent on governance quality.

Trade openness also shows a consistent negative relationship with emissions, both in the short run and long run. These results imply that openness allows countries to access cleaner technologies, shift toward less polluting industries, and benefit from international environmental standards. However, the modest statistical significance suggests that trade

alone is insufficient to guarantee environmental improvements. Without complementary policies such as environmental regulations and technology transfers the potential of trade openness to reduce emissions remains limited.

Finally, per capita GDP exerts a positive and significant impact on emissions, with coefficients of 0.25 (short run) and 0.28 (long run). This finding highlights the classic “scale effect”: economic growth, unless decoupled from fossil fuel use, exacerbates emissions. This result echoes findings by Sun et al. [28] and Chien et al. [27] who report that economic expansion in emerging economies intensifies environmental degradation. However, it contrasts with studies such as Chhabra et al. [13] which emphasize that in certain contexts, trade openness can increase emissions, supporting the pollution haven hypothesis.

A Dumitrescu–Hurlin Granger non-causality test [76] was conducted to assess causal links between variables. As shown in Table 7 and Figure 4, results indicate that trade openness, natural resource rents, and unemployment each Granger-cause CO₂ emissions, but not the reverse.

Table 7. Dumitrescu–Hurlin causality test results.

Variables	Z-Bar Statistics	p-Value
FD→CO ₂	7.883 ***	0.000
REC→CO ₂	5.483 **	0.032
NRR→CO ₂	8.638 ***	0.000
TO→CO ₂	14.641 ***	0.000
TI→CO ₂	4.346 ***	0.000
UNEMP→CO ₂	7.955 ***	0.000

Source: Authors’ computation. Note: **, and *** show significance levels at 5 and 1 percent, respectively.

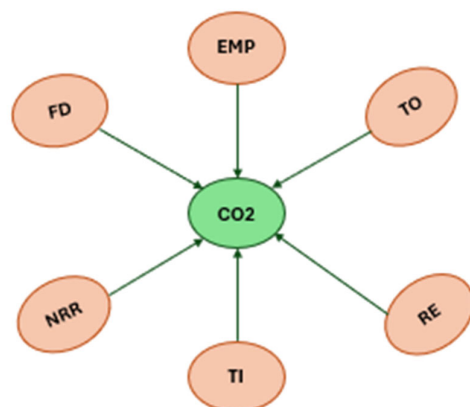


Figure 4. Results of the causality test.

4.2. Policy Implications

The findings from this study offer several policy-related observations. First, Model 3 identifies short- and long-term relationships between unemployment and CO₂ emissions that have implications for labour and environmental policies. In the short term, increased unemployment correlates with higher emissions, which may be due to slower adoption of clean technologies and reduced enforcement of environmental regulations during economic downturns. In contrast, prolonged unemployment is associated with lower emissions because of decreased industrial activity and energy usage. These results indicate that employment growth and environmental sustainability can be addressed simultaneously. Investment in green job creation within sectors such as renewable energy, energy efficiency,

and sustainable infrastructure may help reduce unemployment while contributing to emission reductions over time.

Second, findings show a negative and statistically significant effect of natural resource rents on emissions in both the short and long term, suggesting that resource dependence, if managed effectively, may support environmental improvements. Resource-rich economies, such as the United Arab Emirates, can allocate natural resource rents toward cleaner technology, economic diversification, carbon capture, and sustainable urban development. Governance and reinvestment strategies are thus important for leveraging resource wealth to enhance both economic and environmental resilience.

Finally, the study reports that greater trade openness is linked to lower emissions, challenging the assumption that trade liberalization necessarily harms environmental outcomes. Including environmental provisions in trade agreements, promoting the importation of low-carbon technologies, and supporting export sectors with smaller carbon footprints are potential ways to use trade openness to facilitate sustainable growth.

5. Conclusions

This study investigates the relationship between unemployment, CO₂ emissions, trade openness, and natural resource rents in 20 emerging economies from 1991 to 2020 using the CS-ARDL approach. Results indicate that, in the short term, higher unemployment is linked to increased emissions, likely due to delayed technology adoption and weaker regulatory enforcement. Conversely, in the long run, unemployment reduces emissions through decreased industrial activity. This highlights the importance of developing green employment policies that address both labor market challenges and environmental objectives.

Natural resource rents are found to reduce emissions modestly in both time horizons, suggesting that effective management and governance of such revenues can support environmental improvements. Trade openness consistently correlates with lower emissions, reflecting the positive environmental impact of “clean trade,” including technology transfer and the adoption of international standards.

These findings suggest that promoting green jobs, sound resource management, and sustainable trade can support simultaneous progress on economic growth and emission reduction, aligning with SDGs 8 and 13. However, sustained economic growth remains closely tied to fossil fuel emissions, underscoring the need for integrated policy strategies.

Limitations of the study include potential endogeneity, omission of factors like urbanization, and limited labor market data. Future research should employ broader datasets and advanced models to further clarify these complex relationships.

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