Entrepreneurship Education: Why the Paradigm Shift From Triple Helix to Quadruple Helix Model

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Abstract

This paper examined the interdependence of actors, resources and activities in the innovation eco-system. The aim is to understand the relationships and the value created between different actors. While the Triple Helix and Quadruple Helix are popular in innovation studies, the relations between them have not been addressed extensively in literature. To bridge the research gap, this paper compared the models from the perspective of how they were introduced and how useful they are in addressing the innovation processes in contemporary society. The findings and results indicated that the two models showed that they are complementary in value creation when analyzing innovation processes in the society. They provide ground for synergy building between the two Helix models. The research however, concluded that the fourth helix where societal value creation is generated by the dynamics in the relationships between academic industry and government and providing more value adding activities through society in a quadruple helix will enhance our understanding of the need for informed interactions of these innovation models through a strong civil society. This development has transformed the triple helix into the quadruple helix.

Keywords: *Entrepreneurship, Innovation, Triple Helix, Quadruple Helix, Civil society*

I. Introduction

There are diverse interpretations of helix models in innovation studies. The two models (triple and quadruple) are seemingly competing concepts that have been broadly applied in empirical investigations in Innovation Studies. Cai and Lattu (2021). The Triple Helix model was originally proposed by Etzkowitz and Leydesdorf (1995) to explain the dynamic interactions between academia, industry and government for fostering entrepreneurship, innovation and economic growth in a knowledge-based economy (Etzkowitz & Leydesdorf 2000). Since then, the Triple Helix model has quickly become a popular concept in innovation. At the same time, its explanatory power has been challenged by some skeptics (Cai & Etzkowitz 2020), particularly after the development of the Quadruple Helix model, which incorporates public or civil society as the fourth helix, (Carayannis & Campbell, 2009).

Carayannis and Campbell (2010, 2013) also proposed the Quintuple Helix by adding a fifth helix the natural environments of society. The Quintuple Helix addresses the socio-ecological transition of society and economy in the twenty-first century, bringing an ecologically sensitive perspective to the discussion of innovation and knowledge production (Carayannis & Campbell 2010, 2013). However, it is less popular in empirical studies compared with the Quadruple Helix model, probably because the connection of the environmental helix with the other four helices is a challenge' (Kong et al, 2020:8) in the conceptualization of the Quintuple Helix. In this paper, we exclude the Quintuple Helix from our focus because it largely shares the theoretical rationale of the Quadruple Helix model (Carayannis & Campbell 2021)

Helix represents a basic core models of innovation for the "knowledge economy," while the Quadruple Helix describes the "knowledge society" and "knowledge democracy," the Quintuple Helix refers to as social ecology, society-nature interactions (and) socio-ecological transition". This is connected with an emerging perception: With growing public awareness of socially responsible innovation, as well as the role of civil society in science and technology development in governmental policies, people tend to find the Quadruple Helix model timelier and more suitable for addressing new features of the society (Miller et al. 2018; De Oliveira Monteiro & Carayannis 2017).

The initiators of the Triple Helix model—Leydesdorf and Etzkowitz__were also keen on the change in society and its implications for the Triple Helix model. In 2003, they wrote an article titled 'Can "the public" be considered as a fourth helix in university-industry-government relations? (Leydesdorf & Etzkowitz 2003). In it, they claimed that it is not necessary to transform the Triple Helix into a Quadruple Helix because civil society is not an institutional sphere on the same level as a university, industry or government; rather, the Triple Helix has most efficacious evolved in an overarching societal framework guaranteeing freedom of speech and organization-formation initiative. Instead of being ignored, civil society is considered too important to be a parallel helix to industry, university and government; it is seen as a key enabling condition of triple helix interactions (Etzkowitz 2008; Etzkowitz & Zhou, 2017).

As noted by Leydesdorf (2012), defending the Triple Helix model does not mean being limited to the three helices for the explanation of complex developments. He suggested that whether more than three helices are needed in the analysis depends on the empirical context and the availability of empirical data (Leydesdorf (2012). However, Leydesdorf and Etzkowitz (2003) expressed a warning: So long as one is not able to operationalize and show development in the relatively simple case of three dimensions, one should be cautious in generalizing beyond the TH (Triple Helix) model to an N-tuple of helices. This reflects 'triadic interactions as an Occam's razor principle' (Cai & Etzkowitz 2020: 202)--a theoretical core of the Triple Helix model.

The debates on the two helix models often confuse newcomers to the field as to which helix model should be applied in their empirical research. Partially to respond to the situation, the originators of both the Triple Helix model and Quadruple Helix model, sometimes together with their co-authors, tried to clarify both concepts and the relations between them. For instance, Carayannis and Campbell (2021) articulated the evolution of Quadruple and Quintuple Helix innovation systems by emphasizing that the systems have emerged as a response to the transformation words Society 5.0, which 'aims to put human being as the center of innovation, taking advantage of the impact of technology and the results of industry 4.0 with the deepening of technological integration in improving quality of life, social responsibility and sustainability.

Regardless of the claims by the initiators of the helix models, current research applying Triple/Quadruple Helix models has not clearly explained the two models. These efforts have been hampered by a lack of studies systematically comparing the two models, resulting in diverse interpretations of Triple or Quadruple Helix.

Our study aims to fill the gap outlined above by assessing the two models with appropriate comparative approaches. Specifically, we raise the following research question. What sides of the two models should researchers consider when deciding which model to apply in their empirical studies?

II. Literature Review.

The Triple Helix Model and Quadruple Helix Model are Competing Concepts

The choice of Triple Helix or Quadruple Helix models in some studies is associated with the authors' view of the two helix models as competing concepts. The proponents of the Quadruple Helix model criticize the Triple Helix for its exclusion of civil society from its analytical focus, For instance, in their study on community-driven social innovation in a rural area, Nordberg et al (2020) explained that they prefer the Quadruple Helix to the Triple Helix as a conceptual framework because the former, which adds civil society as a fourth helix, elucidates the variety of formal and informal ways of fostering social innovation. They emphasized that the Quadruple Helix model is especially useful for analyzing the role of community in the innovation process. By the same logic, the Triple Helix model has been considered inadequate for analyzing multiple sectoral collaborations for entrepreneurship in contemporary society (Mok & Jiang, 2020).

The advocates of the Triple Helix model hold the position that the increasingly complex society can only be better understood when there is a clear understanding of the interactions of university, industry and government as the most important innovation players. As Zheng (2010) argued, compared with other approaches to innovation studies, including the Quadruple Helix, 'the Triple Helix model reduces the complexity of the dynamics at play in the innovation systems of the knowledge'. Such a reduction in complexity allows essential dynamics to be more clearly discerned. Similarly, Porto-Gomez et al. (2019) choose the Triple Helix model as an analytical tool for their study of innovation systems in Mexico by taking the 'system' advantage of the model. Thus, 'one can add as many players as one would like to reinforce the strength of the territory under analysis, let it be a country or a set of regions within a country' (Porto-Gomez et al. 2019:2).

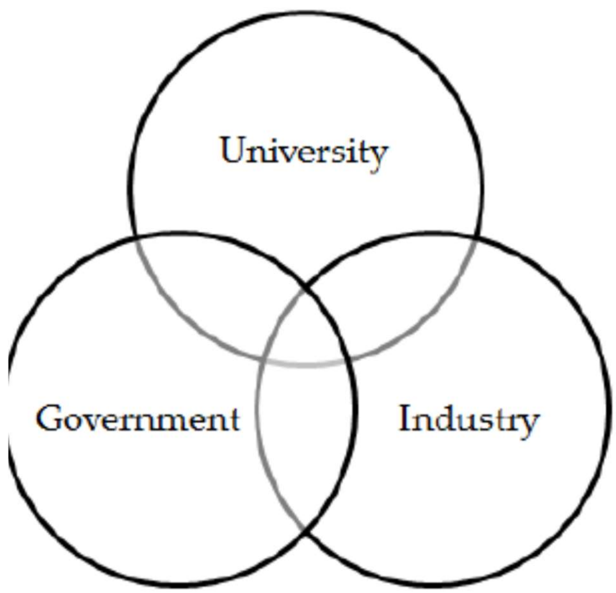

Figure 1: Triple Helix Model

Source: Thathsara Dulangi P (2021).

Evolutionary Process of Quadruple Helix

Studies taking the perspective of quadruple helix share the perception that civil society is not addressed by the Triple Helix model. However, instead of seeing the Triple Helix as an out-of-date concept, the authors value its conceptual elaboration on the interactions of university, industry and government and include civil society in their analytical framework. In other words, they see the transition from the Triple Helix model to the Quadruple Helix model as an evolutionary process. For instance, although the Quadruple Helix model was applied to study the role of non-profit organizations in innovation systems, Arranz at al, (2020) appreciated the theoretical rationales of Triple Helix interactions. Specifically, their analytical framework centered on how non-profit organizations interact with the traditional helices of university, industry and government. By the same token, Marques et al, (2020) developed their Quadruple Helix analytical framework to investigate the influences of multiple stakeholders' motivations on technology transfer in the context of implementing a smart specialization strategy in Europe, largely based on the theoretical and methodological powers of the Triple Helix model. Studies like Lijemark (2004), Khan and Al-Ansari (2005) opined that the fourth helix could include faith-based organization, non-governmental organization (.i.e. civil society) which could combine funding from government with the community and private donors.

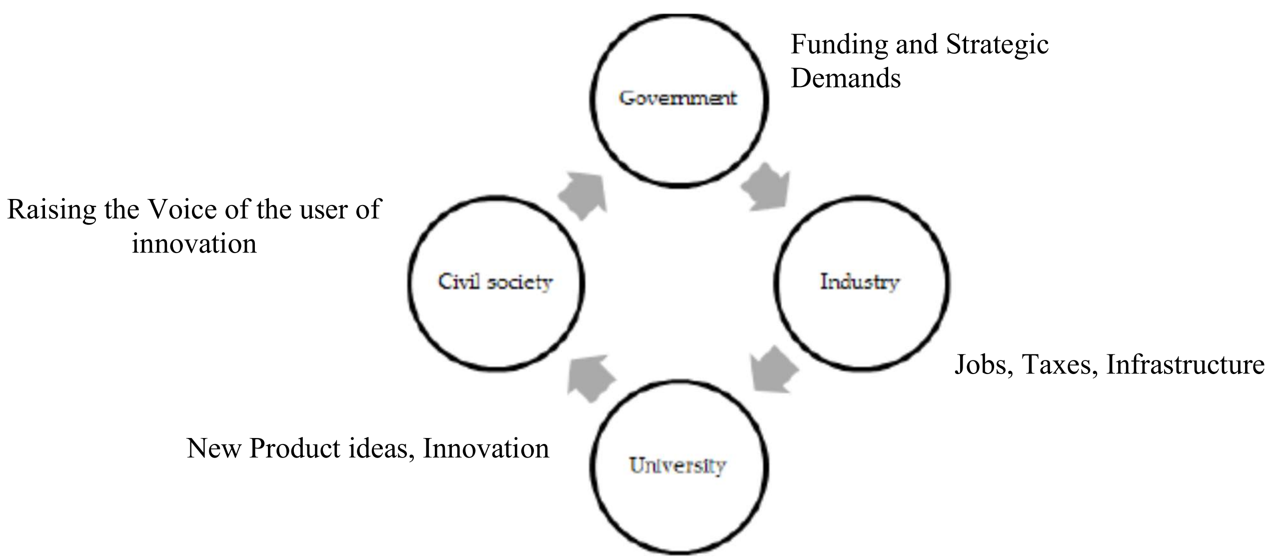

Figure 2: Quadruple Helix Model

Josphert (2016) the civil society serves as the voice of the citizen and could make development to be more human sensitive and the cultural context of the communities. The model (quadruple Helix) is called the citizen centered model, because it is focused on the development of innovations that are relevant and safe for citizens (Arnkil et al., 2010). However, the citizens are hardly able to know the procedures for getting the government and citizen to legally listen to their voices, hence, a strong civil society becomes a very important component to be added to the triple helix (Joshert, 2016).

III. Methodology

This study adopted the causal research design to investigate the Triple Helix and the Quadruple Helix model on the Nigerian economy. The Triple Helix model (TH) focuses on the interaction among universities, industry and government, and considers that these factors are the key factors that contribute to providing conducive environment for innovation and subsequently economic growth, the quadruple helix model, included universities, industry, government and civil society, whose effective relationships generate innovation and economic development.

The data for these sectors were collected from 2000 to 2022 from Central Bank of Nigeria (CBN) and World Governance Indicators (WGI). The Data for University was proxied as government spending on education, for industry, the contribution of Industry to GDP, Government was proxied as government effectiveness, Civil Society measured or proxied as Rule of Law and economic growth and innovation measured as GDP.

Auto-regressive Distributed Lagged (ARDL) technique was applied to investigate the long-run and short-run effect of Triple Helix and the Quadruple Helix model on the Nigerian economy. The ARDL approach was applied regardless of whether unit root level of stationarity is I (0), I (1), or both I (0) and I (1) (Sulaiman & Abdul-Rahim, 2018).

Model Specification

The model for this study followed the study of Afzal et al. (2018).

Triple Helix model

$$\Delta \mathbf{GDP}_t=\alpha_0+\alpha_1\Delta \mathbf{GDP}_{t-i}+\alpha_2\Delta \mathbf{UNI}_{t-i}+\alpha_3\Delta \mathbf{GOV}_{t-i}+\alpha_4\Delta \mathbf{IND}_{t-i}+\beta_1\mathbf{GDP}_{t-1}+\beta_2\mathbf{UNI}_{t-1}+\beta_3\mathbf{GOV}_{t-1}+\beta_4\mathbf{IND}_{t-1}+\varphi z_{t-1}+U_t \quad \dots (1)$$

Quadruple Helix model

$$\Delta \mathbf{GDP}_t = \alpha_0 + \alpha_1 \Delta \mathbf{GDP}_{t-i} + \alpha_2 \Delta \mathbf{UNI}_{t-i} + \alpha_3 \Delta \mathbf{GOV}_{t-i} + \alpha_4 \Delta \mathbf{IND}_{t-i} + \alpha_5 \Delta \mathbf{CVS}_{t-i} + \beta_1 \mathbf{GDP}_{t-1} + \beta_2 \mathbf{UNI}_{t-1} + \beta_3 \mathbf{GOV}_{t-1} + \beta_4 \mathbf{IND}_{t-1} + \beta_5 \mathbf{CVS}_{t-1} + \varphi z_{t-1} + U_t \quad \ldots (2)$$

Where: GDP=economic growth, UNI= University sector the first component of Helix model, GOV=Government sector, IND= the industrial sector, CVS= civil society sector

it-i = Lag length

t = 2000, 2001, 2002…2022

U_{it} = Component error term

Φ = coefficient of the Error correction term

z_{t-1}= Error Correction Variable

α_0 = constant intercept

α_1 and β_1 = the coefficient of GDP.

α_2 and β_2 = the coefficient of university sector

α_3 and β_3 = the coefficients of Government sector

α_4 and β_4 = the coefficients of industrial sector

α_5 and β_5 = the coefficients of civil society sector

Δ = difference operator

Table 1: Study Variables and their Measurement

Variable Acronym	Variable Name	Variable Type	Measurement
UNI	University sector	Independent Variable	Government Spending in Billion naira in the Universities
GOV	Government Sector	Independent Variable	Government Effectiveness measured in index
IND	Industrial Sector	Independent Variable	Industrial sector contributions in billion naira
CVS	Civil Society Sector	Independent Variable	Rule of law in the society measured in index
GDP	Economic Growth	Dependent Variable	Total Amount of Goods and services measured in Billion naira for a period of one year

Source: Authors Computation

IV. Result

Descriptive Statistics

Table 2

Summary of Descriptive Statistic

	GDP	UNI	GOV	IND	CVS
Mean	74481.2603	289.55	-1.05	14145.35	-1.13
Std Dev	57530.38	209.60	0.09	1554.99	0.21
Kurtosis	-0.47	-0.84	-0.83	-0.59	-0.41
Skewness	0.69	0.58	-0.33	-0.33	-0.74
Range	195302.28	663.10	0.32	5779.31	0.70
Minimum	7062.75	39.88	-1.21	10962.84	-1.54
Maximum	202365.03	702.98	-0.90	16742.15	-0.84
Count	23	23	23	23	23

Source: Authors Computation

Table 2 shows the descriptive statistics for variables GDP, UNI, GOV, IND and CVS. The results indicated that the mean of GDP, UNI, GOV, IND and CVS are 74481.26, 289.55, -1.05, 14145.35 and -1.13 respectively. The mean values for the variables are high than the standard deviation values, which are 57530.38, 209.60, 0.09, 1554.99 and 0.21 respectively. This means that the variables are clustered and are not volatile or dispersed.

Table 3

Correlation Matrix

	GDP	UNI	GOV	IND	CVS
GDP	1				
UNI	0.980	1			
GOV	-0.436	-0.438	1		
IND	0.673	0.697	-0.402	1	
CVS	0.809	0.793	-0.439	0.614	1

Source: Authors Computation

Table 3 shows result of the matrix correlation for GDP, UNI, GOV, IND and CVS. The result revealed that UNIV correlated to GDP by 98.0%, indicating strong positive correlation. GOV correlated to GDP was found to be -43.6%, indicating a low negative correlation. But IND and CVS correlated to GDP by 67.3% and 80.9% respectively, indicating a strong positive correlation to GDP in Nigeria.

Table 4

Test for Multicollinearity

Variable	Centered VIF
UNI	3.354259
IND	2.015517
GOV	1.294562
CVS	2.809856

Source: Authors Computation

It is observed that in Table 4, VIF value revealed absence of multicollinearity because the VIF values are way below 10.

Preliminary Analysis

Table 5
Unit-root test

Variable	P-Value Level	P-Value 1st Diff	Order of co-integration
GDP	0.9900	0.010**	I(1)
UNI	0.9900	0.010**	I(1)
GOV	0.0460**	0.010**	I(0)
IND	0.5632	0.0221**	I(1)
CVS	0.1135	0.0100**	I(1)

Source: Author's computation

Table 5 shows the result of the unit root test for the variables under study, which was derived Andrew-Zivots unit root test. The result shows that there mixture of I(1) and I(0) integration. Hence, this study applied the ARDL method of analysis.

Table 6

Results of Bound Cointegration Test

Test Statistic	Value	Signif.	I(0)	I(1)
Quadruple Helix Model				
F-statistic	4.782252	10%	2.45	3.52
K	4	5%	2.86	4.01
		2.5%	3.25	4.49
		1%	3.74	5.06
Triple Helix Model				
		10%	2.72	3.77
F-statistic	14.61356	5%	3.23	4.35
K	3	2.5%	3.69	4.89
		1%	4.29	5.61
		10%	2.72	3.77

Source: Author's computation

Table 6 shows the result of the F-statistics for Triple Helix Model and the Quadruple Helix Model are greater than the significant level at 10%, 5%, 2.5% and 1%. It is concluded that there is bound cointegration indicating the existence of long-run relationship among the variables.

Table 7

Results of Triple and Quadruple Helix Analysis

	Triple Helix Model		Quadruple Helix Model	
	Coeff	**P-value**	**Coeff**	**P-value**
	Long-run		***Long-run***	
UNI_t	15.97459	(0.8847)	-25.92284	(0.8889)
GOV_t	-52739.59	(0.3725)	-151146.5	(0.1808)
IND_t	8.089911	(0.1795)	14.12327	(0.2142)
CVS_t	-	-	-84772.66	(0.2944)
	Short-run		***Short-run***	
ECM(-1)	-0.157651	(0.0000)**	-0.192214	(0.0002)**
ΔGDP_{t-1}	0.157651	(0.0574)***	-0.650089	(0.1225)
ΔUNI_t	-2.518412	(0.8921)	28.79138	(0.2724)
ΔGOV_t	8314.455	(0.3564)	9878.264	(0.2974)
ΔIND_t	1.468361	(0.2818)	2.806298	(0.0683)***
ΔCVS_t	-	-	16294.46	(0.1149)
N	23		23	
F-test	36.71	P-value=0.000	15.41	P-value=0.000
R^2		0.7944	0.8924	
Durbin Watson		2.15	2.17	

Dependent variable: $(GDP)_{it}$ Note: * ** *** show significance at 1%, 5% and 10% respectively

Long-run Relationships

Triple Helix Model

The result revealed that two sectors out of the three sectors (Universities and industries) have positive and insignificant effect on innovation and economic growth in Nigeria while government sector showed negative effects. This means that under the Triple Helix model, government effective in Nigeria does not support innovation and economic growth which resulted to the ineffectiveness of the universities and the industrial sector in Nigeria.

Quadruple Helix Model

Under the Quadruple Helix model, the result revealed that three sectors out of the four sectors (Universities, Government and civil society) have negative and insignificant effect on innovation and economic growth in Nigeria while the industrial sector showed positives effect. This means that under the Quadruple Helix model, the ripple effect of government ineffectiveness in Nigeria affected the performance of the universities and the civil societies to enhance innovation and economic growth in Nigeria. Only the industrial sector indicated a positive effect and this could be attributed to the independence of the industrial sector in Nigeria.

Short-run Relationships

The models (*Triple Helix Model and Quadruple Helix Model*) are certified robust based on the values of the R-squared, F-test and the Durbin-Watson test. The speed of adjustment according to the error correction models (ECM) are slow towards adjusting to equilibrium, despite, meeting the conditions of less than one, negative and significant.

Triple Helix Model

The result revealed that two sectors out of the three sectors (government and industries) have positive and insignificant effect on innovation and economic growth in Nigeria while university sector showed negative effects. This means that under the Triple Helix model, government and industries though positive do not significantly affect innovation and economic growth in Nigeria. The effect of university was found to be negative on innovation and growth in Nigeria.

Quadruple Helix Model

In the case of Quadruple Helix model in the short-run, the result revealed that all the sectors (Universities, Government, industry and civil society) have positive and insignificant effect on innovation and economic growth in Nigeria. However, only the industrial sector had a significant effect on innovation and economic growth.

Conclusion

This study highlighted the importance of interaction between spheres in an advanced innovation setting. In a quadruple helix setting, there is lack of consensus in previous studies on how to operationalize the fourth helix (quadruple helix). As cited by Nordberg (2015), there is a tendency to either take civil society approach or an end user approach. This study showed that collaboration between industry, academic and government strive equally to include and use while trying to improve the civil society. In the light of this, we concluded that the fourth helix, where societal value creation is generated by the dynamics in the relationships between academic, industry, and government and providing more value-adding activities through society in a quadruple helix perspective will enhance our understanding of the need for informed watch-dogs for the interactions of these innovation models through a strong civil society. This development has transformed the triple helix into the quadruple helix.

Contribution to Knowledge

This paper provided information and explanation on triple/quadruple helix innovation model to drive innovation and entrepreneurship. Innovation and entrepreneurship require corporation among different actors (institutions, developers, consumers, academic and research institutions and government agencies. In addition, companies and consultants should participate in innovation competitions to inspire participants to develop their concepts and create applications that fulfil citizen requirements and raise funds for them.

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APPENDICES

DATA PRESENTATION

Year	GDP	UNI	GOV	IND	CVS
2000	7,062.75	57.96	-0.97	10,962.84	-1.16
2001	8,234.49	39.88	-1.04	11,576.32	-1.54
2002	11,501.45	80.53	-1.02	11,725.42	-1.50
2003	13,556.97	64.78	-0.92	13,151.23	-1.51
2004	18,124.06	76.50	-0.94	13,382.86	-1.44
2005	23,121.88	82.80	-0.90	13,609.76	-1.35
2006	30,375.18	119.02	-0.97	13,342.47	-1.08
2007	34,675.94	150.78	-1.03	13,085.27	-1.06
2008	39,954.21	163.98	-0.99	12,817.79	-1.04
2009	43,461.46	137.12	-1.20	13,138.95	-1.16
2010	55,469.35	170.80	-1.17	13,826.43	-1.16
2011	63,713.36	335.80	-1.10	14,986.62	-1.18
2012	72,599.63	348.40	-1.00	15,350.45	-1.14
2013	81,009.96	390.40	-1.00	15,682.46	-1.12
2014	90,136.98	343.75	-1.19	16,742.15	-1.06
2015	95,177.74	325.19	-1.00	16,366.66	-0.98
2016	102,575.42	339.28	-1.12	14,918.15	-1.04
2017	114,899.25	403.96	-1.04	15,238.28	-0.89
2018	129,086.91	465.30	-1.12	15,523.43	-0.92
2019	145,639.14	593.13	-1.21	15,882.35	-0.94
2020	154,252.32	646.79	-1.14	14,953.72	-0.84
2021	176,075.50	620.59	-1.03	14,883.77	-0.87
2022	202,365.03	702.98	-1.04	14,195.58	-0.91

ARDL RESULTS

Dependent Variable: GDP
Method: ARDL
Date: 07/16/24 Time: 20:52
Sample (adjusted): 2002 2022
Included observations: 21 after adjustments
Maximum dependent lags: 2 (Automatic selection)
Model selection method: Akaike info criterion (AIC)
Dynamic regressors (2 lags, automatic): UNI GOV IND CVS
Fixed regressors: C
Number of models evaluated: 162
Selected Model: ARDL(2, 2, 1, 2, 0)

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
GDP(-1)	0.542125	0.371468	1.459411	0.1785
GDP(-2)	0.650089	0.381364	1.704639	0.1225
UNI	28.79138	24.62526	1.169181	0.2724
UNI(-1)	-44.84789	21.94114	-2.044009	0.0713
UNI(-2)	21.03923	20.71011	1.015892	0.3362
GOV	9878.264	8931.928	1.105950	0.2974
GOV(-1)	19174.16	9985.348	1.920230	0.0870
IND	2.806298	1.355278	2.070644	0.0683
IND(-1)	-2.643274	1.681230	-1.572226	0.1503
IND(-2)	-2.877710	1.835034	-1.568205	0.1513
CVS	16294.46	9336.497	1.745244	0.1149
C	85460.71	28846.34	2.962619	0.0159

R-squared	0.998684	Mean dependent var	80846.27
Adjusted R-squared	0.997075	S.D. dependent var	56138.10
S.E. of regression	3036.224	Akaike info criterion	19.17018
Sum squared resid	82967924	Schwarz criterion	19.76705
Log likelihood	-189.2869	Hannan-Quinn criter.	19.29971
F-statistic	620.7445	Durbin-Watson stat	2.173185
Prob(F-statistic)	0.000000		

*Note: p-values and any subsequent tests do not account for model selection.

ARDL Long Run Form and Bounds Test
Dependent Variable: D(GDP)
Selected Model: ARDL(2, 2, 1, 2, 0)
Case 3: Unrestricted Constant and No Trend
Date: 07/16/24 Time: 20:52
Sample: 2000 2022
Included observations: 21

Conditional Error Correction Regression

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	85460.71	28846.34	2.962619	0.0159
GDP(-1)*	0.192214	0.129198	1.487747	0.1710
UNI(-1)	4.982724	31.51457	0.158109	0.8779
GOV(-1)	29052.43	12919.78	2.248678	0.0511
IND(-1)	-2.714686	1.011192	-2.684640	0.0250
CVS**	16294.46	9336.497	1.745244	0.1149
D(GDP(-1))	-0.650089	0.381364	-1.704639	0.1225
D(UNI)	28.79138	24.62526	1.169181	0.2724
D(UNI(-1))	-21.03923	20.71011	-1.015892	0.3362
D(GOV)	9878.264	8931.928	1.105950	0.2974
D(IND)	2.806298	1.355278	2.070644	0.0683
D(IND(-1))	2.877710	1.835034	1.568205	0.1513

* p-value incompatible with t-Bounds distribution.
** Variable interpreted as Z = Z(-1) + D(Z).

Levels Equation
Case 3: Unrestricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
UNI	-25.92284	180.4146	-0.143685	0.8889
GOV	-151146.5	104199.9	-1.450544	0.1808
IND	14.12327	10.56794	1.336426	0.2142
CVS	-84772.66	76139.87	-1.113381	0.2944

EC = GDP - (-25.9228*UNI -151146.5099*GOV + 14.1233*IND -84772.6571 *CVS)

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
			Asymptotic: n=1000	
F-statistic	4.782252	10%	2.45	3.52
k	4	5%	2.86	4.01
		2.5%	3.25	4.49
		1%	3.74	5.06

Dependent Variable: GDP
Method: ARDL
Date: 07/16/24 Time: 20:54
Sample (adjusted): 2001 2022
Included observations: 22 after adjustments
Maximum dependent lags: 2 (Automatic selection)
Model selection method: Akaike info criterion (AIC)
Dynamic regressors (2 lags, automatic): UNI GOV IND
Fixed regressors: C
Number of models evaluated: 54
Selected Model: ARDL(1, 0, 0, 1)
Note: final equation sample is larger than selection sample

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
GDP(-1)	1.157651	0.076991	15.03612	0.0000
UNI	-2.518412	18.27003	-0.137844	0.8921
GOV	8314.455	8754.304	0.949756	0.3564
IND	1.468361	1.318180	1.113931	0.2818
IND(-1)	-2.743745	1.336461	-2.052992	0.0568
C	25378.22	12232.73	2.074617	0.0545

R-squared	0.997482	Mean dependent var	77545.74
Adjusted R-squared	0.996695	S.D. dependent var	56930.42
S.E. of regression	3272.792	Akaike info criterion	19.25168
Sum squared resid	1.71E+08	Schwarz criterion	19.54923
Log likelihood	-205.7684	Hannan-Quinn criter.	19.32177
F-statistic	1267.671	Durbin-Watson stat	2.148902
Prob(F-statistic)	0.000000		

*Note: p-values and any subsequent tests do not account for model selection.

ARDL Long Run Form and Bounds Test
Dependent Variable: D(GDP)
Selected Model: ARDL(1, 0, 0, 1)
Case 3: Unrestricted Constant and No Trend
Date: 07/16/24 Time: 20:54
Sample: 2000 2022
Included observations: 22

Conditional Error Correction Regression

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	25378.22	12232.73	2.074617	0.0545
GDP(-1)*	0.157651	0.076991	2.047647	0.0574
UNI**	-2.518412	18.27003	-0.137844	0.8921
GOV**	8314.455	8754.304	0.949756	0.3564
IND(-1)	-1.275384	0.720314	-1.770594	0.0957
D(IND)	1.468361	1.318180	1.113931	0.2818

* p-value incompatible with t-Bounds distribution.
** Variable interpreted as Z = Z(-1) + D(Z).

Levels Equation
Case 3: Unrestricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
UNI	15.97459	108.4631	0.147281	0.8847
GOV	-52739.59	57482.94	-0.917482	0.3725
IND	8.089911	5.762802	1.403815	0.1795

EC = GDP - (15.9746*UNI -52739.5873*GOV + 8.0899*IND)

F-Bounds Test — Null Hypothesis: No levels relationship

Test Statistic	Value	Signif.	I(0)	I(1)
			Asymptotic: n=1000	
F-statistic	14.61356	10%	2.72	3.77
K	3	5%	3.23	4.35
		2.5%	3.69	4.89
		1%	4.29	5.61
			Finite Sample: n=35	
Actual Sample Size	22			
		10%	2.958	4.1
		5%	3.615	4.913
		1%	5.198	6.845
			Finite Sample: n=30	
		10%	3.008	4.15
		5%	3.71	5.018
		1%	5.333	7.063

t-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
t-statistic	2.047647	10%	-2.57	-3.46
		5%	-2.86	-3.78
		2.5%	-3.13	-4.05
		1%	-3.43	-4.37

ARDL Error Correction Regression
Dependent Variable: D(GDP)
Selected Model: ARDL(1, 0, 0, 1)
Case 3: Unrestricted Constant and No Trend
Date: 07/16/24 Time: 21:11
Sample: 2000 2022
Included observations: 22

ECM Regression
Case 3: Unrestricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	25378.22	2053.707	12.35728	0.0000
D(IND)	1.468361	1.059834	1.385463	0.1849
CointEq(-1)*	0.157651	0.018922	8.331531	0.0000

R-squared	0.794415	Mean dependent var	8877.376
Adjusted R-squared	0.772774	S.D. dependent var	6300.468
S.E. of regression	3003.320	Akaike info criterion	18.97895
Sum squared resid	1.71E+08	Schwarz criterion	19.12773
Log likelihood	-205.7684	Hannan-Quinn criter.	19.01400
F-statistic	36.70956	Durbin-Watson stat	2.148902
Prob(F-statistic)	0.000000		

* p-value incompatible with t-Bounds distribution.

ARDL Error Correction Regression
Dependent Variable: D(GDP)
Selected Model: ARDL(2, 2, 1, 2, 0)
Case 3: Unrestricted Constant and No Trend
Date: 07/16/24 Time: 21:12
Sample: 2000 2022
Included observations: 21

ECM Regression
Case 3: Unrestricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.

C	85460.71	14125.41	6.050139	0.0002
D(GDP(-1))	-0.650089	0.307658	-2.113024	0.0638
D(UNI)	28.79138	14.46838	1.989952	0.0778
D(UNI(-1))	-21.03923	12.07392	-1.742535	0.1154
D(GOV)	9878.264	5619.013	1.758007	0.1126
D(IND)	2.806298	0.969193	2.895499	0.0177
D(IND(-1))	2.877710	1.319353	2.181152	0.0571
CointEq(-1)*	0.192214	0.032706	5.876945	0.0002

R-squared	0.892446	Mean dependent var	9244.311
Adjusted R-squared	0.834533	S.D. dependent var	6210.514
S.E. of regression	2526.291	Akaike info criterion	18.78922
Sum squared resid	82967924	Schwarz criterion	19.18714
Log likelihood	-189.2869	Hannan-Quinn criter.	18.87558
F-statistic	15.40999	Durbin-Watson stat	2.173185
Prob(F-statistic)	0.000023		

* p-value incompatible with t-Bounds distribution.