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# Zero Emissions and Zero Unemployment: A Feasible Future or Conflicting Objectives?

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**ABSTRACT**

Achieving high economic growth along with low unemployment rates and better environmental quality presents a key challenge for economic policy. The study investigates the validity of the Environmental Phillips Curve (EPC) and Environmental Kuznets Curve (EKC) hypotheses in India. This study utilizes a range of econometric methodologies, encompassing the Autoregressive Distributed Lag (ARDL) model, the combined cointegration test, and the Toda-Yamamoto causality test, to analyze annual time series data spanning the period from 1991 to 2022. The findings confirm the validity of the EPC in both the long- and short-run. However, the evidence does not provide strong support for the EKC hypothesis. Among control variables, capital formation and GDP per capita has adverse impacts on environmental quality, while renewable energy consumption has no significant impact. For India, with the world's largest young population, environmentally friendly job creation is crucial. Developing energy-efficient technologies and increasing investment in renewables are key to balancing zero-emission and zero-unemployment goals.

**Keywords:** Environmental Phillips Curve, Unemployment, Environmental Degradation, India
**JEL Classifications:** Q56, O44, O18

## 1. INTRODUCTION

With the advent of the UN's Sustainable Development Goals (SDGs), attaining "zero emissions" and "zero unemployment" stands out as aspirational targets which have taken center stage in policy agendas worldwide. SDGs 8 and 13 specifically aimed at resolving these two issues. Maintaining higher economic growth, along with reducing emissions has been considered as a major challenge, especially for developing economies (Yang et al., 2017; Wang et al., 2019; Azzeddine et al., 2024). Countries all around the world are currently facing threats like food shortages, air pollution, wildfires, and drought (Ullah et al., 2023; Sadiq et al., 2023). These environmental challenges negatively impact human health (Majeed and Ozturk, 2020; Bouchoucha, 2021; Mumtaz et al., 2022). It is widely recognized that anthropogenic greenhouse gas (GHG) emissions induced by human activities are the driving force behind global warming and climate change. Among all GHGs, carbon dioxide ($CO_2$) has been the largest contributor to the greenhouse effect in recent decades. Between 1990 and 2022, $CO_2$ emissions represented the primary component of greenhouse gas (GHG) emissions in the United States, constituting approximately 79.9% of the aggregate (U.S. Environmental Protection Agency, 2024). From 1950 to 1990, global $CO_2$ emissions increased nearly fourfold, rising from 6 billion to over 20 billion tons (Ritchie and Roser, 2020).

India stands as fourth largest emitter of $CO_2$ emissions globally, accounting for 6.6% of global emissions, ranking 8$^{th}$ in the Climate Change Performance Index 2023. In 2022, India's $CO_2$ emissions from fossil fuels and industry increased by 6.5%, reaching a new all-time record of 2.7 billion metric tons. In addition, it is projected that $CO_2$ emissions from fossil fuels will have increased nine- to tenfold from 2005 levels by the year 2050 (van Ruijven et al., 2011). India's two main sources of increasing $CO_2$ emissions are the average household size and the country's growing per capita GDP (Mohammadi et al., 2020). In a country like India which is fourth largest emitter and at the same time passing through the stage of demographic dividend, balancing these goals is a difficult task. In addition to reducing $CO_2$ emissions and transitioning towards a low-carbon economy, it is imperative for India to ensure the continued employment of its substantial population. On the other side, India is a home of world's largest young labor force having more than 65% of the population between the ages of 15 and 59. India will have the largest window of opportunity to take use of its demographic dividend compared to other nations, as the share is predicted to increase till 2035-2040 (Kapoor, 2024). With a median age of 28.4, India's population will be comparatively young compared to other Asian countries by 2030. Therefore, maintaining rapid economic growth rates to reduce poverty as well as unemployment and at the same time shifting to more environmentally friendly, sustainable practices are both important for India. These two variables have been studied under the so-called *Environmental Phillips Curve* (EPC), which reveals a potential association between environmental quality and unemployment. The concept of EPC emerged from studies by Kashem and Rahman (2020) and Anser et al. (2021). In essence, the EPC asserts that attempts to lower $CO_2$ emissions makes the unemployment rate higher. On the other hand, initiatives aimed at lowering unemployment could result in increasing emissions since rising consumption and output increase carbon footprints.

In order to understand if it is possible to achieve "zero emissions" and "zero unemployment" in India given its socioeconomic conditions, it is imperative to comprehend such a dichotomy. However, little is known on the connection between unemployment and environmental degradation in India. This research aims to fill this gap by investigating empirically the trade-off between environmental degradation and unemployment rate in India over the period 1991-2022. Specifically, the present research examines the validity of the EPC hypothesis in India using the autoregressive distributed lag (ARDL) model. By doing so, the present study contributes to the body of knowledge in many ways. First, this research is among the scarce studies analyzing empirically the environmental implications of unemployment in India. As discussed previously, this issue is important for India, given its status as a major emission emitter, its ambitious net-zero emission target, and its ongoing demographic dividend. Moreover, an in-depth investigation of the connection between $CO_2$ emissions and unemployment rate in India has received little attention on behalf of scholars. For example, Anser et al. (2021) analyzed the EPC hypothesis in BRICST, including India. Moreover, Tariq et al. (2022) examined the EPC in selected South Asian countries, while Sahin et al. (2025) recently explored the linkages between $CO_2$ emissions and unemployment in most polluting emerging countries, including India. Although India belongs to samples studies in these studies, the panel data approach employed does not allow for specific conclusions regarding India. To the best of authors' knowledge, Shastri et al. (2023) is the only study considering the validity of the EPC for both male and female unemployment in India. Consequently, the question of whether India can simultaneously achieve zero emissions and zero unemployment, as envisioned in the SDGs, remained largely unanswered. Second, the empirical investigation includes additional control variables, alongside unemployment rate and $CO_2$ emissions. Specifically, investment, clean energy, and income are introduced in the analysis to reduce the problems of misspecification and omitted variables. Furthermore, income square in introduced in the analysis to assess the validity of the Environmental Kuznets Curve (EKC).

This paper proceeds as follows. Section 2 discusses the existing literature, while Section 3 provides insights about the data and econometric methods. Section 4 is reserved for a discussion of the empirical findings. Finally, Section 5 summarizes the main points and discusses policy implications.

## 2. LITERATURE UNDERPINNINGS

Studying the issue of climate change, numerous researchers have highlighted the increase in human resources during the 1980s, as major cause behind this phenomenon (Bilgili et al., 2019). A substantial body of research has focused on the drivers of human-based $CO_2$ emissions (Pachauri et al., 2014; Deng et al., 2022). The research on the determinants of $CO_2$ emissions may be categorized into two groups. The first, designated as traditional determinants, encompasses factors such as trade openness, urbanization, income, energy demand, industrial activity and tourism (Acaravci and Ozturk, 2010; Antonakakis et al., 2017; Islami et al., 2022; Warsame et al., 2023; Lee and Zhao, 2023; Agasalim, 2024). The second group, unconventional factors, is composed of factors including female employment, education level, technology, and innovation (Samargandi, 2017; Chen and Lee, 2020; Bilal et al., 2022; Ben-Salha and Zmami, 2024; Ragmoun and Ben-Salha, 2024). Less focus has been placed on the latter group of drivers.

### 2.1. Unemployment and Environmental Degradation

According to Bhowmik et al. (2021), the impact of unemployment on environmental quality can be attributed to two distinct channels. The growth channel posits that unemployment hampers economic growth, resulting in a subsequent reduction in energy consumption and, ultimately, a decrease in $CO_2$ emissions. This, in turn, contributes to an enhancement in environmental quality. Conversely, the preference channel posits that unemployment exerts a detrimental effect on the environment. This is attributed to the fact that it leads to a decline in consumer income, which, in turn, hinders individuals and households in fulfilling their needs and maintaining a healthy lifestyle. This, in turn, results in a deterioration in environmental quality. A small but growing number of works, though, have looked into the linkages among unemployment and $CO_2$ emissions (Joshua and Alola 2020; Gyamfi et al., 2020; Liu and Feng, 2022; Xin et al., 2023). The unemployment-environmental degradation nexus has recently been the subject of increasing empirical examination. Kashem and Rahman (2020) were among the pioneering studies to investigate the connection between unemployment and the environment by focusing on a sample of 30 countries between 1990 and 2016.

The authors introduced the concept of Environmental Phillips Curve, which describes the negative association between the two variables. Anser et al. (2021) checked the validity of the EPC using the PMG-ARDL panel data model in BRICST for the period of 1992-2016. The findings support the EPC by showing that there is a significant linkage between environmental degradation and unemployment. Ng et al. (2022) explored the EPC hypothesis for OECD countries. The results supported the EPC by revealing the negative relationship between environmental deterioration and unemployment.

Adesina and Mwamba (2019) examined the repercussions of unemployment rates on $CO_2$ emissions in selected African nations. The analysis shows that unemployment has a negligible adverse influence on $CO_2$ emissions across the full sample or in lower-middle and upper-middle-income nations. However, it dramatically lowers $CO_2$ emissions in low-income nations. Using the STIRPAT model, Liu and Feng (2022) explored the effects of unemployment on $CO_2$ emissions in 77 nations. The findings revealed that $CO_2$ emissions are negatively affected by unemployment in Africa, America, Europe, and Asia-Pacific. The EPC hypothesis has been also supported in South Asian nations (Tariq et al., 2022) and the United States (Bhowmik et al., 2021). Wang and Li (2021) also found evidence in favor of EPC hypothesis by revealing the inverse association between unemployment and $CO_2$ emissions. Contrary to the conclusions of the EPC, studies by Wang and Li (2021), Cui et al. (2022), and Xin et al. (2023) have demonstrated a positive correlation between $CO_2$ emissions and unemployment. In summary, the literature on the unemployment-environmental degradation nexus is inconclusive, with studies reporting both positive and negative associations.

### 2.2. Economic Growth and Environmental Degradation

There has been a lot of work examining the effects of income on environmental deterioration. This association has been explored within the framework of the EKC hypothesis, according to which there exists an inverted U-shaped connection between income and $CO_2$ emissions. Empirical studies have found diverse relationship patterns (Tsuzuki, 2009; Bernaciak, 2013; Abid, 2016). Destek et al. (2020) demonstrated that the association varies across countries. Specifically, the relationship was found to be M-shaped in the UK and Canada, N-shaped in France, inverted N-shaped in Germany, and inverted M-shaped in Italy, Japan, and the US. Furthermore, Mardani et al. (2019) revealed bidirectional causal flows between emissions and economic growth. Contrary to these studies, Mose (2017) argued that the causal linkage between emissions and income is not verified, suggesting that economic growth can occur without a corresponding increase in $CO_2$ emissions. Roberts and Grimes (1997) concluded that the linkage between national $CO_2$ intensity and income shifted from primarily linear in 1965 to strongly curvilinear in 1990. Villanthenkodath et al. (2021) explored the outcomes of GDP on $CO_2$ emissions in India between 1971 and 2014 and revealed a negative linkage between them.

### 2.3. Capital Formation and Environmental Degradation

Relatively few research explored the influence of capital formation (CF) on $CO_2$ emissions. Mitić et al. (2020) examined the impacts of CF on $CO_2$ emissions in selected Balkan countries and concluded a significant long-run connection between CF on $CO_2$ emissions. Additionally, unidirectional causal flows from CF to $CO_2$ emissions is revealed. Prakash and Sethi (2023) analyzed the effects of gross capital formation on $CO_2$ emissions in India between 1971 and 2021. The results suggest that GFCF exhibited no significant relationship with $CO_2$ emissions prior to liberalization, while demonstrating a significant positive impact post-liberalization. Furthermore, Alshammry and Muneer (2023) investigated the case of Saudi Arabia and revealed the presence of a significant long-run relationship between the variables. Nur et al. (2024) examined the influence of GCF on environmental degradation in Somalia. The ARDL model suggests that GCF has no significant impact on $CO_2$ emissions. Finally, Satrovic et al. (2020) revealed a bidirectional causal relationship between GCF and $CO_2$ emissions in Turkey and Kuwait over the period 1971-2014.

### 2.4. Renewable Energy Consumption and Environmental Degradation

A boom in studies analyzed the impact of renewable energy consumption (REC) on environmental quality. Using the PMG-ARDL model, Yazdi and Beygi (2017) found a negative impact of REC on $CO_2$ emissions in 25 African countries. Moreover, Dong et al. (2020) examined the association between REC and $CO_2$ emission in 120 countries. The finding revealed negative impact on $CO_2$ emissions. Moreover, Nguyen and Kakinaka (2019) analyzed the same variables in 107 economies between 1990 and 2013. The authors concluded that there is a positive impact of REC on $CO_2$ emissions in low-income economies, but the effect turned out to be negative in high-income economies. Ben-Ahmed and Ben-Salha (2024) employed a spatial Durbin model to examine the impact of different energy sources, including renewable energy, on $CO_2$ emissions in 135 countries between 2000 and 2019. The findings suggest that REC has a negative (direct and indirect) impact on $CO_2$ emissions, i.e., reduces $CO_2$ emission and improves environmental quality.

## 3. DATA AND METHODOLOGY

### 3.1. Data

This study employs annual time series data on India in the post reform period (1991-2022). The variables used are total $CO_2$ emissions (dependent variable), unemployment rate (interest variable), while GDP per capita, CF and REC are control variables. Table 1 provides details on the data sources.

### 3.2. Methodology

To examine the validity of the EPC hypothesis in India, we employ the following estimation model:

**Table 1: Data description**

| Variables | Symbol | Source |
|---|---|---|
| $CO_2$ emissions | CE | World carbon atlas |
| Unemployment rate | UR | WDI |
| GDP Per capita | PCI | WDI |
| Capital formation | CF | WDI |
| Renewable energy consumption | REC | WDI |
| GDP per capita square | PCISQ | Authors calculations |

$$lnCE_t = \propto_0 + \propto_1 lnUR_t + \propto_2 lnPCI_t + \propto_3 lnPCISQ_t + \propto_4 lnCF_t + \propto_5 lnREC_t + \varepsilon_t \quad (1)$$

Where *CE* stands for $CO_2$ emissions, *UR* stands for unemployment rate, *PCI* and *PCISQ* stand for per capita income and its square, respectively. *CF* represents capital formation and, finally, *REC* represents renewable energy consumption and $\varepsilon$ is the error term.

Equation (1) is estimated using ARDL model to determine the long-run and short-run effects. The ARDL model developed by Pesaran and Shin (1999) and Pesaran et al. (2001) has an advantage over other econometric models, as it allows the incorporation of combination of I(0) and I(1) variables. Furthermore, the model is suitable for small samples (Pesaran and Shin, 1999). The ARDL model may be expressed as follows:

$$\Delta CE_t = \propto_0 + \sum_{i=0}^{n} \propto_{1i} lnCE_{t-i} + \sum_{i=0}^{n} \propto_{2i} lnUR_{t-i} + \sum_{i=0}^{n} \propto_{3i} lnPCI_{t-i} + \sum_{i=0}^{n} \propto_{4i} lnPCISQ_{t-i} + \sum_{i=0}^{n} \propto_{5i} lnCF_{t-i} + \sum_{i=0}^{n} \propto_{6i} lnREC_{t-i} + \beta_1 lnCE_{t-1} + \beta_2 lnUR_{t-1} + \beta_3 lnPCI_{t-1} + \beta_4 lnPCISQ_{t-1} + \beta_5 lnCF_{t-1} + \beta_6 lnREC_{t-1} + \epsilon_t \quad (2)$$

In Equation (2), parameters ($\propto_0$–$\propto_6$) capture short-run coefficients, while ($\beta_1$–$\beta_6$) capture long-run coefficients. The ARDL model allows also assessing the existence of long-run association between the series based on the bounds test. Indeed, the F-statistic should be greater than upper bound value to confirm the existence of long-run relationship. Following the same process and upon confirmation of cointegration, an error-correction model (ECM) is estimated:

$$\Delta CE_t = \propto_0 + \sum_{i=0}^{n} \propto_{1i} lnCE_{t-i} + \sum_{i=0}^{n} \propto_{2i} lnUR_{t-i} + \sum_{i=0}^{n} \propto_{3i} lnPCI_{t-i} + \sum_{i=0}^{n} \propto_{4i} lnPCISQ_{t-i} + \sum_{i=0}^{n} \propto_{5i} lnCF_{t-i} + \sum_{i=0}^{n} \propto_{6i} lnREC_{t-i} + \lambda_1 ECT_{t-1} + \epsilon_t \quad (3)$$

In Equation (3), *ECT*, denotes the error-correction term, which measures the adjustment speed, while the remaining coefficients capture short-run dynamics.

## 4. EMPIRICAL ANALYSIS

### 4.1. Unit Root Analysis Results

Prior to estimating the ARDL model, it is essential to test the variables for stationarity at either level, I(0), or first-difference, I(1). To test for stationarity, this study used the ADF unit root test developed by Dickey and Fuller (1979) and the LM unit root test with breakpoint developed by Lee and Strazicich (2003). The unit root test results for all variables-$CO_2$ emissions, unemployment rate, GDP, CF, and REC-are displayed in Table 2.

The ADF unit root test indicates that $CO_2$ emissions, GDP, and GDP square are stationary at level, whereas unemployment rate, CF, and REC become stationary at the first-difference. On the other hand, the Lee Strazicich LM unit root test with breakpoint shows that unemployment rate, GDP per capita and its square are stationary at levels. For all the other variables, stationarity is proven when considering their first-differences. The mixed order of integration among the variables makes the ARDL model suitable for the analysis.

### 4.2. Cointegration Analysis Results

To examine long-term relationships between the variables, we implement the ARDL bounds testing approach (Pesaran et al., 2001) and the combined cointegration test (Bayer and Hanck, 2013). According to Zmami et al. (2021), the combined cointegration test integrated four cointegration tests. Therefore, it allows for cointegration testing using multiple procedures simultaneously. The null hypothesis in both tests is the absence of cointegration. For a long-run relationship to be established by the ARDL approach, the F-statistic should surpass upper bound. Table 3 displays the outcomes of the bounds test, while the combined cointegration test results are summarized in Table 4.

The calculated F-statistic (11.590) exceeds the 1% critical value (4.68), indicating statistical significance. This confirms

**Table 2: Unit root tests**

| Variables | ADF unit root test | Lee Strazicich LM unit root test with breakpoint | |
|---|---|---|---|
| | Statistics | Statistics | Date of breakpoint |
| Level | | | |
| *CE* | −5.329*** | −2.944 | 2018 |
| *UR* | −2.415 | −4.015* | 2001 |
| *PCI* | −5.372*** | −7.172*** | 2018 |
| *PCISQ* | −4.583*** | −5.980*** | 1998 |
| *CF* | −1.902 | −4.039 | 2005 |
| REC | −1.274 | −3.766 | 2006 |
| First difference | | | |
| Δ*CE* | −7.456*** | −8.781*** | 2016 |
| Δ*UR* | 13.533*** | −4.700** | 2006 |
| Δ*PCI* | −7.284*** | −5.144*** | 2017 |
| Δ*PCISQ* | −5.621*** | −6.827*** | 2001 |
| Δ*CF* | −5.939*** | −7.712*** | 1999 |
| Δ*REC* | −3.781*** | −4.191** | 2013 |

***, **, and * denote the rejection of the null hypothesis of a unit root at 1%, 5% and 10% level, respectively.

**Table 3: ARDL bounds test results**

| F-statistic | k | Critical values | | |
|---|---|---|---|---|
| | | Significance (%) | Lower bound | Upper bound |
| 11.5907*** | 5 | 10 | 2.26 | 3.35 |
| | | 5 | 2.62 | 3.79 |
| | | 2.5 | 2.96 | 4.18 |
| | | 1 | 3.41 | 4.68 |

*** denotes the rejection of the null hypothesis of no cointegration at the 1% level.

cointegration, suggesting a long-term equilibrium relationship where $CO_2$ emissions are influenced by unemployment rate, income per capita, CF, and REC. These findings are confirmed by the two versions of the Bayer and Hanck (2013) test, which strongly suggest the presence of cointegration at 1% level. The statistics are equal to 27.552 and 138.076, both higher than the 1% critical values (15.701 and 29.850). Consequently, the rejection of the null hypothesis of no cointegration by both tests provides strong evidence of significant long-run relationships.

### 4.3. Model Estimation Results

Given the existence long-run equilibrium, the ARDL model is appropriate for estimating both long-run and short-run coefficients. The results reported in Table 5 show that unemployment rate is negatively and significantly related to the environmental degradation. This negative relationship validates the EPC hypothesis in India. In other words, such findings suggests that environmental degradation rises with increase in employment. These findings partially corroborate those of Shastri et al. (2023), who concluded that only male unemployment rate reduces $CO_2$ emissions in India. A potential explanation is that rising employment boosts incomes, both nationally and for individuals, leading to increased consumption. This rise in consumption is then associated with more production and higher environmental pollution. India is the 4th largest GHG emitter, accounting for about 6% of total emissions and at the same time it houses the world's largest workforce. Therefore, job creation efforts may contribute to increased air pollution and environmental degradation.

The positive coefficient of CF shows the direct relationship between capital formation and environmental degradation. Increased capital formation contributes to environmental degradation, a finding supported by previous studies. Baek (2015) employed the PMG-ARDL model and noticed that increase in CF adversely influence the environmental in East Asian countries. One explanation is that economic growth, driven by increased CF, may require greater energy consumption and resource extraction, which in turn increases GHG emissions and deteriorates the environment. Furthermore, industrial development in India exhibits a strong dependence on conventional energy sources, which are associated with elevated levels of $CO_2$ and other GHG emissions. This puts pressure on the government to shift toward green investments and directing capital towards environmentally friendly projects.

**Table 4: Combined cointegration test results**

| Test | Statistics | Critical values | | |
|---|---|---|---|---|
| | | 1% | 5% | 10% |
| *EG-JOH* | 27.552*** | 15.701 | 10.419 | 8.242 |
| *EG-JOH-BO-BDM* | 138.076*** | 29.850 | 19.888 | 15.804 |

***denotes the rejection of the null hypothesis of no cointegration at the 1% level

**Table 5: Results of the ARDL model**

| Variables | Coefficient | Std. error | t-Statistic | P-value |
|---|---|---|---|---|
| Long-run coefficients | | | | |
| *UR* | −1.637** | 0.647 | −2.531 | 0.019 |
| *PCI* | 0.434** | 0.172 | 2.527 | 0.020 |
| *PCISQ* | −0.051 | 0.019 | −0.369 | 0.645 |
| *CF* | 1.265*** | 0.385 | 3.285 | 0.004 |
| *REC* | −0.066 | 0.049 | 1.344 | 0.193 |
| *Constant* | 2.680 | 4.458 | 0.601 | 0.554 |
| Short-run coefficients | | | | |
| Δ*CE* (−1) | −0.340** | 0.145 | −2.355 | 0.028 |
| Δ*UR* | −2.194** | 0.871 | −2.520 | 0.020 |
| Δ*PCI* | 0.581** | 0.239 | 2.430 | 0.024 |
| Δ*PCISQ* | −0.002 | 0.026 | −0.069 | 0.946 |
| Δ*CF* | 0.721 | 0.521 | 1.384 | 0.181 |
| Δ*REC* | −0.990 | 0.622 | −1.593 | 0.126 |
| *ECT* (−1) | −0.940*** | 0.144598 | −9.270426 | 0.000 |

*** and ** denote the statistical significance at 1% and 5% level, respectively.

Furthermore, the findings indicate that GDP per capita is positive and significant. This shows that a 1% rise in GDP leads to 0.434% environmental degradation in the long-run. These outcomes corroborate with those of many prior studies. Mardani et al. (2019) found a bidirectional causallity between $CO_2$ and economic growth. However, these results contradicts with Villanthenkodath et al. (2021), who found a negative coefficient of GDP in India. Following the economic liberalization process, India's economy became more globally integrated, and economic activity spurred industrial development. This, in turn, has increased energy consumption due to both expanded production and greater transportation needs. The rising GDP growth rate and the changing economic structure in India post-1980 have substantially increased energy consumption (Deb and Appleby, 2015), which leads to greater $CO_2$ emissions. This suggests that policymakers should identify sectors contributing most to environmental degradation and develop policies to improve environmental quality. To address rising household carbon footprints, India has implemented initiatives such as the UJJALA LED and gas connection schemes, which contribute to $CO_2$ emission reductions. The coefficient of squared GDP is negative but not significant, suggesting the nonvalidity of the EKC hypothesis. This shows that India has not shifted towards the second stage, in which the economy starts using more sustainable energy sources and, consequently, a rise in GDP will be associated with reduced $CO_2$ emissions. Although the coefficient for REC has the expected sign, it is not significant. These findings do not corroborate with those of Dong et al. (2020) and Nguyen and Kakinaka (2019), who concluded that rise in clean energy consumption is beneficial for environmental quality.

Additionally, the short-run coefficients in Table 5 indicate that unemployment has a negative coefficient. Therefore, a rise in unemployment lessens $CO_2$ emissions and improves environmental quality, which validates the EPC hypothesis in the short-run. Our results are in line with the previous research by Anser et al. (2021), who confirmed the validity of the EPC hypothesis in BRICST countries. According to the results, unemployment negatively affects environmental degradation. Shastri at al. (2023) also concluded that male unemployment rate reduces short-run $CO_2$ emissions in India using the ARDL model. This may be attributed to the fact that, in the short run, job creation is largely dependent on the consumption of fossil fuels. As in the long-run, GDP per capita has a harmful impact on short-run environmental quality. Moreover, GDP per capita squared has a positive coefficient, however not statistically significant. Furthermore, CF has a positive impact on environmental deterioration. However, the associated coefficient is not statistically significant. The coefficient of REC

**Table 6: Diagnostic test results**

| Test | Statistics | P-value |
|---|---|---|
| Ramsey RESET misspecification test | 0.816 | 0.377 |
| Breusch-Pagan-Godfrey heteroskedasticity test | 2.160 | 0.115 |
| Breusch-Godfrey serial correlation LM test | 2.107 | 0.250 |

**Table 7: Toda-Yamamoto Granger causality test results**

| Null hypothesis | Chi-square | P-value |
|---|---|---|
| *UR* does not cause *CE* | 18.019*** | 0.000 |
| *PCI* does not cause *CE* | 13.314*** | 0.001 |
| *PCISQ* does not cause *CE* | 10.213*** | 0.006 |
| *CF* does not cause *CE* | 5.512* | 0.063 |
| *REC* does not cause *CE* | 1.065 | 0.587 |

*** and * represent the rejection of the null hypothesis of no Granger causality at 1% and 10% level, respectively.

shows favorable repercussions on environmental conditions in the short-run. Finally, the error-correction term is negative and significant, which shows that short-run deviations from the long-run equilibrium are corrected. Specifically, the negative and significant term suggests a high adjustment speed of 94%.

### 4.4. Diagnostic Analysis

The following section aims to assess the validity of the ARDL model findings. Table 6 reports the findings of the diagnostic tests. The null hypothesis of Ramsey RESET test posits that model is accurately specified. The P = 0.377 confirms that there is no statistically significant evidence of model misspecification. The Breusch-Pagan-Godfrey test yielded a P = 0.115, indicating no evidence of heteroskedasticity. Finally, the Breusch-Godfrey serial correlation LM test is employed for the detection of autocorrelation. The test statistics suggest no autocorrelation. Therefore, the validation tests provide evidence that our model is correctly specified and exhibits no autocorrelation or heteroskedasticity.

### 4.5. Toda-Yamamoto (TY) Granger Causality Test Results

The final stage of the analysis consists of testing the existence of causal flows. The Toda-Yamamoto (TY) Granger causality test is implemented. According to Ben-Salha et al. (2023), the TY causality test outperforms other standard causality tests because it can handle variables with various degrees of integration and cointegration properties. The TY test findings are reported in Table 7. The results provide strong evidence of Granger causality from unemployment rate, CF, GDP per capita, and GDP per square to $CO_2$ emissions. These findings particularly confirm the validity of the EPC hypothesis in India.

## 5. CONCLUSION AND POLICY IMPLICATIONS

India has the world's largest labor force, giving the country a significant opportunity to effectively utilize its working population. However, achieving sustained economic growth, high employment rates, and environmental quality simultaneously is a complex task. This paper analyzes the nexus between unemployment and environmental quality in India, with a specific focus on the validity of the EPC and EKC hypotheses. The analysis employed annual data from 1991 to 2022 and examined the short-and long-run dynamics using a battery of econometric techniques, including the ARDL model, the combined cointegration test and the Toda-Yamamoto causality test. The variables incorporated include $CO_2$ emissions, unemployment rate, GDP per capita and its square, CF, and renewable energy use. The long-run results show that unemployment rate reduces long-run $CO_2$ emissions, thus confirming the validity of EPC hypothesis. GDP per capita and CF negatively affect environmental quality, while the insignificant effect of GDP per capita squared suggests no evidence for the EKC hypothesis in India. Finally, REC has no influence on the environment. The results are supported by the TY causality test, which confirms that unemployment rate, GDP per capita and its square, and CF Granger cause $CO_2$ emissions.

The outcomes of the present study offer many important policy implications. The negative coefficient of unemployment suggests that the government should prioritize environmentally sustainable job creation. The primary policy options include promoting ecologically sustainable development and fostering innovation to generate employment. Fiscal policy should be used to encourage environmentally friendly sectors through tax exemptions and subsidies, and to discourage pollution through taxes and restrictions. The observed positive correlation between GDP, capital formation, and environmental degradation necessitates policy interventions focused on promoting green growth, incentivizing investments in clean technologies, and fostering the adoption of environmentally sustainable production practices. Furthermore, renewable energy consumption has no significant impact on environmental quality. Consequently, the government should increase investment in clean energy sources of energy, such as hydropower, wind energy, solar energy and nuclear energy which would reduce environmental degradation. Given the low proportion of renewable energy within India's energy mix, increased investment in renewable sources is expected to positively impact environmental quality. Policymakers are pursuing green energy targets, such as the Green Hydrogen Mission and the goal of zero railway emissions by 2030. This study further recommends mandating that industries and firms allocate a substantial proportion of their profits to environmentally beneficial projects designed to mitigate environmental damage and climate change.

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