

## Peer-reviewed research

# CO2 Emission, Energy Consumption, and Economic Growth in Latin America

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Mexico, Argentina, and Brazil are the only three developing countries equipped with nuclear energy capabilities in Latin America. This paper explores the impact of urbanization, nuclear energy consumption, and thermal power consumption on carbon dioxide emissions (CO<sub>2</sub>), and thus the broader environment. The results show that these countries do not conform to the EKC model; energy consumption consistently increases CO<sub>2</sub> emissions, and urbanization only has a negative influence on CO<sub>2</sub> emissions in the long run. We conclude with recommendations for policymakers of these countries.

### I. Introduction

The world has seen an increase in the level of production (GDP) and the quality of people's lives due to technological development. However, in the face of rapid growth in energy consumption (due to high population and urbanization), greenhouse gases from conventional energy sources cause significant harm to the environment. Addo et al. (2023) identify fossil fuels as a major cause of greenhouse gas emissions. Many countries now choose nuclear energy as an alternative to conventionally fueled thermal electricity, recognizing nuclear fission energy as a reliable, clean, and economically viable source of electricity (Zinkle & Was, 2013).

Past studies have found a link between economic growth and CO<sub>2</sub> emissions in developing countries. Intense economic expansion can lead to a substantial increase in CO<sub>2</sub> emissions (Wu et al., 2018). This study focuses on three fast-growing developing countries in Latin America: Mexico, Brazil, and Argentina. Since the primary source of electricity in Latin America is thermal (fossil fuels), accounting for 67% of total electricity output, only Argentina, Brazil, and Mexico have developed nuclear power thus far. Additionally, nuclear energy accounts for 6.2% of total electricity generation in Argentina, about 4.6% in Mexico, and 2.8% in Brazil, compared to 14.3% of energy globally (Arguello, 2010). Likewise, the consumption of traditional fuels in these three countries is enormous, with a 2.5-fold increase in total CO<sub>2</sub> emissions from the petrochemical, chemical, steel, and cement sectors in Mexico between

1965 and the beginning of the 21st century (González & Martínez, 2012); Brazil has the sixth highest GHG emissions in the world (Adebayo et al., 2021); and from 1990 to 2015, Argentina increased its dependence on fossil fuels to meet its local energy needs (Yuping et al., 2021). All these countries have experienced different levels of increase in CO<sub>2</sub> emissions during their modernization processes. Currently, the energy demand in Mexico, Brazil, and Argentina has reached unprecedented levels. This study investigates the potential trade-off between economic growth and the social ecosystem in Latin American countries that have adopted atomic energy. The ultimate objective is to establish a sustainable path for the region's future development, even though nuclear power currently contributes only a small portion to their overall energy mix.

Apergis & Payne (2009) suggest that as economies grow, an increase in real output may reduce emissions. However, Richmond & Kaufman (2006) argue that CO<sub>2</sub> emissions in most middle- and low-income countries continue to rise. Narayan & Narayan (2010) find support for the EKC hypothesis in more than 30 countries, including Mexico. Kijima et al. (2010) point out that there may be future changes in Mexico regarding economic development and energy consumption.

The relationship between GDP and CO<sub>2</sub> emissions has also been extensively studied. Lee & Yoo (2016) observe a unidirectional relationship from economic growth to CO<sub>2</sub> emissions. Soytaş et al. (2007) find that reducing energy consumption is the most effective way to mitigate environmental degradation. Iwata et al. (2011) emphasize the pos-

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itive impact of nuclear energy on reducing CO2 emissions. Finding a sustainable development path for Mexico, Brazil, and Argentina aligns with the primary objective of this paper.

## II. Data and Methodology

This study employs an econometric approach to examine the relationship between CO2 emissions and various economic and energy consumption variables in Mexico, Brazil, and Argentina. The analysis is based on annual data from 1965 to 2021.

### A. Data

Data on CO2 emissions, energy consumption, nuclear energy, and thermal energy are collected from the Energy Institute, while GDP and urbanization figures are obtained from the World Development Indicators. The variables are defined as follows. CO2 emissions are measured in million tons per capita; GDP (Y) is evaluated in constant local currency units; Urbanization (URP) refers to the size of the urban population; Nuclear Energy Consumption (NCE) is the percentage of electricity generated from nuclear sources; Thermal Power Consumption (THE) is the percentage of electricity generated from thermal sources.

### B. Methodology

The ARDL model is central to this econometric analysis and is particularly suited for small sample sizes. One of the requirements for ARDL Bounds testing is that the dependent variable must be I(1), while the explanatory variables can be either I(0) or I(1) (see Durmaz, 2023). Additionally, as noted by Pesaran et al. (2001), this approach has the advantage of bypassing pre-unit-root testing. In this study, our dependent variable is I(1), and the included regressors are either I(0) or I(1). Based on these methodological considerations, we analyze both the short and long run by constructing six models with 12 equations. The notation  $L$  in front of each variable represents log form of the variable. All variable shortforms are defined in the previous subsection.

#### Model 1

$$\Delta LCO2_t = \delta_0 + \delta_1 \Delta LY_{t-1} + \delta_2 \Delta LY^2_{t-1} + \delta_3 \Delta LENC_{t-1} + \epsilon_{t-1} \quad (1)$$

$$LCO2_t = \beta_0 + \beta_1 LY_t + \beta_2 LY^2_t + \beta_3 LENC_t + \epsilon_t \quad (2)$$

#### Model 2

$$\Delta LCO2_t = \delta_0 + \delta_1 \Delta LY_{t-1} + \delta_2 \Delta LY^2_{t-1} + \delta_3 \Delta LENC_{t-1} + \delta_4 \Delta LURP_{t-1} + \epsilon_{t-1} \quad (3)$$

$$LCO2_t = \beta_0 + \beta_1 LY_t + \beta_2 LY^2_t + \beta_3 LENC_t + \beta_4 LURP_t + \epsilon_t \quad (4)$$

#### Model 3

$$\Delta LCO2_t = \delta_0 + \delta_1 \Delta LY_{t-1} + \delta_2 \Delta LY^2_{t-1} + \delta_3 \Delta LENC_{t-1} + \delta_4 \Delta LURP_{t-1} + \delta_5 \Delta LNCE_{t-1} + \epsilon_{t-1} \quad (5)$$

$$LCO2_t = \beta_0 + \beta_1 LY_t + \beta_2 LY^2_t + \beta_3 LENC_t + \beta_4 LURP_t + \beta_5 LNCE_t + \epsilon_t \quad (6)$$

#### Model 4

$$\Delta LCO2_t = \delta_0 + \delta_1 \Delta LY_{t-1} + \delta_2 \Delta LY^2_{t-1} + \delta_3 \Delta LENC_{t-1} + \delta_4 \Delta LURP_{t-1} + \delta_5 \Delta LTHE_{t-1} + \epsilon_{t-1} \quad (7)$$

$$LCO2_t = \beta_0 + \beta_1 LY_t + \beta_2 LY^2_t + \beta_3 LENC_t + \beta_4 LURP_t + \beta_5 LTHE_t + \epsilon_t \quad (8)$$

#### Model 5

$$\Delta LCO2_t = \delta_0 + \delta_1 \Delta LY_{t-1} + \delta_2 \Delta LY^2_{t-1} + \delta_3 \Delta LENC_{t-1} + \delta_4 \Delta LNCE_{t-1} + \epsilon_{t-1} \quad (9)$$

$$LCO2_t = \beta_0 + \beta_1 LY_t + \beta_2 LY^2_t + \beta_3 LENC_t + \beta_4 LNCE_t + \epsilon_t \quad (10)$$

#### Model 6

$$\Delta LCO2_t = \delta_0 + \delta_1 \Delta LY_{t-1} + \delta_2 \Delta LY^2_{t-1} + \delta_3 \Delta LENC_{t-1} + \delta_4 \Delta LTHE_{t-1} + \epsilon_{t-1} \quad (11)$$

$$LCO2_t = \beta_0 + \beta_1 LY_t + \beta_2 LY^2_t + \beta_3 LENC_t + \beta_4 LTHE_t + \epsilon_t \quad (12)$$

## III. Results and Discussion

We present the results of ARDL models in three tables. Panel A shows the short-run estimates, Panel B presents the long run estimates, and Panel C includes the cointegration and the diagnostic tests.

In Mexico, the short-run analysis reveals that  $ENC$  and  $URP$  have a positive impact on CO2 emissions. However,  $URP$  also has a negative effect, indicating that while energy consumption can increase CO2 emissions, urbanization might initially decrease CO2 emissions but could lead to increased emissions later. The relationship between urbanization and CO2 emissions in the short run follows a U-shape. In the long run, urbanization is expected to reduce CO2 emissions in Mexico. In models 4 and 6, the relationship is significant only in the short run. Both models show a negative relationship between  $Y$  and CO2 emissions and a positive relationship between  $ENC$  and CO2 emissions. This suggests that increases in individual income in the short run may help reduce CO2 emissions. Regarding  $THE$ , model 4 shows a positive effect on CO2 emissions, while model 6 shows a negative effect. In the short run, energy consumption in Mexico can increase CO2 emissions, and this effect persists into the long run. Nuclear energy use in Mexico has a minimal impact on CO2 emissions.

In Brazil,  $Y$  and  $URP$  have a negative impact on CO2 emissions, while  $URP$  have a positive impact. This indicates a U-shaped relationship between economic development and CO2 emissions, and an inverted-U-shaped relationship between urbanization and CO2 emissions.  $ENC$  positively influences CO2 emissions, meaning that increased energy consumption will raise CO2 emissions in Brazil. In models 4 and 6,  $THE$  has a negative impact on CO2 emissions in the short run, suggesting that the use of thermal energy can help reduce CO2 emissions temporarily, though this effect does not extend into the long run. In the long run, only  $ENC$  and  $URP$  in model 3 are significant, with  $THE$  having a significant positive effect on CO2 emissions.

**Table 1. Results - Mexico**

|                                                  | Model 1           | Model 2            | Model 3            | Model 4            | Model 5             | Model 6            |
|--------------------------------------------------|-------------------|--------------------|--------------------|--------------------|---------------------|--------------------|
| <b>Panel A: Estimated short-run coefficients</b> |                   |                    |                    |                    |                     |                    |
| $\Delta LY$                                      | -0.06<br>(-0.04)  | -1.03<br>(-0.69)   |                    | -7.73<br>(-2.86)** | 6.39<br>(0.59)      | -8.42<br>(-3.07)** |
| $\Delta LY2$                                     | 0.00<br>(0.00)    | 0.06<br>(0.74)     |                    | 0.43<br>(2.89)     | -0.34<br>(-0.58)    | 0.47<br>(3.07)**   |
| $\Delta LENC$                                    | 1.13<br>(14.67)** | 1.12<br>(15.16)**  |                    | 1.11<br>(18.89)**  | 1.19<br>(11.72)**   | 1.13<br>(20.12)**  |
| $\Delta LURP$                                    |                   | 7.46<br>(3.11)**   |                    | 1.80<br>(1.02)     |                     |                    |
| $\Delta LURP1$                                   |                   | -6.60<br>(-2.84)** |                    | -2.95<br>(-1.88)*  |                     |                    |
| $\Delta LNCE$                                    |                   |                    |                    |                    | 0.00<br>(0.00)      |                    |
| $\Delta LTHE$                                    |                   |                    |                    | 0.05<br>(-5.04)**  |                     | -0.05<br>(-4.99)** |
| $\Delta LCO21$                                   |                   |                    |                    | -0.05<br>(-1.27)   |                     | -0.07<br>(-1.82)*  |
| <b>Panel B: Estimated long-run coefficients</b>  |                   |                    |                    |                    |                     |                    |
| $LY$                                             | -3.84<br>(-0.04)  | -3.15<br>(-0.69)   | -9.79<br>(-0.713)  | 29.87<br>(0.18)    | 403.07<br>(0.28)    | 50.55<br>(0.59)    |
| $LY2$                                            | 0.02<br>(0.00)    | 0.19<br>(0.74)     | 0.56(0.74)         | -1.55<br>(-0.18)   | -21.72<br>(-0.28)   | -2.54<br>(-0.59)   |
| $LENC$                                           | 2.38<br>(0.36)    | 1.16<br>(8.41)**   | 1.16<br>(20.01)**  | 1.07<br>(0.63)     | -1.61<br>(-0.23)    | -0.48<br>(-0.23)   |
| $LURP$                                           |                   | -0.91<br>(-6.25)** | -0.87<br>(-8.56)** | 0.33<br>(0.06)     |                     |                    |
| $LNCE$                                           |                   |                    | 0.10<br>(5.39)**   |                    | 0.00<br>(0.00)      |                    |
| $LTHE$                                           |                   |                    |                    | -1.23<br>(-0.21)   |                     | -1.58<br>(-0.47)   |
| $INPT$                                           | 29.19<br>(0.06)   | 28.89<br>(1.28)    | 57.30<br>(0.92)    | -146.10<br>(-0.17) | -1866.50<br>(-0.28) | -240.89<br>(-0.59) |
| <b>Panel C: Cointegration &amp; diagnostics</b>  |                   |                    |                    |                    |                     |                    |
| $F$                                              | 1.53              | 3.15               | 0.75               | 2,66**             | 1.31                | 1.50               |
| $LM$                                             | 1.02              | 0.30               | 0.11               | 0.37               | 0.36                | 0.74               |
| $RESET$                                          | 0.14              | 0.01               | none               | 3.77*              | 1.64                | 2.88*              |
| Adjusted $R^2$                                   | 0.88              | 0.91               |                    | 0.96               | 0.89                | 0.96               |
| $ecmt-1$                                         | -0.02<br>(-0.31)  | -0.33<br>(-2.72)** |                    | 0.02<br>(0.20)     | -0.02<br>(-0.30)    | 0.02<br>(0.48)     |

Note: The values reported in parentheses are t-statistics. \* and \*\* indicate significance at the 10% and 5% levels, respectively. The critical value of the F-statistic (with unrestricted intercept and no trend) at the 5% significance level has an upper bound of 4.02 and a lower bound of 2.90. The critical values for the residual serial correlation test (Lagrange Multiplier, LM) are 21.02 and 18.54 at the 5% and 10% significance levels, respectively. Critical values for misspecification, assessed by Ramsey's test, are 2.71 and 3.84 at the 10% and 5% levels, respectively.

In Argentina, *ENC* is positively related to CO2 emissions, indicating that increased energy consumption can lead to higher emissions. Both *URP* and *THE* are negatively related to CO2 emissions, suggesting that urbanization and thermal energy can help reduce CO2 emissions. Among the six models, *ENC* consistently shows a significant positive relationship with CO2 emissions. In models 2, 3, and 4, this relationship extends into the long run, similar to the findings for Mexico and Brazil, indicating that energy consumption has a positive impact on CO2 emissions in all three coun-

tries. However, all three countries show a minimal relationship between *NCE* and CO2 emissions.

#### IV. Conclusion

This paper explores the factors that influence CO2 emissions and, consequently, the overall environmental development in Latin American countries. The results show no support for the EKC hypothesis in these three countries. Instead, the relationship between economic development and CO2 emissions is U-shaped. Energy consumption con-

**Table 2. Results - Brazil**

|                                                  | Model 1            | Model 2             | Model 3             | Model 4             | Model 5            | Model 6             |
|--------------------------------------------------|--------------------|---------------------|---------------------|---------------------|--------------------|---------------------|
| <b>Panel A: Estimated short-run coefficients</b> |                    |                     |                     |                     |                    |                     |
| $\Delta LY$                                      | -1.07<br>(-1.93)*  | -2.23<br>(-2.45)**  | -8.07<br>(-2.00)*   | -3.13<br>(-1.49)    | -20.30<br>(-1.75)* | -3.14<br>(-1.51)    |
| $\Delta LY1$                                     |                    |                     |                     |                     | 25.29<br>(2.55)**  |                     |
| $\Delta LY2$                                     | 0.08<br>(2.38)**   | 0.13<br>(2.57)**    | 0.42<br>(1.86)*     | 0.18<br>(1.55)      | 1.18(1.80)*        | 0.18<br>(1.57)      |
| $\Delta LY21$                                    |                    |                     |                     | 0.01<br>(1.67)      | -1.44<br>(-2.57)** | 0.01<br>(1.77)*     |
| $\Delta LENC$                                    | 1.05<br>(6.35)**   | 1.44<br>(8.49)**    | 2.39<br>(7.27)**    | 1.45<br>(14.00)**   | 0.86<br>(3.03)**   | 1.46<br>(15.53)**   |
| $\Delta LURP$                                    |                    | -21.51<br>(-4.09)** | -35.62<br>(-5.50)** | 0.01<br>(0.09)      |                    |                     |
| $\Delta LURP1$                                   |                    | 21.73<br>(3.86)**   | 24.52<br>(4.61)**   |                     |                    |                     |
| $\Delta LNCE$                                    |                    |                     | -0.00<br>(-0.55)    |                     | 0.01<br>(1.51)     |                     |
| $\Delta LTHE$                                    |                    |                     |                     | -0.53<br>(-11.12)** |                    | -0.52<br>(-11.48)** |
| $\Delta LCO21$                                   |                    | 0.10<br>(1.49)      |                     |                     | 0.36<br>(1.90)*    |                     |
| <b>Panel B: Estimated long-run coefficients</b>  |                    |                     |                     |                     |                    |                     |
| $LY$                                             | -9.64<br>(-1.33)   | -9.64<br>(-1.33)    | -39.32<br>(-1.12)   | 6.61<br>(0.25)      | -105.05<br>(-1.19) | 4.68<br>(0.45)      |
| $LY2$                                            | 0.58<br>(1.41)     | 0.58<br>(1.41)      | 2.07<br>(1.06)      | -0.44<br>(-0.30)    | 5.90<br>(1.20)     | -0.34<br>(-0.53)    |
| $LENC$                                           | 0.48<br>(1.58)     | 0.48<br>(1.58)      | 5.05<br>(3.00)**    | 1.53<br>(0.50)      | 0.42<br>(1.39)     | 1.74<br>(1.09)      |
| $LURP$                                           |                    |                     | -6.78<br>(-2.63)**  | 0.42<br>(0.08)      |                    |                     |
| $LNCE$                                           |                    |                     | -0.04<br>(-1.24)    |                     | 0.06<br>(1.35)     |                     |
| $LTHE$                                           |                    |                     |                     | -0.72<br>(-0.68)    |                    | -0.66<br>(-0.99)    |
| $INPT$                                           | 39.34<br>(1.23)    | 39.34<br>(1.23)     | 304.03<br>(1.67)    | -30.99<br>(-0.16)   | 467.12<br>(1.19)   | -14.98<br>(-0.33)   |
| <b>Panel C: Cointegration &amp; diagnostics</b>  |                    |                     |                     |                     |                    |                     |
| $F$                                              | 3.56               | 4.38**              | 2.12                | 5.03**              | 2.02               | 3.43**              |
| $LM$                                             | 1.47               | 1.47                | 0.15                | 0.92                | 0.30               | 0.85                |
| $RESET$                                          | 0.00               | 0.01                | 0.40                | 0.54                | 0.12               | 0.54                |
| Adjusted $R^2$                                   | 0.80               | 0.85                | 0.89                | 0.95                | 0.77               | 0.95                |
| $ecmt-1$                                         | -0.11<br>(-2.08)** | -0.15<br>(-1.29)    | -0.21<br>(-1.63)    | -0.03<br>(-0.51)    | -0.19<br>(-1.47)   | -0.03<br>(-0.76)    |

Note: The values reported in parentheses are t-statistics. \* and \*\* indicate significance at the 10% and 5% levels, respectively. The critical value of the F-statistic (with unrestricted intercept and no trend) at the 5% significance level has an upper bound of 4.02 and a lower bound of 2.90. The critical values for the residual serial correlation test (Lagrange Multiplier, LM) are 21.02 and 18.54 at the 5% and 10% significance levels, respectively. Critical values for misspecification, assessed by Ramsey's test, are 2.71 and 3.84 at the 10% and 5% levels, respectively.

sistently increases CO2 emissions in the long run. These countries heavily rely on fossil fuels for energy, highlighting the need to further explore the role of nuclear energy in reducing CO2 emissions and contributing to global sustainable development. Nuclear power has played a negligible role in all three countries, and they have not fully utilized this clean energy source.

This research addresses three main gaps. First, it provides a comprehensive understanding of the situation across Latin America, given the similarities in geology, policy, and economic growth among these countries, which can inform strategies applicable to other Latin American nations. Second, it demonstrates that these countries do not support the EKC hypothesis. Third, by using updated

**Table 3. Results - Argentina**

|                                                  | Model 1           | Model 2            | Model 3           | Model 4             | Model 5           | Model 6            |
|--------------------------------------------------|-------------------|--------------------|-------------------|---------------------|-------------------|--------------------|
| <b>Panel A: Estimated short-run coefficients</b> |                   |                    |                   |                     |                   |                    |
| $\Delta LY_t$                                    | -2.30<br>(-0.96)  | -1.88<br>(-0.81)   | -1.74<br>(-0.65)  | 0.02<br>(0.02)      | -1.62<br>(-0.60)  | -0.19<br>(-0.12)   |
| $\Delta LY_{t2}$                                 | 0.13<br>(0.96)    | 0.10<br>(0.80)     | 0.09<br>(0.65)    | 0.4718E-3<br>(0.01) | 0.09<br>(0.62)    | 0.01<br>(0.15)     |
| $\Delta LENC$                                    | 1.21<br>(11.62)** | 1.24<br>(12.07)**  | 1.24<br>(8.55)**  | 1.19<br>(17.04)**   | 1.17<br>(8.58)**  | 1.19<br>(16.30)**  |
| $\Delta LURP$                                    |                   | -0.29<br>(-1.88)*  | -0.25<br>(-1.31)  | -0.25<br>(-2.28)**  |                   |                    |
| $\Delta LNCE$                                    |                   |                    | -0.01<br>(-0.57)  |                     | -0.01<br>(-0.97)  |                    |
| $\Delta LTHE$                                    |                   |                    |                   | -0.07<br>(-7.76)**  |                   | -0.08<br>(-8.02)** |
| <b>Panel B: Estimated long-run coefficients</b>  |                   |                    |                   |                     |                   |                    |
| $LnY_t$                                          | -72.45<br>(-0.59) | -11.01<br>(-0.80)  | -7.99<br>(-0.66)  | 0.12<br>(0.02)      | -11.61<br>(-0.60) | -3.41<br>(-0.12)   |
| $LnY_{t2}$                                       | 3.94<br>(0.60)    | 0.59<br>(0.80)     | 0.43<br>(0.66)    | 0.00<br>(0.01)      | 0.64<br>(0.62)    | 0.23<br>(0.15)     |
| $LnENC$                                          | 0.55<br>(0.34)    | 1.54<br>(2.44)**   | 1.22<br>(1.82)*   | 1.16<br>(3.76)**    | 0.40<br>(1.08)    | 0.40<br>(0.81)     |
| $LnURP$                                          |                   | -1.69<br>(-2.78)** | -1.15<br>(-1.53)  | -1.17<br>(-3.59)**  |                   |                    |
| $LnNCE$                                          |                   |                    | -0.04<br>(-0.60)  |                     | -0.10<br>(-1.16)  |                    |
| $LnTHE$                                          |                   |                    |                   | -0.06<br>(-3.15)**  |                   | -0.16<br>(-1.38)   |
| $INPT$                                           | 333.12<br>(0.59)  | 80.15<br>(1.31)    | 57.21<br>(1.00)   | 19.25<br>(0.61)     | 53.25<br>(0.59)   | 13.37<br>(0.11)    |
| <b>Panel C: Cointegration &amp; diagnostics</b>  |                   |                    |                   |                     |                   |                    |
| F                                                | 1.12              | 1.54               | 0.85              | 1.17                | 1.06              | 1.38               |
| LM                                               | 0.01              | 0.35               | 0.28              | 0.00                | 0.07              | 0.22               |
| RESET                                            | 1.15              | 1.70               | 1.61              | 0.74                | 0.83              | 0.84               |
| Adjusted R <sup>2</sup>                          | 0.85              | 0.86               | 0.84              | 0.94                | 0.84              | 0.94               |
| ecmt-1                                           | -0.03<br>(-0.52)  | 0.17<br>(-1.80)*   | -0.22<br>(-1.95)* | -0.21<br>(-2.44)**  | -0.14<br>(-1.46)  | -0.06<br>(-1.00)   |

Note: The values reported in parentheses are t-statistics. \* and \*\* indicate significance at the 10% and 5% levels, respectively. The critical value of the F-statistic (with unrestricted intercept and no trend) at the 5% significance level has an upper bound of 4.02 and a lower bound of 2.90. The critical values for the residual serial correlation test (Lagrange Multiplier, LM) are 21.02 and 18.54 at the 5% and 10% significance levels, respectively. Critical values for misspecification, assessed by Ramsey's test, are 2.71 and 3.84 at the 10% and 5% levels, respectively.

data on environmental and economic development, we offer a more nuanced analysis of the short- and long-term relationships. Importantly, the use of nuclear energy in these countries remains minimal. They should consider transitioning from traditional energy sources to more environ-

mentally friendly options. For long-term development, promoting urbanization is also crucial.

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