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A Note on Cross-Panel Data Techniques

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ABSTRACT

The research led to the development of novel cross-panel data (CPD) approaches, whereby the regressand of a single nation relies concurrently on regressor from a wide variety of other countries. This research developed the Augmented Cross-Panel (ACP) unit root test and the Cross-Panel ARDL (CPARDL) estimator. It used them to measure Pakistan's environmental quality, which is sensitive to the choices made by other nations in the South Asian region. The information ranges from 1990 to 2021. The CPARDL estimates demonstrate that Pakistan's carbon emissions are mitigated by the increased contribution of India's alternative energy sources and Afghanistan's economic development. The political unrest in Bangladesh negatively impacted Pakistan's ecological stability. The CPD approach evaluates multi-regional projects to ensure sustainable infrastructure development.

Keywords: Cross-panel data; Cross-panel variables; Cross-panel regression; Augmented cross-panel unit root; Cross-panel ARDL estimator.

1. INTRODUCTION

A number made new pledges of nations, corporations, and municipalities during the COP26 conference in Glasgow in 2021. However, existing promises fall short of what the scientific community thought to be essential to limit global warming below 1.5 degrees Celsius. In addition, due to the worldwide economic crisis and the war in Ukraine, countries are regressing as a collective response (Njung'e, 2022). Weather events, disproportionately severe storms, unpredictable rainstorms, and changed hydrological cycles in biologically vulnerable places like the Himalayas put South Asian nations among the most in danger from global warming consequences.

Extreme weather events, movement and relocation are expected to affect South Asia significantly. For societies without the financial means to adapt, controlling rising temperatures is a matter of life and death. South Asian countries, like much of the rest of the developing world, depend on aid from wealthier nations to help them achieve their Paris Agreement commitments and improve their adaptation and mitigation efforts (The Third Pole, 2022). The policies remain needed to compare cross-country differences to make them green and clean, and there is a wide range of literature in favour of supporting South Asia's developmental agenda (Usman et al., 2021; Chien et al., 2022; Ahmad et al., 2022). The primary purpose of this research is to evaluate how the member states of the SAARC bloc have influenced Pakistan's ecology, which is particularly vulnerable to the effects of global warming. Sustainable environmental policies are essential for protecting against climate change.

2. MATERIALS AND METHODS

Time series, cross-sectional, and panel data have been the three most common forms of data sets discovered via a literature search thus far. The study introduced a new, crucial data set—the cross-panel data (CPD) set—that is often overlooked in the mathematical and statistical fields. The CPD is characterized by the cross-movement of variables from one nation to another within the regressors and within the dependent variable. This is a one-of-a-kind panel data set that may be used to compare the results of policy decisions made in one nation to those made in another and to identify the precise nature of the connection between variables across many cross-sections and periods. In order to analyze the effect of W and X country variables on Y country variables, it is necessary to organize such data sets into a response variable and its regressors, also known as cross-panel variables (CPV). Cross-panel regression (CPR) extends the panel OLS approach incorporating CPD and CPV into the regression process. The CPR formulation is shown by Equation (1), which is as follows:

$$Y_{i,t} = \alpha + \lambda X_{j,k,t} + \varepsilon_{i,j,k,l,t} \tag{1}$$

Where 'i' shows Y of different panel of countries and 'j' and 'k' shows X of different panel of countries, ε shows error term of 'i', 'j', and 'k' countries, and 't' shows time period.

The evaluation of the unit root in time series data and panel data sets is primarily carried out by various tests. These tests include Dickey-Fuller (DF), Augmented DF, Phillips-Perron (PP), the Levine-Lin-Chu, Im, Pesaran, and Shin Tests, etc. To evaluate data from many nations that have been included in the cross-panel, the authors developed the Augmented Cross-Panel (ACP) unit root test. This test allows for the estimation of unit roots under three different scenarios for dependent variable: no trend, a constant, and constant and trend, i.e.,

Dependent Variable at None:

$$\Delta\left(\sum_{i=j=k=1}^{M} \frac{Y_i}{\bar{X}_{j,k}}\right)_t = \varphi\left(\frac{Y_i}{\bar{X}_{j,k}}\right)_{t-1} + \left(\sum_{i=j=k=1}^{M} \Delta \frac{Y_i}{\bar{X}_{j,k}}\right)_{t-1} + \varepsilon_{i,j,k,t} \tag{2}$$

Dependent Variable at Constant:

$$\Delta\left(\sum_{i=j=k=1}^{M} \frac{Y_i}{\bar{X}_{j,k}}\right)_t = \alpha + \varphi\left(\frac{Y_i}{\bar{X}_{j,k}}\right)_{t-1} + \left(\sum_{i=j=k=1}^{M} \Delta \frac{Y_i}{\bar{X}_{j,k}}\right)_{t-1} + \varepsilon_{i,j,k,t} \tag{3}$$

Dependent Variable at Constant and Trend:

$$\Delta\left(\sum_{i=j=k=1}^{M} \frac{Y_i}{\bar{X}_{j,k}}\right)_t = \alpha + \beta TIME + \varphi\left(\frac{Y_i}{\bar{X}_{j,k}}\right)_{t-1} + \left(\sum_{i=j=k=1}^{M} \Delta \frac{Y_i}{\bar{X}_{j,k}}\right)_{t-1} + \varepsilon_{i,j,k,t} \tag{4}$$

Where 'i' shows Y of different panel of countries, 'j' and 'k' shows X of different panel of countries, Δ shows first difference operator, and 't' shows time period.

Independent Variable (X) at None:

$$\Delta\left(\sum_{i=j=k=1}^{M} X_{j,k} \times Y_t\right)_t = \varphi\left(\sum_{i=j=k=1}^{M} Y_{i-1} \times X_{j,k}\right)_t + \sum_{i=k=1}^{M} \Delta(Y_{i,t-1} \times X_{j,k,t-1)} + \varepsilon_{i,j,k,t} \tag{5}$$

Independent Variable (X) at Constant:

$$\Delta\left(\sum_{i=j=k=1}^{M} X_{j,k} \times Y_t\right)_t = \alpha + \varphi\left(\sum_{i=j=k=1}^{M} Y_{i-1} \times X_{j,k}\right)_t + \sum_{i=k=1}^{M} \Delta(Y_{i,t-1} \times X_{j,k,t-1)} + \varepsilon_{i,j,k,t} \tag{6}$$

Independent Variable (X) at Constant and Trend:

$$\Delta\left(\sum_{i=j=k=1}^{M} X_{j,k} \times Y_t\right)_t = \alpha + \beta TIME + \varphi\left(\sum_{i=j=k=1}^{M} Y_{i-1} \times X_{j,k}\right)_t + \sum_{i=k=1}^{M} \Delta(Y_{i,t-1} \times X_{j,k,t-1)} + \varepsilon_{i,j,k,t} \tag{7}$$

The panel ARDL method as developed by Pesaran et al. (2001) was designed for the mixed order of integration while the same condition followed the CPD for model building. The study proposed Cross-Panel ARDL (CPARDL) modelling techniques for short- and long-run parameter estimates, i.e.,

$$\Delta \ln(Y)_{i,t} = \alpha_0 + \alpha_1 \sum_{i=1}^{P} \Delta \ln(Y)_{i,t-1} + \alpha_2 \sum_{i=1}^{P} \Delta \ln(X)_{j,k,t-1} + \alpha_3 \sum_{i=1}^{q} \ln(X)_{j,k,t-1} + \rho ECT_{t-1} + \varepsilon_{i,j,k,t} \quad (8)$$

The null hypothesis is evaluated against the alternative hypothesis of the cointegration relationship between the variables, i.e.,

H_0: $\alpha_3 = 0$

H_A: $\alpha_3 \neq 0$

The rejection of the null hypothesis confirmed the long-run cointegration relationship in the model. By using equation (8), the study formed the regression equation by using the CPARDL method, i.e.,

$$\begin{aligned}\Delta \ln(PAK\_CO2)_{i,t} &= \alpha_0 + \alpha_1 \sum_{i=1}^{P} \Delta \ln(PAK\_CO2)_{i,t-1} + \alpha_2 \sum_{i=1}^{P} \Delta \ln(IND\_REC)_{j,k,t-1} + \alpha_3 \sum_{i=1}^{q} \ln(IND\_REC)_{j,k} \\ &+ \alpha_4 \sum_{i=1}^{P} \Delta \ln(BAN\_PINS)_{j,k,t-1} + \alpha_5 \sum_{i=1}^{q} \ln(BAN\_PINS)_{j,k} + \alpha_6 \sum_{i=1}^{P} \Delta \ln(SRI\_RQ)_{j,k,t-1} + \alpha_7 \sum_{i=1}^{q} \ln(SRI\_RQ)_{j,k} \\ &+ \alpha_8 \sum_{i=1}^{P} \Delta \ln(NEP\_FDI)_{j,k,t-1} + \alpha_9 \sum_{i=1}^{q} \ln(NEP\_FDI)_{j,k} + \alpha_{10} \sum_{i=1}^{P} \Delta \ln(AFG\_GDPPC)_{j,k,t-1} + \\ &\alpha_{11} \sum_{i=1}^{q} \ln(AFG\_GDPPC)_{j,k} + \delta ECT_{t-1} + \varepsilon_{i,j,k,t}\end{aligned} \quad (9)$$

Figure 1 shows the theoretical framework of the study.

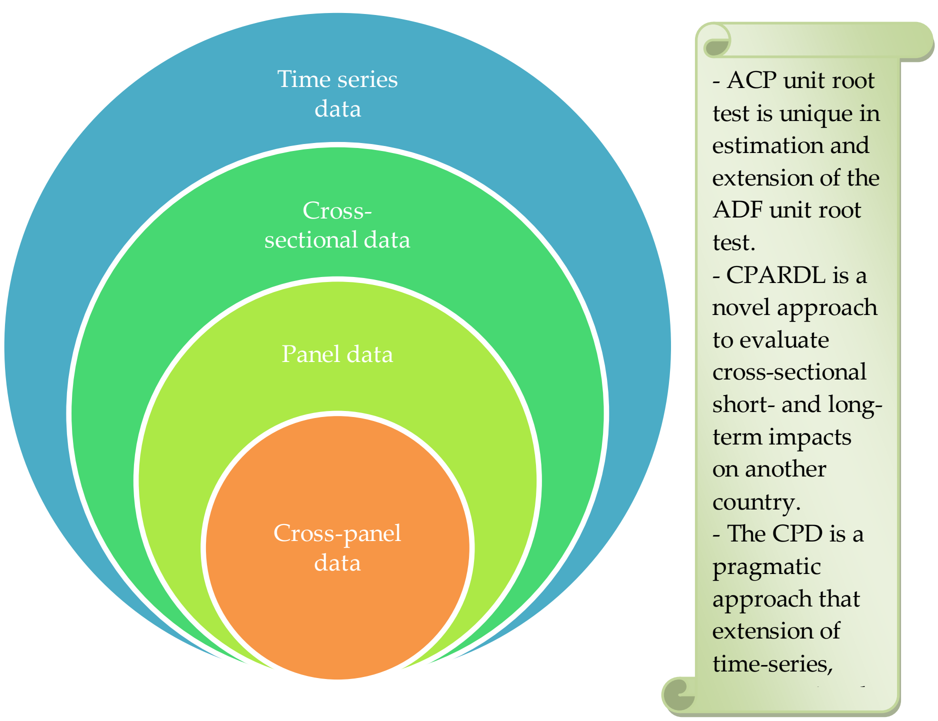

Figure 1: Theoretical Framework
Source: Author's extraction.

The ACP unit root test is a distinct method for determining the presence of a unit root in a time series, and it builds upon the ADF unit root test by incorporating additional parameters. The CPARDL approach is a novel method for evaluating the short-term and long-term impacts of one country on another, using cross-sectional data. The CPD approach is a practical method for extending traditional time-series, cross-sectional, and panel data analysis methods. This approach is used in logical econometrics to analyze and make predictions about economic systems.

The stated techniques were validated by using the real-time data of Pakistan's carbon emissions in metric tons per capita (denoted by PAK_CO2) that served as the regressand of the study. While India's renewable energy supply as % of total energy use (denoted by IND_REC), Bangladesh's political instability as index value range from -2.5 to +2.5 (denoted by BAN_PINS), Srilanka regulatory quality as index value range from -2.5 to +2.5 (denoted by DRI_RQ), Nepal's inbound FDI as current US$ (denoted by NEP_FDI), and Afghanistan's GDP per capita in US$ (denoted by AFG_GDPPC) served as regressors of the study. The data is collected for a period of 1990 to 2021 from the World Development Indicators (WDI, 2022) and World Governance Index (WGI, 2022).

3. RESULTS AND DISCUSSION

The ACP unit root test was applied on the given data set to find the order of integration between the variables. Table 1 shows the unit root estimates for ready reference.

Table 1: ACP unit Root Estimates

Variables	Level		Fist Difference		Decision
	Constant	Constant and Trend	Constant	Constant and Trend	
PAK_CO2	-5.812 (0.000)	-5.720 (0.000)	-10.448 (0.000)	-5.607 (0.000)	I(0)
IND_REC	-1.278 (0.626)	-1.805 (0.655)	-5.259 (0.000)	-5.288 (0.000)	I(1)
BAN_PINS	-1.442 (0.548)	-1.514 (0.802)	-5.954 (0.000)	-5.904 (0.000)	I(1)
SRI_RQ	-2.730 (0.080)	-2.769 (0.218)	-6.726 (0.000)	-6.606 (0.000)	I(0)
NEP_FDI	-0.600 (0.856)	-3.765 (0.032)	-9.952 (0.000)	-4.162 (0.015)	I(0)
AFG_GDPPC	0.236 (0.970)	-1.890 (0.635)	-4.810 (0.000)	-4.764 (0.003)	I(1)

Note: Small bracket shows probability value.

Table 1 shows that carbon emissions, regulatory quality, and inbound FDI exhibit level stationary variables, whereas renewable energy supply, political instability, and GDP per capita exhibit a first difference stationary. The high volatility in the Increase share of India's renewable energy supply, Bangladesh's political instability, and Afghanistan's GDP per capita verified the random walk hypothesis and followed the first order of integrated series, i.e., I(1). The stationary movement in Pakistan's carbon intensity, Srilanka's regulatory quality, and Nepal's inbound FDI confirmed the zero order of integrated series, i.e., I(0). Based on the mixed order of integration, the study first checked the lag length selection criteria and then moved to the CPARDL estimates. Table 2 shows the lag length selection criteria for ready reference.

Table 2: Lag Length Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-754.1060	NA	4.10e+14	50.67373	50.95397	50.76339
1	-592.6290	247.5980	1.01e+11	42.30860	44.27028*	42.93616
2	-541.5001	57.94614*	5.03e+10*	41.30001*	44.94312	42.46547*

Note: * indicates selected lag order criteria.

Based on the AIC estimates, the lag length of the CPARDL would be preferred to estimate the short- and long-run estimates between them. Table 3 shows the CPARLD estimates for ready reference.

Table 3: CPARDL Estimates

Dependent Variable: PAK_CO2				
Selected Model: ARDL(1, 0, 2, 0, 1, 2)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(IND_REC)	-0.013513	0.005149	-2.624405	0.0172
D(BAN_PINS)	0.017367	0.018382	0.944791	0.3573
D(BAN_PINS(-1))	-0.053309	0.022623	-2.356374	0.0300
D(SRI_RQ)	0.046645	0.070951	0.657416	0.5192
D(NEP_FDI)	2.77E-10	1.58E-10	1.746998	0.0977

Dependent Variable: PAK_CO2				
Selected Model: ARDL(1, 0, 2, 0, 1, 2)				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
D(AFG_GDPPC)	-0.000251	0.000172	-1.457863	0.1621
D(AFG_GDPPC(-1))	-0.000298	0.000212	-1.402936	0.1776
CointEq(-1)	-0.592642	0.187650	-3.158222	0.0054
Long Run Coefficients				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
IND_REC	-0.022802	0.003346	-6.814589	0.0000
BAN_PINS	0.120901	0.057536	2.101319	0.0500
SRI_RQ	0.078706	0.107393	0.732882	0.4731
NEP_FDI	3.26E-10	1.62E-10	2.012673	0.0594
AFG_GDPPC	-0.000819	0.000161	-5.080114	0.0001
Constant	1.921230	0.192059	10.003353	0.0000

Source: Author's estimate.

Based on these findings, it is clear that increasing India's renewable energy contribution would aid in the success of regional environmental programmes like reducing the intensity of carbon emissions in Pakistan's economy. Furthermore, the first lag of Bangladesh's political infrastructure improves Pakistan's environmental quality in the short-run. However, greater political instability damages regional environmental quality, mainly affecting Pakistan's economy, where devastating floods damage health and infrastructure. Finding a significant correlation between incoming FDI from Nepal and carbon emissions in Pakistan supports the pollution haven hypothesis, which states that investment from outside increases environmental risk and average temperature, increasing climate change vulnerabilities in Pakistan. In the end, a stable economy in Afghanistan is more suited to addressing Pakistan's socioeconomic and environmental difficulties. The use of biofuels, which help keep environmental costs down, is only one embodiment of the need to diversify energy sources (Zaman et al., 2016; Rashid Khan et al., 2021). Furthermore, there is an urgent need to enhance the value of the global supply chain in order to enhance industrial infrastructure and reduce waste. As a result, circular business models contribute to environmental and economic growth via technological advancement (Begum et al., 2022; Awan & Sroufe, 2022, 2020). An approach to economic development that is both environmentally responsible and capable of fostering widespread green innovation and mass manufacturing of environmentally friendly goods is pivotal for addressing global climate change challenges (Wan et al. 2018, Sasmoko et al. 2022).

4. CONCLUSIONS

The aim of the study is to develop another pragmatic estimator that extended the existing ADF unit root test and ARDL estimator, called augmented cross-panel (ACP) unit root test and cross-panel ARDL (CPARDL) estimator, respectively. The CPD technique is applied on real data of SAARC countries that effect on Pakistan's environment by their policy instruments. The ACP unit root test confirmed the mixture of variables' order of integration that provides a basis to use for CPARDL estimator. The results show that an increase in the India's share of using renewable energy and Afghanistan's economic initiatives helps to lessen Pakistan's carbon emissions. On the other hand, political unrest in Bangladesh and massive inbound FDI in Nepal damages Pakistan's environmental quality level.

When considering whether or not to invest in infrastructure that is more resistant to natural disasters, the governments of Asia should consider the potential savings of resources and financial gain, in addition to the reduction in economic losses. The intricacy of natural disasters is growing, making them harder to handle. If nothing is done to stop them, they will undermine the progress that has been achieved in development over the last several years and produce a more uncertain and appallingly uneven vision. There is a pressing need to promote pragmatic and risk-informed solutions to increase Asia's adaptability to combat climate change. Green energy must be a central part of Pakistan's economic plan if the country is to reduce its carbon footprint. The country must work closely with the other SAARC member states to share technological know-how and provide financial support for carbon-reduction initiatives.

Ethical approval

Not Applicable.

Informed consent

The study was conducted with equal participation by all authors.

Conflicts of interests

The authors declare that there are no conflicts of interests.

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Data and materials availability

The data is freely available at World Development Indicators published by World Bank (2022) at https://databank.worldbank.org/source/world-development-indicators

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