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Decoding the Financial Risk Puzzle: The Interplay of Biopsychosocial Indicators and Financial Literacy among Indian Investors

Shakira MUKHTAR,¹ Anisa JAN,² Adil ZAHoor,³
Danish MEHRAJ,⁴ Viqar U. NISSA⁵

^{1, 2, 3} Department of Management Studies, Islamic University of Science and Technology,
Awantipora, J&K, India

^{4, 5} Department of Management Studies, North Campus, University of Kashmir,
Baramulla, J&K, India

e-mails: ¹shakiramukhtar@yahoo. in; ²anisa. jan@islamicuniversity.edu.in;
³adylzahoor7@gmail.com; ⁴khandanish11@gmail.com; ⁵nissaviqar@gmail.com

Abstract. This study examined the influence of biopsychosocial indicators (personality type A\B, self-esteem, and sensation seeking) on the financial risk tolerance of individual investors, and the mediating effect of financial literacy. The present study used structured questionnaire to collect the data from 586 Indian retail investors and adopted the convenience sampling technique followed by snowball sampling. The results revealed that personality type, self-esteem, and sensation seeking play a significant and vital role in influencing financial risk tolerance. Financial literacy partially mediates the relationship between personality type, self-esteem, and risk tolerance. However, our analysis did not find any significant mediating effect of financial literacy in the relationship between sensation seeking and financial risk tolerance. These findings highlight the significance of psychology of an investor and thus provide a unique contribution to the financial risk tolerance literature.

Keywords: biopsychosocial indicators, sensation seeking, self-esteem, personality type A\B, financial risk tolerance

JEL Classification: G11, G41, O3

1. Introduction

Financial risk tolerance (FRT) pertains to investor's willingness to endure uncertain changes in their investment outcomes that differ from their expectations (Grable et al., 1999). FRT assumes a pivotal role in various contexts of financial decision making (Rai et al., 2021). For example, FRT affects individuals' routine debt-versus-savings decisions (Lawson et al., 2005), the mortgage choice (Grable, 1999), adoption and management of credit card (Campbell, 2006), long-term and short-term patterns of expenditure (Sung et al., 1996), purchasing of insurance (Shusha, 2017), and assets distribution (Nguyen et al., 2019). Furthermore, across the globe, financial advisors are mandated by financial regulatory bodies to conduct a client risk assessment before implementing any investment plans (Hari et al., 2018). Financial advisors in developed nations are obliged by law to undertake risk assessments of their clients (Wahl et al., 2020). Wealth managers in India have been urged by the regulatory bodies, such as the Securities Exchange Board of India (SEBI), to provide useful guidance to their clients by taking their risk aversion and financial goals into account. Therefore, wealth managers have a legal and ethical obligation to have an exhaustive and full awareness of their investor's FRT. However, risk and reward are considered one of the utmost important factors required for executing optimal portfolio selections, but the most significant and crucial factor is the knowledge of investors' risk tolerance level (Droms, 1987; Owusu et al., 2023). The development of investment strategies is dependent on a decision model with four essential inputs: objective, time horizon, financial stability, and an intricate FRT evaluation (Garman et al., 2011; Grable, 1999). Despite the simplicity and accessibility of the first three inputs for planners and managers, FRT is highly individualized and difficult to evaluate (Larkin et al., 2013). Because of this, a growing body of research has been conducted to better understand how an individual's tolerance for risking their current wealth in the hopes of growing it in the future may be utilized to create financial advising services that are specifically matched to their needs (Gibson et al., 2013).

Due to the multifaceted nature of FRT, it becomes challenging to measure it. It is inherently difficult to define and comprehend FRT, as it seems to be shaped by various predisposing factors, including demographic, environmental, and psychosocial factors (Sung et al., 1996). FRT has garnered significant attention from contemporary researchers due to its pivotal role in decision-making in the financial context (Rahman et al., 2019). Consequently, numerous studies have been conducted and documented in the existing literature, exploring various factors that influence FRT as well as its potential outcomes (Eker et al., 2010; Kannadhasan et al., 2016; Naqvi et al., 2020; Sachdeva et al., 2023). The existing body of literature indicates that demographic characteristics have been extensively studied as determinants of FRT (Choudhary et al., 2021; Larkin et al., 2013; Muktadir, 2020; Shah et al.,

2020; Shusha, 2017). Similarly, Mukhtar et al. (2023) explored the influence of dynamic personality traits on financial risk tolerance and discovered that financial self-efficacy, positive emotions, and resilience positively contribute to an investor's financial risk tolerance. However, it is important to acknowledge that there are various other factors that may also exert a substantial impact on determining an individual's FRT. These factors include an individual's personality, which falls under the realm of psychology, as well as their genetics, which is a biological aspect. After conducting a comprehensive literature review, it has been determined that there is a paucity of scholarly works that specifically address the role of diverse biopsychosocial factors in the assessment of FRT within the investor population. The biopsychosocial indicators (BPS) encompass a wide range of factors that have an impact on an individual's overall well-being and behaviour (Kannadhasan et al., 2016). These factors include demographic characteristics, social interactions, cultural influences, and an extensive range of personality traits as categorized by Irwin Jr (1993) in his infamous work *Adolescence and Risk Taking: How They Are Related*. After a thorough literature review, it has been deduced that the role of BPS indicators in FRT is underexplored. Therefore, the primary aim of this study is to examine the impact of BPS factors (personality type (PT), self-esteem (SE), sensation seeking (SS)), and investors' financial risk tolerance.

Financial literacy (FL) is an additional crucial factor that plays a substantial role in the investment decision making of the investor because it has the potential to link personality traits with FRT (Janor et al., 2016). Prior literature provides ample evidence to support the notion that FL involves the comprehension of financial terminology and mathematical proficiency (Awais et al., 2016). FL has been defined by Sharma (2020) as the capability to make sound financial decisions that take into account both immediate and long-term goals. The ramifications of lacking FL are substantial. Individuals who possess insufficient knowledge and understanding of financial matters are faced with challenges in adequately strategizing and preparing for their retirement (Bayar et al., 2020). As a result, they have less wealth as they approach retirement, which limits their ability to invest in stocks (Lusardi et al., 2020). Furthermore, these individuals are more likely to borrow at high interest rates (Awais et al., 2016). Therefore, the lack of adequate FL has a negative influence on investment decision-making, while a high level of FL has a substantial impact on the economic behaviour of an investor (Prasad et al., 2020). The possession of FL allows investors to anticipate and acknowledge adverse fluctuations, thereby suggesting that FL has the capacity to improve FRT (Anastasia et al., 2021). Prior literature has rigorously emphasized the importance of FL in determining an investor's FRT (Akhtar et al., 2023; Akims et al., 2023; Ansari et al., 2022; Cupák et al., 2022; Raut, 2020). However, the level of FL is also influenced by various individual and social factors. The current investigation focuses on how FL being the intervening

variable mediates the relationship between BPS indicators and the FRT of an individual investor. Nevertheless, the investigation of FL through mediation has not been adequately expounded upon in previous studies (Jain et al., 2022). Hence, the primary objective of this study is to examine the potential mediating role of financial literacy in the association between biopsychosocial factors and investors' financial risk tolerance. Although a number of studies (Grable et al., 2004; Kannadhasan et al., 2016; Kuzniak et al., 2017; Naqvi et al., 2020) have investigated the impact of BPS on FRT, they have not considered financial literacy as a mediating variable. To the researcher's understanding, the present study represents a novel attempt to analyse the association between BPS and FRT by considering FL as a potential mediator.

Based on the objectives, this study adopted mediation approach to thoroughly investigate the concept of BPS indicators, financial literacy, and FRT, which represents a novel attempt in this field by addressing literature and empirical gaps in prior literature. In the context of the emerging financial market, the current research will provide valuable insights into the behaviour of various stakeholders. In the context of behavioural finance, the present study introduces the mediating effects of financial literacy for the first time in understanding the established relationships between BPS and FRT within an emerging market economy such as India. The present study provides a significant contribution to the extant scholarly literature through an analysis of the various factors that influence individual investors' FRT. Therefore, individuals with the capability of evaluating and forecasting FRT can advance towards a theoretical framework that combines psychological and economic perspectives. This approach will enhance the comprehension of the attitudes and actions related to risk-taking exhibited by retail investors. The current research will provide valuable insights for financial advisors, policymakers, and researchers regarding the investors' levels of risk tolerance. This knowledge will enable them to make informed recommendations regarding suitable investment options for their clients.

The subsequent sections of the article are outlined as following: Section 2 presents a comprehensive overview of the theoretical framework that serves as the foundation for the study. The discussions within this section will aid in the formulation of hypotheses regarding the correlation between PT, SS, SE, and FRT with a particular emphasis on the potential mediating influence of FL. Section 3 outlines the research methodology utilized to collect data, describes how the constructs were measured, and elaborates on the analysis technique employed. In section 4, the research findings and results are presented. The author provides a thorough examination of the acquired findings in Section 5, emphasizing the importance of this research within the realm of behavioural finance, encompasses both theoretical and practical implications, elucidating the potential contributions of this research and the limitations of the study research.

2. Literature Review

2.1. The Role of Biopsychosocial Indicators in Investors' Financial Risk Tolerance

The understanding of personality traits is of paramount importance in comprehending the behavioural patterns of individuals when making decisions (Buccioli et al., 2017; Jain et al., 2022; Ozer et al., 2019; Rizvi et al., 2015). Personality traits are stable aspects of an individual's character that vary from one person to the next and can have a wide range of values (Thanki et al., 2020). Myers–Briggs Type Predictor (MBTI), Big Five Model, and Personality Type A and Type B are well-known personality trait models. According to the MBTI personality theory, individuals have inherent preferences that determine their behaviour in specific situations (Dhiman et al., 2018). Pak et al. (2015) suggested that investment advisors should take into account the personality type of investors for client profiling and for proposing appropriate investment alternatives. Barnewall (1987) suggests that advisers should familiarize themselves with the characteristics of their clients while recommending them investment alternatives. The primary objective of this study is to measure the impact of personality type on individuals' levels of FRT. The two personality types, A and B, exhibit contrasting characteristics, with the former displaying aggression, passion, and a constant sense of urgency, while the latter demonstrating a relaxed, contented, and unhurried demeanour (Carducci et al., 1998). Research findings indicate that individuals classified as type A exhibit a higher propensity for risk-taking compared to those classified as type B. Consequently, type A individuals exhibit higher levels of educational attainment, financial literacy, income, and occupational status (Parsaeemehr et al., 2013). There is a scarcity of research that has examined the correlation of personality type with financial risk tolerance by categorizing investors into type a and type b (Hallahan et al., 2004). Hence, the present study endeavours to address the existing gap in the literature by investigating the influence of PT on the FRT of individual investors.

Self-esteem is widely recognized as a fundamental multidimensional personality trait encompassing various dimensions such as skills, social competence, and self-perceived worth (Filosa et al., 2022). It is defined as an individual's perception and confidence in their own capability to possess the requisite skills and competencies needed to effectively achieve specific goals (Sekścińska et al., 2021). Furthermore, it illustrates an individual's perception of their self-worth (Yao et al., 2005). SE influences a person's portfolio allocation (Tang et al., 2016), wealth creation (Swarn Chatterjee et al., 2011), and trading behaviour (Kourtidis et al., 2017). Rosenberg (1965) argues that SE can be both positive and negative, i.e. constructive and destructive. Krueger Jr et al. (1994) found that individuals who had scored

higher on positive self-esteem tended to have more risk tolerance as compared to individuals who had scored high on negative self-esteem. Individuals with a positive self-esteem exhibit a sense of self-assurance, while those with a negative self-esteem tend to experience constant confusion and fear regarding potential outcomes (Naqvi et al., 2020). If, for example, investors experience a loss in their investments, those with high self-esteem react more positively than those with low self-esteem (Arkes et al., 1985). Also, individuals with a high self-esteem tend to refrain from experiencing regret upon encountering losses, as such outcomes are likely to diminish their self-esteem, which is regarded as a valuable attribute (Thanki et al., 2014; Yao et al., 2005). Upon analysing demographic variables, it has been observed that males with a positive self-esteem tend to participate in trading activities more frequently and excessively compared to females. Mansour et al. (2006) found that there existed a tendency of women to exhibit higher levels of pessimism compared to men, and they tended to employ strategies to counteract the decline in their self-esteem following investment failures. Grable et al. (1999) highlight that investors with a positive self-esteem tend to actively engage in the acquisition of financial knowledge and actively seek financial advice. The acquisition of financial education helps people to understand and manage their finances according to their preferences (Pinjisakikool, 2017).

Sensation seeking is an additional trait that has consistently demonstrated a relationship with FRT (Harlow et al., 1990; Rabbani et al., 2020). SS refers to an individual's propensity to seek out diverse, fresh, and intricate sensations and experiences, coupled with their readiness to undertake physical or social risks (Zuckerman, 1994). This behaviour can be explained by biological processes taking place in the brain (Anitei, 2014). The concept of SS behaviour is often characterized as a form of risk-taking behaviour (Zaleski, 1984). Carducci et al. (1998) in their study reported a significant and positive correlation between SS and the frequency of engagement in risky behaviours, commonly referred to as the financial risk tolerance. Further, the researchers discovered that engaging in financial risk-taking behaviour can elicit emotional responses (Brooks et al., 2022; Rubaltelli et al., 2015). These emotional experiences have been identified as key motivators for individuals with a propensity for seeking thrilling sensations (Heilman et al., 2010). Additionally, it was discovered that males exhibit a greater propensity for engaging in financial risk-taking activities in comparison to females (Lerner et al., 2015). Roberti (2004) concludes that this trait pertains to the behavioural manifestations commonly referred to as risky, including engagement in high-risk sports, gambling activities, substance consumption, alcohol consumption, and preferences for adventurous holiday activities. Therefore, individuals possessing such a characteristic demonstrate a tendency to engage in high-risk financial investments (Kannadhasan et al., 2016). The results of empirical studies have provided evidence that individuals who possess sensation seeking traits tend to

display a greater degree of risk tolerance when compared to individuals who do not possess such traits (Morse, 1998; Sjöberg et al., 2009). The examination of financial risk behaviour can be readily conducted within the framework of this characteristic (Gable et al., 2004; Naqvi et al., 2020). However, there is a paucity of research that has empirically examined the correlation between SS and FRT. The above-mentioned discussion results in the formulation of the following hypotheses:

H1: Biopsychosocial indicators are positively correlated with financial risk tolerance.

H1a: Personality type is positively correlated with financial risk tolerance.

H1b: Self-esteem is positively correlated with financial risk tolerance.

H1c: Sensation seeking is positively correlated with financial risk tolerance.

2.2. Financial Literacy as a Mediator Between Biopsychosocial Indicators and FRT

Financial literacy encompasses the ability to make well-informed judgments regarding the use and management of financial resources (Bongomin et al., 2017; Tamimi et al., 2009). FL refers to the knowledge individuals need to make significant financial decisions that align with their best interests (Ahmed et al., 2021; Awais et al., 2016). The foundation of FL lies in the development of anticipations pertaining to various factors, including investment and savings. These expectations are supported by various indicators from the biopsychosocial framework (Naqvi et al., 2020). The lack of financial literacy has resulted in individuals refraining from engaging in investment activities (Oppong et al., 2023). Lusardi et al. (2008) suggest that an increase in FL is positively correlated with an increased likelihood of individuals engaging in stock market participation. The present study aims to examine the mediating effect of FL on the relationship between BPS indicators and FRT. Individuals with different personality types exhibit distinct attitudes towards FL (Thanki et al., 2019). Individuals classified as type A exhibit characteristics such as competitiveness, diligence, and self-assurance, which consequently drive them to maintain a heightened awareness of various facets pertaining to the field of investment (Zsoter, 2017). Given that investors are required to navigate various economic factors, such as investment, saving, and interest rates, it is crucial for them to have a deeper comprehension of these concepts in order to enhance their performance (Naqvi et al., 2020).

Kahneman et al. (2013) found that individuals classified as type A tend to exhibit higher FL. In contrast, individuals classified as type B exhibit greater inclination towards relaxation and tranquilly, thereby displaying a diminished concern for acquiring knowledge pertaining to economic concepts (Kannadhasan et al., 2016). Consequently, their level of financial knowledge is comparatively lower. It can be extrapolated that a higher level of FL is related to greater risk-

taking propensity (Killins, 2017). Individuals with a propensity for sensation seeking consistently exhibit a proclivity for seeking novel and distinctive ways. Consequently, they tend to possess a greater depth of understanding regarding contemporary economic concepts, thereby resulting in an elevated level of risk tolerance (Hussain et al., 2023). Given their understanding of these concepts, individuals adjust their expectations accordingly, resulting in a positive correlation between FL and FRT (Sachdeva et al., 2023; Stanovich, 2016). Individuals with a high level of self-esteem possess a strong belief in their own capabilities, enabling them to easily grasp and apply various components of macroeconomics with minimal exertion (Kannadhasan et al., 2016). Consequently, they are able to effectively align their actions and behaviours in accordance with the principles and dynamics of the macroeconomic system. As a result of their self-assurance and elevated level of FL, individuals develop a capacity for resilience in the face of financial risks (Lusardi et al., 2020). There exists a notable relationship between financial education and monetary accumulations, as individuals who possess knowledge regarding the utilization of stock premiums on equity investments are better equipped to capitalize on such opportunities (Reddy et al., 2017). There is a positive relationship between FL and the planning of retired income behaviour, as indicated by Lusardi et al. (2008). Empirical research findings suggest that individuals who demonstrate a higher degree of confidence in their financial literacy are more inclined to actively participate in financial planning activities (Lontchi et al., 2022; Witteloostuijn et al., 2008). Based on the evidence presented, it is possible to draw the following hypotheses:

H2: Financial literacy significantly mediates the relationship between biopsychosocial indicators and financial risk tolerance.

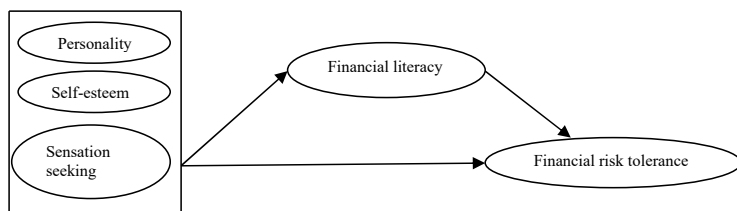
H2a: Financial literacy significantly mediates the relationship between personality type and financial risk tolerance.

H2b: Financial literacy significantly mediates the relationship between self-esteem and financial risk tolerance.

H2c: Financial literacy significantly mediates the relationship between sensation seeking and financial risk tolerance.

Research Model

The research model in this article has been developed by drawing upon existing literature, as depicted in *Figure 1*. The study investigated the proposed relationships through the utilization of covariance-based structured equation modelling (SEM).



Source: authors' compilation

Figure 1. *Proposed model*

3. Methodology

3.1. Sampling and Data Collection

The present research used a cross-sectional survey design to investigate the relationship between biopsychosocial factors and individuals' propensity to take financial risks. The primary data for this study were collected through a structured questionnaire. Convenience sampling followed by snowball sampling technique was utilized to collect the data from 690 individual investors, who have an accumulated trading experience ranging from 1 to 10 years. The snowball sampling method was also used by asking respondents to identify further respondents who possess the desired characteristics of the target population. Firstly, in the case of investors working in government organizations, a few departments were randomly selected for the collection of data – e.g. The Department of Health and Medical Education, The Department of Higher Education, etc. In the case of private organizations, we collected data from Policy Bazaar, Sher Khan Securities Limited, Bajaj Alliance, Jkb Financial Services Limited, Hdfc Bank, and Axis Bank. The investors' group present on a social media platform (Indian traders' and investors' club, Indian retail investors, mutual fund investors group of India, private investors' group) also served as a potential database for data collection. Similarly, purposive sampling was done in the case of businessmen and professionals.

Hair et al's (2010) criterion was used for determining the sample size of the study, which suggests that there should be 10 respondents for every single item. The Kaiser–Meyer–Olkin (2017) test was used to check for sample adequacy. The value of the test was 0.862, suggesting the sample adequacy for the study (Field, 2009). A pilot study of 185 investors and the discussion with financial experts was done before conducting the final survey. Out of the 690 responses, only 586 were considered valid for the statistical analysis because of the apparent inconsistencies or missing values in the different sections of the questionnaire. The study targeted various age groups, occupations, trading experiences, marital statuses, genders, and educational qualifications. Gender distribution revealed the dominance of male

respondents: 76% males and 24% females. Almost 398 investors were single, and the rest were married. The majority of the respondents had completed at least the bachelor's level education. The respondents had an average trading experience of 4 years and a mean age of 36, as represented in *Table 1*.

Table 1. *Respondents' demographic profile*

Characteristics	Frequency	Percentage
Age		
20–30	125	21.3
31–40	358	61.1
41–50	68	10.2
51 and above	35	5.9
Gender		
Male	398	67.9
Female	188	32.1
Marital status		
Married	215	36.7
Unmarried	371	63.3
Monthly income (Rs)		
Below 25,000	56	9.1
25,000–50,000	301	51.4
50,000–75,000	118	20.1
75,000–100,000	84	14.3
Above 100,000	27	4.6
Occupation		
Student	58	9.9
Government employee	205	34.9
Private employee	218	37.2
Educational background		
Up to higher secondary level	95	16.2
Graduate	316	53.9
Post-graduate	77	13.1
PhD or above	56	9.5
Professional	43	7.3

The respondents of the study were required to fill in the multiple sub-sections of demographics, financial literacy, biopsychosocial indicators, and financial risk tolerance. The study consisted of three independent variables, namely personality type, self-esteem, and sensation seeking, and one dependent variable, namely financial risk tolerance, with the mediating variable of financial literacy. In order to measure the self-esteem, which is a dependent variable, the authors used a 10-item scale developed by Rosenberg (1965). The 4-point scale ranged

from 1 (= strongly agree) to 4 (= strongly disagree), e.g. “I think I have a number of good qualities.”; “I feel I do not have much to be proud of.”; etc. High scores represented positive self-esteem, whereas low scores represented negative self-esteem. Personality type was measured with the help of a 6-item scale developed by Grable et al. (2004). The 4-point scale ranged from 1 (= not at all) to 4 (= very well). The scale contained items such as “usually feeling pressed for time”, “eating too quickly”, “upset when have to wait for anything”, etc. High scores represented personality type A, whereas low scores represented personality type B. A 5-item scale developed by Grable et al. (2004) was employed for measuring the sensation seeking indicator. Some of the items used in the scale are: “It is fun and exciting to perform or speak before a group.”; “I would like to travel to places that are strange and far away.”, etc. The 4-point scale ranged from “not at all” to “very well”. For measuring financial literacy, we adopted a 7-item scale developed by Cude et al. (2006). Some of the items included in the scale are: “I can prepare my own weekly (monthly) budget.”; “I can understand financial affairs and keep records.”; etc. Lower values on the scale indicated respondents possessing a low level of financial literacy, and higher values indicated individuals possessing a high level of financial literacy. For measuring the financial risk tolerance of an individual investor, a 5-item scale developed by Grable et al. (2004) has been employed. The scale collected the responses on a 5-point Likert scale ranging from “strongly disagree” to “strongly agree”, e.g. “When I think of the word ‘risk’, the term ‘loss’ comes to mind immediately.”; “I am more comfortable putting my money in a bank account than in the stock market.”; etc. The previous literature review highlights that financial literacy as a mediating variable is underexplored in the context of investment decision making. Therefore, this study makes an attempt to look into its mediating effect with respect to investors’ financial risk tolerance.

4. Data Analysis and Results

To examine the hypothesis of the research, the statistical software SPSS and the technique of structural equation modelling (SEM) were employed. Additionally, the software AMOS was used to assess the direct and indirect impact of the independent variables on the dependent variable. The decision to accept or reject a hypothesis is contingent upon the statistical significance of the obtained results. According to Nusair et al. (2010), in management research, the most appropriate and empirically supported method for examining the intricate behavioural cause-and-effect relationships is SEM. Hearman’s single-factor test was employed to ascertain the presence of common method bias in the study. The test yielded a total variance of 38.92%, which falls below the threshold value of 50%.

4.1. Measurement Model

The statistical methodologies proposed by Fornell et al. (1981) were employed to ascertain the validity and reliability of the constructs under investigation. The reliability analysis of the variables was done with the use of Composite Reliability (CR) and Cronbach's alpha. All the constructs of the model had a composite reliability and Cronbach's alpha above the cut-off value of 0.7 (F. Ali et al., 2018), as shown in *Table 2*. Therefore, all scales are reliable. Similarly, the convergent validity of the study variables was established using the master validity tool by Gaskin and Linn (2016). Average Variance Extracted (AVE) was used for checking the internal consistency and multicollinearity of the data. Similarly, all constructs had convergent validity above the threshold value of 0.5 (Fornell et al., 1981), as shown in *Table 2*. The Heterotrait-Monotrait (HTMT) ratio was used to check the discriminant validity. Henseler et al. (2015) suggested that all values should be lower than 0.9. Test results are shown in *Table 3*. Further, as part of the measurement model, factor loading for each indicator item was ascertained. As shown in *Table 2*, all values were greater than the 0.7 threshold value (Gefen et al., 2005). The overall goodness of fit of the models was measured using model fit indices (CMIN/df, CFI, TLI, RMSEA, and GFI). The hypothesised 5-factor CFA model fits the sample data extremely well, and all values were within their respective permissible ranges.

Table 2. *Measurement model*

Constructs	Items	Factor loading	Alpha	CRE	AVE
Personality type	AB1	.821	.927	.827	.602
	AB2	.728			
	AB3	.701			
	AB4	.812			
	AB5	.810			
	AB6	.948			
Self-esteem	SE1	.726	.911	.926	.638
	SE2	.903			
	SE3	.798			
	SE4	.840			
	SE5	.885			
	SE6	.913			
	SE7	.793			
	SE8	.729			
	SE9	.907			
	SE10	.858			

Constructs	Items	Factor loading	Alpha	CRE	AVE
Sensation seeking	SS1	.822	.869	.904	.758
	SS2	.843			
	SS3	.801			
	SS4	.724			
	SS5	.705			
Financial literacy	FL1	.839	.825	.903	.616
	FL2	.825			
	FL3	.714			
	FL4	.804			
	FL5	.759			
	FL6	.821			
	FL7	.707			
Financial risk tolerance	FRT1	.822	0.826	0.818	0.721
	FRT2	.764			
	FRT3	.860			
	FRT4	.879			
	FRT5	.756			

Table 3. *Discriminant validity (HTMT ratio)*

	PT	SE	SS	FL	FRT
Personality type (PT)					
Self-esteem (SE)	0.264				
Sensation seeking (SS)	0.328	0.269			
Financial literacy (FL)	0.390	0.412	0.218		
Financial risk tolerance (FRT)	0.250	0.398	0.307	0.424	

Table 4. *Model fit indices*

Fit Indices	RMSEA	GFI	SRMR	TLI	CFI	CMIN/df
Values	0.054	.923	.043	.910	.982	2.69

4.2. Structural Model

The hypothesis-testing procedure employed in this study involved an evaluation of the correlation and significance of the associations between the independent variables and the dependent variable. To accomplish this, structural equation modelling (SEM) was utilized, specifically the Amos software package. The findings presented in *Table 5* illustrate that the biopsychosocial indicators, namely personality type ($b = 0.327$, $p < 0.01$), self-esteem ($b = 0.283$, $p < 0.01$), and

sensation seeking ($b = 0.398$, $p < 0.01$), had a significant impact on individuals' financial risk tolerance prior to conducting the mediation analysis. The findings of the study indicate a statistically significant positive correlation between personality type and FRT, thereby supporting the acceptance of hypothesis H1a. The findings of this study also indicate a positive and statistically significant correlation between self-esteem and FRT, thereby providing support for the acceptance of hypothesis H1b. The positive and significant relationship between self-esteem and FRT leads to the acceptance of H1b. Similarly, it was found that sensation seeking had a positive and significant correlation with FRT, thereby resulting in the acceptance of H1c. The overall results lead to the acceptance of H1, which suggests that BPS indicators are positively correlated with the FRT of an individual investor.

Table 5. *Direct effect before mediation analysis*

Hypothesis	Parameters	Direct effect before mediation (b)	P-value
H1a	PT-->FRT	0.163	***
H1b	SE-->FRT	0.198	**
H1c	SS-->FRT	0.398	***

The next step is to evaluate the mediating role of financial literacy after analysing the direct correlations between the study variables. Consequently, the present study investigated the individual impact of BPS indicators under study on FRT. The findings revealed that, with the exception of sensation seeking ($b = 0.018$, $p > 0.05$), all other indicators, namely personality type ($b = 0.238$, $p < 0.01$) and self-esteem ($b = 0.159$, $p < 0.01$), exhibited statistically significant effects on financial literacy, as depicted in *Table 6*. In the same way, it is worth noting that financial literacy also significantly impacted investors' financial risk tolerance ($\beta = 0.196$, $p < 0.05$). Following an evaluation of the direct effect, the bootstrapping procedure was employed to examine the indirect effects of the mediation analysis. The process of bias-corrected bootstrapping was conducted in AMOS 22, involving 5,000 resamples and a confidence interval of 95%. This analysis aimed to investigate the indirect effects on FRT. The findings from the test, as presented in *Table 6*, suggest that financial literacy plays a mediating role in the relationship between personality type, self-esteem, and FRT. Therefore, hypotheses H2a and H2b were deemed valid and supported by the evidence. Nevertheless, the analysis did not reveal any mediation effects of financial literacy in relation to the association between sensation seeking and FRT, resulting in the rejection of hypothesis H2c.

Table 6. *Direct and indirect effect after mediation analysis*

Relationship	Direct effect	Indirect effect	Confidence interval		P-value	Conclusion
			LOWER BOUND	UPPER BOUND		
PT-->FL-->FRT (H2a)	0.378***	0.074	0.168	0.356	0.008**	Partial mediation
SE-->FL-->FRT (H2b)	0.298**	0.058	0.172	0.383	0.004***	Partial mediation
SS-->FL-->FRT (H2c)	0.301***	0.059	-0.008	0.027	0.68 ^{ns}	No mediation

4.3. Correlation Analysis

Table 7 shows matrices indicating the correlations between constructs, means, and standard deviations (SD). The findings indicate that a significant correlation exists between the majority of the constructs examined in the study. The analysis of the correlation matrix indicated that all correlation coefficients were below 0.9, providing evidence that there was no multicollinearity present among the studied constructs.

Table 7. *Inter-item correlation matrix*

	PT	SE	SS	FL	FRT	Mean	SD
PT	1					3.286	0.731
SE	0.46***	1				3.184	0.623
SS	-0.28***	-0.17*	1			3.028	0.821
FL	0.42**	0.32***	-0.28**	1		2.988	0.796
FRT	0.38***	0.48***	0.39***	0.43***	1	3.028	0.825

5. Discussions and Findings

The primary objective of this study was to examine the relationship between the biopsychosocial indicators, financial literacy, and financial risk tolerance among individual investors within the Indian context. In the developing market economy, the active participation of individual investors has an immense significance, especially given the presence of a highly heterogeneous retail investor base within the country. The analysis revealed that all BPS were positively and significantly associated with FRT before the introduction of the mediation test. Therefore, the findings of the present study align with the prior findings of Baumeister et al. (2003), Grable et al. (2004), Kannadhasan et al. (2016), and Naqvi et al. (2020). With respect to the first hypothesis of the study, the findings posit that personality type has a substantial influence on FRT and is supported by the data collected from retail investors in India. The obtained results are consistent with the findings reported

in prior research (Carducci et al., 1998; Hallahan et al., 2004; Kannadhasan et al., 2016; Naqvi et al., 2020; Wong et al., 2016). However, these findings contradict the findings reported by Grable. The findings of our study are further corroborated by the prospect theory, which explains how type A and type B personalities might perceive and approach risk differently. A possible explanation is that individuals exhibiting type A characteristics, such as competitiveness, ambition, and a sense of urgency, exhibit a higher propensity to participate in financial ventures that involve greater levels of risk (Thanki et al., 2019). Within the context of financial risk tolerance, individuals classified as type A exhibit behavioural tendencies that are congruent with a greater inclination to participate in risk-taking activities (Dinç Aydemir et al., 2017; Wong et al., 2016). Individuals' propensity for competition and aspiration for achievement renders them more prone to actively pursue investment prospects that offer higher returns (Harlow et al., 1990). Furthermore, individuals' lack of patience and heightened sense of urgency may result in a preference for obtaining immediate gains rather than long-term stable and secure investments (Houston et al., 1988). Conversely, individuals classified as type B exhibit a demeanour that is more inclined towards relaxation and a laid-back approach. Individuals of this group exhibit a tendency towards patience, a lower inclination towards competition, and a greater level of satisfaction with the existing state of affairs (Zuckerman et al., 2000). The propensity for individuals to exhibit a preference for lower-risk financial decisions can be ascribed to their prioritization of stability and a sense of security over potential gains (Thanki et al., 2014).

Further, the findings revealed that self-esteem significantly influences the FRT of individual investors. Our results are consistent with several prior findings (Chatterjee et al., 2009; Grable et al., 2004; Kannadhasan et al., 2016; Naqvi et al., 2020; Rosenberg, 1965; Zuckerman et al., 2000). The self-verification theory provides a robust framework for comprehending the association between self-esteem and financial risk tolerance. Individuals with a high level of self-esteem typically have a more favourable self-concept, leading to enhanced trust in their capabilities and decision-making (Josephs et al., 1992). This confidence can extend to their financial decisions, making them more at ease with taking financial risks. They are more likely to believe they can handle prospective losses and have confidence in their ability to make profitable investment decisions (Chatterjee et al., 2009). On the contrary, investors with a reduced level of self-esteem might display a greater aversion to risk. They may perceive themselves as less competent in financial matters and be fearful of making mistakes (Kannadhasan et al., 2016). Therefore, they may prefer secure, low-risk investments to avoid the possibility of failure and safeguard their fragile self-concept. The subsequent hypothesis of the study was "Sensation seeking is positively correlated with financial risk tolerance." The results of our study are supported by previous findings (Grable et al., 2004; Kuzniak et al., 2017; Rabbani et al., 2020; Roberti, 2004), and they suggest that

sensation seeking has a significant influence on the FRT of individual investors. The plausible explanation is that individuals having inclination towards sensation seeking exhibit a tendency to actively pursue and engage in activities that provide a heightened state of stimulation and exhilaration (Zuckerman, 1994). Within the realm of financial decision-making, individuals who exhibit sensation-seeking tendencies may demonstrate an ability to tolerate financial risk. Individuals are inclined to participate in activities that involve risk-taking as they seek potentially advantageous experiences. The willingness to engage in risk-taking activities can be observed in different domains of personal finance, including investment activities, entrepreneurial endeavours, and discretionary spending. Individuals who exhibit elevated levels of sensation-seeking tendencies frequently demonstrate a preference for investment opportunities that offer the possibility of substantial returns (Naqvi et al., 2020). For instance, individuals may exhibit a preference for investing in high-volatility stocks, speculative assets, or ventures within emerging markets. The allure of unpredictability and the potential for significant rewards act as compelling incentives for individuals with a propensity for seeking thrilling experiences (Rabbani et al., 2020).

Further, the results of this study revealed the significant influence of financial literacy on the personality type and self-esteem where no mediation was found with respect to sensation seeking. This is one of the pioneer studies where the mediating effect of FL was ascertained on the relationship between BPS and FRT. Individuals with higher self-esteem may display greater motivation and confidence in their abilities, which can extend to their willingness to acquire financial knowledge (Ali et al., 2021). The attainment of financial literacy empowers individuals to effectively evaluate risk and assess potential financial decisions with precision (Hassan Al-Tamimi et al., 2009). Those with higher financial literacy are more capable of understanding the trade-offs between risk and reward, as well as the consequences of their actions. The more financial knowledge people gain and the more they understand financial concepts, the more informed and rational decisions they will make about risks (Tang et al., 2016). This implies that investors possessing a higher level of FL are more inclined to adopt a cautious and deliberate approach when engaging in financial risk-taking activities (Ansari et al., 2022). Conversely, individuals possessing lower levels of FL may exhibit a greater susceptibility to emotional and cognitive biases, resulting in more impulsive and less meticulous decision-making regarding risks. Higher self-esteem leads to higher FL, which, in turn, contributes to a more informed and rational approach to financial risk (Sekścińska et al., 2021). When considering the mediating role of financial literacy, we find that the relationship between personality type and financial risk tolerance is partially explained by individuals' differing levels of financial knowledge (Kannadhasan et al., 2016). Personality type A indirectly influences FRT through financial literacy, leading to a more informed and rational

approach to financial risk. On the other hand, personality type B individuals may have lower financial literacy levels, potentially contributing to a more cautious and risk-averse financial decision-making process (Thanki et al., 2020). Therefore, the results of our study lead to the acceptance of the hypothesis that FL significantly mediates the relationship between personality type and FRT. H2c is rejected because our results reveal that financial literacy plays an insignificant role in the relationship between sensation seeking and FRT (Worthy et al., 2010). The study indicates that financial literacy does not significantly mediate the relationship between sensation seeking and financial risk tolerance. The findings suggest that individuals with higher levels of sensation seeking are more willing to take financial risks regardless of their financial knowledge and understanding. While financial literacy remains important for making informed financial decisions, it appears to have a limited impact on how sensation seekers approach and perceive financial risks (Naqvi et al., 2020).

The inaccurate assessment of the FRT can potentially result in opting for inappropriate investment alternatives. Consequently, this may lead to the dwindling of investors' financial resources and a reduced overall well-being. Financial service providers may face negative consequences when clients make poor investment decisions such as selling a profitable investment or investing in an inappropriate portfolio. The consequences of such actions include a negative impact on their credibility and reputation, leading to a decline in customer base, among other potential outcomes. This study is expected to yield a substantial scholarly contribution by expanding the scope of discussion and analysis in the fields of FRT and FL. The theory pertaining to financial decision making and FRT is expected to be reinforced. The present study's practical implications will be of value to retail investors, as they provide insights into the association between their personality traits, self-esteem, sensation seeking, and their financial literacy and financial risk tolerance. While formulating macroeconomic and investment policies, policymakers in India and other nations can also benefit significantly from the recommendations of the current study.

In addition to the noteworthy contributions made by this research, it is imperative for future researchers to take into account several limitations associated with this study. The present study examined only three biopsychosocial indicators, neglecting the inclusion of demographic and environmental factors. In order to enhance the scope of research, future researchers may also take into consideration these factors. Moreover, the present study was carried out within the specific context of India. Lastly, it is suggested that future researchers should be encouraged to conduct cross-national studies to create a multidimensional model to comprehend the impact of biopsychosocial indicators in the context of FRT and investment decision making.

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The Asymmetric Effect of Selected Agricultural Commodities and Oil Prices on Economic Growth in Nigeria

Umaru AMINU

Publications and Editorial Unit, Research Department, Central Bank of Nigeria, P.M.B. 0187 Abuja, Nigeria. aminu_umaru2007@yahoo.com; +2348082837043. <https://orcid.org/0000-0002-8805-2686>

Matthew Oladapo GIDIGBI

Department of Economics, Faculty of Social and Management Sciences, Modibbo Adama University, P.M.B. 2076, Yola 640001, Nigeria 234. gidigbimdres@gmail.com; +2348039222756; <https://orcid.org/0000-0002-5788-9598>
Department of Economics, Faculty Economics and Management Sciences, University of Ibadan, Nigeria

Bishara Saidu DOGO

Publication and Editorial Unit, Research Department, Central Bank of Nigeria, P.M.B. 0187 Abuja, Nigeria. dogobishara@gmail.com; +2347012536392; <https://orcid.org/0000-0002-6418-2830>

Abstract. This paper asymmetrically examined the effect of selected commodity prices on Nigeria's economic growth using the Non-linear Autoregressive Distributed Lagged (NARDL) model. Data extracted from the Central Bank of Nigeria's *Statistical Bulletin* covering the period from 2010:1 to 2021:1 were used. We found that the effect of the selected commodities' prices on economic growth is mixed, as some of the selected commodities are positively related to outputs, while some are not. Therefore, the investigation is still open due to the mixed results. This study recommends the sustained support and possible expansion of the agricultural commodities boosting the programme of the Central Government with the adequate monitoring and evaluation of such programmes. Also, the government should tackle the issue of oil importation by developing an adequate refining infrastructure through privatization or public-private partnerships to meet domestic oil demand.

Keywords: asymmetrically, commodities price, economic growth, NARDL

JEL Classification: F43, C24, Q11, Q31

1. Introduction

Economic growth, as measured by the gross domestic product (GDP), is a critical macroeconomic indicator used in capturing many economic indicators about a country such as standard of living and progress in national output, among other things. Modern financial derivatives have become vital in affecting future economic growth by providing global price information, commonly generated from commodity prices (Cheng and Xiong, 2014; Ge and Tang, 2020; Karali and Power, 2013). A commodity is usually an intermediate good. It is mainly consumed for different production processes. We could say it is raw materials for industrial production (Ge and Tang, 2020). Investigating the effect of commodities' prices on economic growth generally reveals a strong impact because of the duality of predicting power embedded in it due to the interaction of the goods and financial market's effect on the commodities market. This assertion is interpreted differently to imply that commodity prices comprise hard and soft data (Ge and Tang, 2020).

The established notion of a positive correlation between commodity prices and economic fluctuations has long been recognized, as commodity price trends typically align with economic cycles, as noted by Fama and French (1988) and Harvey et al. (2017), as cited in Ge and Tang (2020). Events in the crude oil market, coupled with economic realities during specific periods, underscore the significance of commodity prices in influencing economic dynamics. Instances such as the Arab oil embargo in 1970, the Iran–Iraq war in 1980, the Gulf War in 1990, the global financial crisis in 2008, the impact of COVID-19, and the OPEC/Russia price war in 2020, as highlighted by Adeosun et al. (2022), emphasize the non-negligible role of commodity prices in shaping economic outcomes.

In contrast, Borožan and Cipčić (2022) challenged the conventional wisdom put forth by Hamilton (1983), which posits a positive association between outputs and an increase in oil prices. They questioned this notion by asserting that several authors found the lack of a robust relationship between commodity prices and economic growth. Furthermore, Liu and Serletis (2022) corroborated these mixed findings. In their examination of commodity prices and output growth in the G7 and EM7, they obtained varying results, establishing a positive relationship in some economies but not universally across all economies.

Crude oil, constituting approximately 33 percent of the global primary energy and 94 percent of energy utilized in the transport system, holds a significant position among globally traded commodities (Van Eyden et al., 2019, as cited in Adeosun, Tabash, and Anagreh, 2022; Borožan and Cipčić, 2022). Elevated oil prices adversely impact production, leading to increased production costs and subsequently higher prices. The positive impact of a commodity price shock is acknowledged as favourable for exporting nations, while importing economies bear the immediate consequences of price hikes and heightened production costs.

This observation is a widely acknowledged reality in the context of commodity prices, particularly crude oil (Adeosun, Tabash, and Anagreh, 2022). However, the influence of commodity prices, specifically crude oil, on economic growth varies across different economies (Ahmadi and Manera, 2021; Nasir et al., 2019).

As a nation heavily reliant on exports, Nigeria experiences fluctuations in commodity prices. Recognized not only as an exporting country but also as an importing one, Nigeria often imports refined products for its energy needs and processed goods for its agricultural commodities. However, the impact of commodity price fluctuations presents both advantages and disadvantages for exporting and importing countries. In Nigeria's case, the benefits gained from subsidy reform during the decline in oil prices in 2020 were later eroded. The situation worsened for the population within a short period due to a significant positive change in the international oil market, which also affected agricultural commodity prices. Nigeria, maintaining its dual status as both an exporting and importing country, especially in energy commodities, coupled with the fact that existing studies on the effects of commodity prices on economic growth offer mixed findings, and the subject remains open for further exploration, motivates the investigation undertaken in this paper.

This paper employed Non-linear Autoregressive Distributed Lagged (NARDL) model in answering the concern raised therein (Shin, 2014) and in fitting forty-six quarterly time series observations into the model covering the following significant variables: Real Gross Domestic Products (RGDP), Oil Price (OLP), Price of Cocoa (COC), Price of Wheat (WHT), Price of Soybeans (SOY), and Price of Palm Oil (PAL). The explanatory variables are mainly agricultural and energy commodities, explaining the real gross domestic products. The model formation was sequenced to reflect long cycles related to macroeconomic fluctuations as in earlier studies (Aye and Odhiambo, 2021; Igan et al., 2022; Liu and Serletis, 2022; Umaru and Inusa, 2022).

The long-run symmetric ARDL estimation revealed that cocoa and soybean prices exert a positive impact on economic growth. Both the cocoa price (LCOC) and soybean price (LSOY) demonstrated an asymmetric effect on economic outputs, prompting a more comprehensive examination of their long-run effects through a non-linear estimation approach. Employing the non-linear autoregressive model (NARDL) revealed that a positive percentage change in cocoa prices would enhance national outputs by 9 percentage basis points, while an adverse change in the same commodity would decrease output by 14 percentage basis points. Similarly, a positive change in soybean prices would reduce outputs by 15 percentage basis points, whereas a negative change would increase outputs by 43 percentage basis points. Additionally, in short-run asymmetric estimation, a negative change in soybean prices negatively impacted the economy by 53 percentage basis points, and a positive change in palm oil prices equally detrimentally affected the economy by

49 percentage basis points. Conversely, a positive change in cocoa prices boosted economic outputs by 41 percentage basis points. The short-term behaviour of price changes in palm oil exhibited erratic patterns. This study reinforces the dynamic relationship between commodity prices and economic growth in Nigeria during the specified timeframe. It affirms the existence of mixed findings regarding the relationship between commodity prices and economic growth, with certain commodities demonstrating a positive relationship and others exhibiting a negative effect. These effects vary based on the timeframe, the specific commodity, and the economic structure of the economy concerned. Post-diagnostic tests were conducted to ensure the estimates were logical and suitable for policy implications.

The rest of this paper is divided further into four subcategories. First comes the review of the relevant literature, and then the methods are presented – this covers the approach through which the extracted data were analysed. Third are the estimations and results, and fourth are the conclusions and policy implications.

2. Review of the Relevant Literature

Several channels have been considered in explaining the link between commodity prices, especially crude oil prices' economic growth. The most explored are fiscal, exchange rate, wealth, and Dutch disease channels (Hamilton, 1983; Mork, 1989). A positive fluctuation in oil prices hurts disposable income and consumption, and a permanent increment in price hurts private investment (Adeosun, et al., 2022). The impact of commodity prices on growth is ascribed to the part that causes the price change. The causes could be a stronger global demand with attendant higher commodity prices, global under-supply mostly occasioned by the adverse weather effect and geopolitical tension invoking the exporting economies, and stockpiling for precautionary reasons may give credence to the cause (Igan et al., 2022). The first noted cause is effecting higher commodity prices and translating them into an effect on macroeconomic conditions. According to Igan et al. (2022), commodity prices, specifically oil and wheat, have been closely associated with the prices of consumption goods such as premium motor spirit and bread. Also, it turns into a higher cost of production and consequently into the monetary response due to persistent rises in price, thereby slowing economic growth.

Similarly, the cause warrants change in the production pattern and generates economic distortions due to response to its produced dynamics. The effect of the third cause is ambiguous, as the distribution of income increment due to higher prices determines the direction of the effect. Commodity price volatility is, however, an inevitable reality. The changes in commodity prices severely affect emerging countries compared to rich countries, thus inhibiting developing countries' economic growth. The price volatility of the commodity is witnessed in the export

revenues associated with natural resources (Jacks et al., 2011). Diversifying from an oil-dependent economy mode is highly encouraged, especially for achieving economic diversification, long-term sustainability, job creation, attracting foreign investment, and addressing environmental concerns (Mensi et al., 2018).

In the pool of exporting/importing commodities, crude oil stands out. It is considered a major commodity in processing all other commodities. Oil is considered pivotal in processing other commodities due to its usage in machinery and as a combustion lubricant for machinery and equipment, special consideration in literature and studies being ascribed to it (Aye and Odhiambo, 2021). There are more studies on the relationship between oil and economic outputs than on any other globally traded commodities featured. However, apart from the three earlier causes, crude oil is a microcosm of the first cause that triggers fluctuation within the fluctuation. Aye and Odhiambo (2021) revealed that there are threshold levels of oil prices at which agricultural growth will start bearing a negative effect of the oil price, though the finding was based on South African data. Empirical investigation from the East African countries affirmed the position of Aye and Odhiambo (2021) when the study posited that global oil prices mainly bore an effect on food prices through transport costs, which was against any other stated factor or cause (Baumeister and Kilian, 2014; Dillon and Barrett, 2016).

The energy and non-energy commodity price trends between 1960 and 2015 showed that both exhibited a similar pattern. Tying the trend became much more feasible in 1980 and was maintained throughout the years. The closeness of the trend started as a result of the price spike in energy commodities in 1973 and 1978, which was intense and long enough for the effect to be feasible. The general downward trend in non-energy commodity prices was equally notable from the mid-1960s until around 2000. In the same vein, a rise in the energy commodity prices again spiked the rise in the non-energy commodity prices and simultaneously fell as a response to the pre-crisis peak of the global economic/financial melt-down in 2008 (Foster-McGregor et al., 2018). Bello and Gidigbi (2022) gave credence to the former assertion when they asserted that low energy prices exhibit a second-round effect on another commodity, with added terms-of-trade changes for several commodity exporters. Two potential scenarios are contemplated regarding the presence of a long-run relationship between oil and non-oil commodities: i) the continued presence of oil rent-seeking strategies and ii) challenges diversifying a country's income (Mensi et al., 2018). Meanwhile, in most developing economies, the second possibility has usually prevailed, i.e. difficulty in maintaining sustainable diversification of the economy.

A different view of the ties between energy and non-energy commodity prices has been related to biodiesel and bioethanol. The validity is challenging because agricultural or non-direct energy commodities, such as corn, compete with crude oil in producing refined products such as diesel and ethanol, which could signal higher

prices (Baumeister and Kilian, 2014). The relationship of the energy commodity prices was related to the agricultural products used in energy generation such as corn and soybean (Zafeiriou et al., 2018). Consistent with the study of Zafeiriou et al. (2018), which established a linkage between energy prices and agricultural commodity prices, it implies that outputs slow down if there is a positive change in the energy commodity prices. However, this finding refutes the position of Dillon and Barrett (2016), which empirically revealed that the price effect is mainly a pass-through effect on transport costs. However, Balcilar et al. (2016) had earlier affirmed the relationship between the two and statistically confirmed that oil prices affected agricultural commodity prices; otherwise, it was a decision informed by the methodological approach, which may be misleading. The study employed a linear causality test, which revealed that oil prices did not influence agricultural commodity prices. The study classified the test result as misleading (Balcilar et al., 2016).

Economic outputs have undoubtedly a relationship with commodity prices. It is clear that higher commodity prices have slowed down economic growth. *BIS Bulletin* (54) reported that the price distortion in the form of higher commodity prices in 2022 would result in a decline of 0.7 basic points in the gross domestic products of the advanced economies by the end of 2023 (Igan et al., 2022). Income growth has been identified as a push factor for energy price changes. Oil consumption has increased due to the income increment among the population, especially in China, while income growth regarding agricultural commodities is considered to be mixed and limited (The World Bank, 2014). The strong and sustained economic growth witnessed between 2002 and 2012 is known to be the longest period of demand-driven commodity prices in the last four decades prior to the date concerned.

The rise in commodity prices, particularly evident in the People's Republic of China, is identified as a key factor contributing to the surge during the specified period (Cheng and Xiong, 2014; The World Bank, 2014). This development suggests a potential causality between commodity prices and economic growth. Ge and Tang (2020) delved into the relationship between commodity prices and GDP growth across 27 countries with commonly traded commodity futures indices. Their study categorized commodities into energy, metals, livestock, and agriculture, exploring their effects on consumption growth, government expenditure growth, investment growth, and net export growth. Agricultural commodities yielded a positive coefficient for investment growth and net export growth, while energy showed a negative coefficient for net export growth only. These findings support Nasir et al's (2019) assertion on the varied impact of commodity prices on different economies. Liu and Serletis (2022) investigated commodity price dynamics in G7 and EM7 economies, revealing symmetric weak tail dependence in some countries such as France, Germany, and Japan. Borožan and Cipcic (2022) explored the asymmetric and non-linear impact of oil prices on economic growth in Croatia, finding direct short-run effects.

In Malaysia, Wong and Shamsudin (2017) used a non-linear auto-regressive distributed lag (NARDL) model to examine the impact of crude oil prices, exchange rates, and real GDP on food price fluctuations. They identified a long-run relationship with food prices, where only crude oil prices exhibited a symmetric long-run effect, while real GDP and exchange rates showed asymmetric long- and short-run effects. Gruss (2014) suggested that the commodity price cycle could imply both output growth and lower growth for exporting economies in Latin America and the Caribbean. Cantavella (2020) and Charfeddine and Barkat (2020) conducted studies on oil-exporting economies, highlighting varied responses to oil price shocks and emphasizing the importance of considering specific economic contexts. Charfeddine and Barkat (2020) found short-term asymmetric effects of oil prices on real GDP and economic diversification in an oil-dependent economy, with positive shocks having a more lasting impact on economic activity than negative shocks.

Ahmadi and Manera (2021) studied the impact of oil price shocks on economic growth in developed oil-exporting countries, revealing that the effect depends on the underlying cause of the shocks. Akinsola and Odhiambo (2020) explored the asymmetric effect of oil prices on economic growth in seven low-income oil-importing sub-Saharan African countries, finding a significant negative impact in the long run. Another study in Saudi Arabia by Lianos, Pseiridis, and Tsounis (2023) employed the asymmetric non-linear autoregressive distributed lag (NARDL) model, confirming a long-term relationship between oil and non-oil GDP and suggesting a continued influence of oil rent-seeking strategies on non-oil GDP.

The development was much more pronounced in the People's Republic of China and was the main reason assumed for the surge in commodity prices within the studied period (Cheng and Xiong, 2014; The World Bank, 2014). A posteriori, this is indicative of a possible causality between commodity prices and economic growth.

Ge and Tang (2020) conducted a research on the relationship between commodity prices and GDP growth in nations with 27 widely traded commodity futures indices. They categorized commodities into energy, metals, livestock, and agriculture, examining the impact of each category on consumption growth, government expenditure growth, investment growth, and net export growth. Agricultural commodities produced a positive coefficient for investment growth and net export growth only, whereas energy commodities yielded a negative coefficient for net export growth only. These findings align with Nasir et al's (2019) argument regarding the varying effects of commodity prices across economies. Another investigation into the interplay between commodity prices and economic growth in the G7 and EM7 economies, using a semi-parametric GARCH-in-Mean copula approach, uncovered that certain economies, including France, Germany, and Japan, displayed a symmetric weak tail dependence between commodity prices and outputs (Liu and Serletis, 2022). In Croatia, a study covering the period from 1995:Q1 to 2019:Q4

indicated a positive correlation between commodity prices, especially oil, and economic growth, employing asymmetric and non-linear methodologies. The results supported the notion of asymmetric, non-linear, and direct short-run effects of oil price shocks on real GDP growth (Borożan and Cipicic, 2022).

Moreover, an investigation into the fluctuations in Malaysia's food prices, considering crude oil prices, exchange rates, and real GDP, implemented a non-linear auto-regressive distributed lag (NARDL) model. This study affirms the existence of a long-run relationship with food prices, with only crude oil prices demonstrating a symmetric long-run effect. Conversely, real GDP and exchange rates exhibit asymmetric long- and short-run effects (Wong and Shamsudin, 2017). The research underscores the importance of focusing on exchange rates rather than on crude oil prices in shaping food price policies within the economy. Additionally, a study conducted by Gruss (2014) suggests that the commodity price cycle may signal future output growth for Latin America and the Caribbean but lower growth for the exporting economies in the region. This outcome is contingent on whether the interaction between commodity prices is energy- or non-energy-oriented, leading to a mixed impact on economic growth based on the economic status of the concerned economies.

Building on the outcome of mixed findings, it is evident that oil-exporting economies have shared responses regarding oil price shocks, but the specific impact and resilience vary from one economy to another (Cantavella, 2020; Charfeddine and Barkat, 2020). Charfeddine and Barkat (2020) further explain this relationship by employing the ABSVARX and NARDL models to evaluate the short- and long-term asymmetric effects of oil prices and oil and gas revenue on real GDP and economic diversification in an oil-dependent economy. The study found that both total and non-oil real GDP exhibit more significant responses to negative shocks on oil prices and oil and gas revenues than to positive shocks, indicating an asymmetric impact in the short run. The impact of these shocks, however, is not persistent in the long run. Over the long term, positive oil price shocks and changes in oil and gas revenue exert a more significant influence on economic activity than negative changes, underscoring the resilience of the Qatari economy to adverse shocks.

Ahmadi and Manera (2021) investigated the impact of oil price shocks on economic growth in developed oil-exporting nations, using the threshold structural VAR approach and organizing data into different regimes. They found that the influence of oil price shocks is highly contingent on the root cause of the shocks. Additionally, the study revealed a limited evidence of an asymmetric effect on economic growth. In another study on the asymmetric effect of oil prices on economic growth in seven low-income oil-importing sub-Saharan African countries, employing panel-ARDL and NARDL, it was observed that a positive increase in oil prices significantly hampers economic growth. While the short-term significance of oil price changes on

economic growth could not be established, the asymmetric effect was observed to be delayed and confined to the long run (Akinsola and Odhiambo, 2020). Additionally, an investigation into the relationship between oil and non-oil GDP in Saudi Arabia, using the asymmetric non-linear autoregressive distributed lag (NARDL), validates the existence of a long-term relationship. This suggests that Saudi Arabia's non-oil GDP continues to be influenced by oil rent-seeking strategies despite efforts to diversify the economy and reduce reliance on oil. The study proposes a re-evaluation of the subsidy strategy by the government and the allocation of funds to industrial sectors that are more efficient and less dependent on oil.

Furthermore, the government should also consider developing sectors, such as tourism, that are not associated with oil (Mensi et al., 2018). In other words, public investment should be reoriented towards non-oil productive industrial sectors. Similarly, a study on the interaction between oil prices and economic growth in the G7 group, OPEC countries, and including Russia, China, and India revealed that the interaction between changes in oil prices and economic growth could not be established for all the economies considered except for the G7 group, where a unidirectional relation is running from the changes in the oil price towards gross domestic products (Ghalayini, 2011).

In Nigeria, Tumala et al. (2022) studied the commodity and economic growth nexus, but oil was the particular commodity studied. Crude oil prices concerning economic growth were examined using an ADL-MIDAS approach on aggregate and sectoral disaggregated data. Their findings align with conventional commodity prices and economic growth price fluctuation expectations. They recommend adjusting recurrent expenditure in managing the economy during the negative crude oil price fluctuation because of the government involvement in the economy, which is estimated to be at an 80/20 ratio – recurrent to capital expenditure. Also, the study on energy consumption and economic growth in Nigeria with data coverage from 1981 to 2018, using the ARDL approach, described both short- and long-run relationships between the two, among other variables in the study's model. However, the relationship was noted to be statistically insignificant in the short run but significant in the long run. The study concludes that energy consumption dynamically contributed to the output in Nigeria during the period under investigation (Dada, 2018).

3. Methods

This paper used quarterly data to carry out the estimation reported in this study. The data involved forty-six (46) time series observations covering 2010Q1 to 2021Q1. The data were taken from the Central Bank of Nigeria's publication (*Statistical Bulletin*). The sourced data are Real Gross Domestic Products (RGDP),

Oil Price (OLP), Price of Cocoa (COC), Price of Wheat (WHT), Price of Soybeans (SOY), and Price of Palm Oil (PAL). RGDP was used to capture economic growth. The price for oil and all other variables are the selected agricultural products as captured in the model of interest to this study.

RGDP was measured in a million naira and as nominal GDP expressed in terms of prices of goods and services. The price of Wheat (WHT), Price of Soybeans (SOY), and Price of Palm Oil (PAL) were measured in US\$/Metric ton, the Price of Cocoa (COC) was measured in US\$/Ton, while Oil Price (OLP) was measured in US\$/barrel of crude oil exports.

Several studies asserted that commodity prices exhibit long cycles and are often related to macroeconomic fluctuations (Aye and Odhiambo, 2021; Igan et al., 2022; Liu and Serletis, 2022). Likewise, oil price relates to macroeconomic fluctuations with attendant effects such as commodity prices. The influence of oil price fluctuation was not limited to the macroeconomics of the energy-exporting country but equally affected the monetary channel (Ahmadi and Manera, 2021). Oil is the most globally traded commodity, with its prices exerting an attendant effect on the global economies (Aye and Odhiambo, 2021). It is clear from the extant studies – some cited herein too – that commodities' prices are related to economic growth.

3.1. Model Specification and Theoretical Expectations of the Parameters

The Non-linear Autoregressive Distributed Lagged (NARDL) model – as informed by the data of interest to the study – was adopted. The model decomposes explanatory variables into positive and negative partial sums for short- and long-run nonlinearities, while asymmetric dynamic multipliers are derived (Shin et al., 2014). NARDL helps circumvent the inherent inadequacies that reside in inferences from either extreme sides (short- or long-run), as the approach is a transverse between the two.

$$\begin{aligned}
 \Delta \log RGDP_t = & \gamma_0 + \gamma_1 \log RGDP_{t-1} + \gamma_2 \log OLP_{t-1P_{t-1}} + \gamma_3 \log OLP_{t-1N_{t-1}} + \\
 & \gamma_4 \log COC_{t-1P_{t-1}} + \gamma_5 \log COC_{t-1N_{t-1}} + \gamma_6 \log WHT_{t-1P_{t-1}} + \gamma_7 \log WHT_{t-1N_{t-1}} + \gamma_8 \log SOY_{t-1P_{t-1}} + \\
 & \gamma_9 \log SOY_{t-1N_{t-1}} + \gamma_{10} \log PAL_{t-1P_{t-1}} + \gamma_{11} \log PAL_{t-1N_{t-1}} + \sum_{k=1}^n \gamma_{12} \Delta \log RGDP_{t-1} + \sum_{k=1}^n \gamma_{13} \Delta \\
 & \log OLP_{P_{t-1}} + \sum_{k=1}^n \gamma_{14} \Delta \log OLP_{N_{t-1}} + \sum_{k=1}^n \gamma_{15} \Delta \log COC_{P_{t-1}} + \sum_{k=1}^n \gamma_{16} \Delta \\
 & \log COC_{N_{t-1}} + \sum_{k=1}^n \gamma_{17} \Delta \log WHT_{P_{t-1}} + \sum_{k=1}^n \gamma_{18} \Delta \log WHT_{N_{t-1}} + \sum_{k=1}^n \gamma_{19} \Delta \\
 & \log SOY_{P_{t-1}} + \sum_{k=1}^n \gamma_{20} \Delta \log SOY_{N_{t-1}} + \sum_{k=1}^n \gamma_{21} \Delta \log PAL_{P_{t-1}} + \\
 & \sum_{k=1}^n \gamma_{22} \log PAL_{N_{t-1}} + \tau ECM(-1) + \varepsilon_{t1},
 \end{aligned} \tag{3.1}$$

where RGDP is real GDP, OLP is the oil price, COC is the cocoa price, WHT is the wheat price, SOY is the soybean price, and PAL is the palm oil price. Subscript p is positive changes, while N is negative changes. Further, the prefix log indicates the natural logarithm of the variable having it. As associated with variables in the specified model, subscripts p (positive) and n (negative) indicate the decomposition of explanatory variables into positive and negative partial sums in both the short- and long-run respectively. This decomposition has a time dimension as well. The partial sums of the regressor variables' decomposition for the specified model are specified as follows:

$$\{OLP_t^{+,-}\} = \begin{bmatrix} \sum_{j=1}^t \Delta OLP_j^P \\ \sum_{j=1}^t \Delta OLP_j^N \end{bmatrix} = \begin{bmatrix} \sum_{j=1}^t \max(\Delta OLP_j, 0) \\ \sum_{j=1}^t \min(\Delta OLP_j, 0) \end{bmatrix} \quad (3.2)$$

A priori, $\gamma_0, \gamma_2, \gamma_4, \gamma_6, \gamma_8, \gamma_{10}, \gamma_{13}, \gamma_{15}, \gamma_{17}, \gamma_{19}, \gamma_{21}$ are expected to exhibit a positive relationship with the regressand in the specified model (eq. (3.1)), while the following parameters are expected to exhibit a negative relationship with the dependent variables: $\gamma_3, \gamma_5, \gamma_7, \gamma_9, \gamma_{11}, \gamma_{14}, \gamma_{16}, \gamma_{18}, \gamma_{20}, \gamma_{22}$.

3.2. Testing for Stationarity

Stationarity testing is an evitable test for time series regressions, as the property is needed to ensure guidance against inefficient estimates, sub-optimal forecasts, and invalid significance tests (Diop and Traoré, 2022). The ideal approach to the stationarity test is to include constant and trend. This general approach is considered in testing the stationarity of the variables captured in the specified model. The general approach model for testing for unit-root is captured thus:

$$\Delta y_t = \beta_0 + \beta_1 t + \rho y_{t-1} + \sum_{i=1}^{\rho} \alpha_i \Delta y_{t-i} + u_t; u_t \sim i.i.d(0, \sigma_u^2) \quad (3.3)$$

From equation (3.3), if the null hypothesis $\rho = 0$ is rejected by performing a Dickey and Fuller test, y_t is a stationary process, and it is possible to test the linear trend by performing standard tests. In an instance of non-stationarity of the process, the significance of the trend and the subsequent constant are checked before changing the test integration order. This process is repeated until the stationarity of the variables of interest is achieved, building on and adjusting the standard test as specified in equation (3.3), where y is the variable of interest subjected to a test, followed by intercept, trend, and ρ (stationarity coefficient) being tested.

The Phillip–Perron (PP) unit root test approach estimates the non-augmented DF test equation (3.3) and modifies the t-ratio to avoid disturbance of asymptotic distribution of the statistic due to serial correlation. The PP test, therefore, is based on the following statistic:

$$\tilde{t}_\alpha = t_\alpha \left(\frac{\gamma_0}{f_0} \right)^{1/2} - \frac{T(f_0 - \gamma_0)(se(\hat{\alpha}))}{2f_0^{1/2}}, \quad (3.4)$$

where $\hat{\alpha}$, t_α , and $se(\hat{\alpha})$ denote the estimate, standard error, and the t-ratio of α of the test regression respectively. Further, γ_0 is a consistent estimate of the error variance in (3.3), which is calculated as $\frac{(T-k)s^2}{T}$, where k is the number of regressors. f_0 is an estimator of the residual spectrum at frequency zero.

4. Estimations and Results

Table 1 shows the average values for the model series. The statistics showed that the average value for the regressand was far higher than the average values of any other model series. Also, considering the Jarque–Bera statistics and its probability value, it becomes clear that the normality in the model series distribution only holds for RGDP, OLP, and COC. Given the disparity in average values and concerns about normality, it is sufficient to apply natural logarithms on the model series to control for the huge disparity in the average values of the series and the normality distribution of the series, despite the observation size, which satisfies the Central Limit Theorem assumption of normal distribution of series due to the observation size.

Table 1. *Descriptive statistics*

	RGDP	OLP	COC	WHT	SOY	PAL
Mean	16353331	77.26	127.82	106.90	121.08	94.02
Maximum	19550148	120.79	197.39	192.37	264.63	206.06
Minimum	12583478	27.49	75.29	58.00	74.91	54.09
Std. Dev.	1722762	27.68	33.96	26.96	37.72	30.49
Jarque–Bera	0.77	3.56	1.93	7.59	43.77	49.71
Probability	0.68	0.16	0.38	0.02	0.00	0.00
Observations	45	45	45	45	45	45

Source: authors' computation using EViews 11

The correlation analysis reported in *Table 2* showed that all the model series have a fair correlation coefficient with the dependent variable, which is ideal in guiding against multicollinearity. The correlation coefficients concerning the RGDP are

not that high to pose a possible multicollinearity problem. However, the oil price produced negative coefficients with all the pair-correlation coefficient results. It more or less exhibits an inverse relationship with all other model series. Also, the degree of association between SOY (the price of soybean) and PAL (the price of palm oil) is high. However, the variable was not dropped from the model series because it has a relatively fair association with all other series. No excessive degree of association is found with any other variables when considering PAL (palm oil price).

Table 2. *Correlation analysis*

Variables	RGDP	OLP	COC	WHT	SOY
OLP	-0.51	1			
COC	0.61	-0.78	1		
WHT	0.33	-0.00	0.41	1	
SOY	0.44	-0.32	0.69	0.85	1
PAL	0.29	-0.29	0.65	0.77	0.94

Source: authors' computation using EViews 11

Table 3. *Stationarity test outputs*

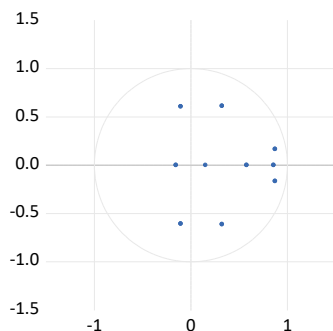
Variables	Phillip–Perron (PP)			Augmented Dicky–Fuller (ADF)		
	t-stats		Order of integration	t-stats		Order of integration
	At levels	At first diff.		At level	At first diff.	
	[Prob. value]			[Prob. value]		
LRGDP	-5.21 [0.00]		I(0)	-1.20 [0.89]	-1.91 ¹ [0.05]	I(1)
LOLP	-2.29 [0.43]	-6.32 [0.00]	I(1)	-2.29 [0.43]	-6.31 [0.00]	I(1)
LCOC	-2.56 [0.29]	-7.56 [0.00]	I(1)	-2.65 [0.25]	-5.62 [0.00]	I(1)
LSOY	-1.35 [0.86]	-4.09 [0.01]	I(1)	-2.00 [0.58]	-4.35 [0.00]	I(1)
LWHT	-1.99 [0.58]	-4.97 [0.00]	I(1)	-1.52 [0.80]	-4.94 [0.00]	I(1)
LPAL	-1.29 [0.87]	-4.36 [0.00]	I(1)	-1.79 [0.69]	-4.40 [0.00]	I(1)

Table 3 shows the results of the stationarity test based on the Phillip–Perron (PP) and the Augmented Dicky–Fuller (ADF) approaches. As stated earlier, the test followed a standard procedure to achieve the series' order of integration. Under the PP, all the series were of induced stationarity at first difference except for the dependent variable (LRGDP), which was stationary at level. Also, the ADF test

1 The estimate here is without constant and trend.

revealed that all the variables are stationary at first difference. However, the trend and constant component of the standard test were dropped for the dependent variable (LRGDP) to achieve its integration at the first difference. Furthermore, the graph in *Figure 1* shows that VAR satisfies the stationarity condition, as no root is located outside the circle. In a nutshell, the model series is stationary.

Inverse Roots of AR Characteristic Polynomial



Source: authors' computation using EViews 11

Figure 1. Graphical stationarity check

Model Lag Selections

All the variables in the specified model were included in the test for lag selection, with 43 observations selected. Six statistics presented in *Table 4* were used in the selection of optimal lag for the model of this study. Five of these six tests indicated between lag 2 and 1. LR, FPE, and AIC suggested two lag orders, while SC and HQ favoured one lag order (see *Table 4*). Based on these test results, lag two is considered the upper band of the lag selection, and lag one is considered the lower band lag selection for the model estimations in this paper.

Table 4. Lag selection

Lag	LogL	LR	FPE	AIC	SC	HQ
0	89.86	NA	1.33e-08	-3.94	-3.74	-3.87
1	227.69	237.19	7.05e-11	-9.19	-7.96*	-8.74*
2	255.44	41.311*	6.51e-11*	-9.32*	-7.07	-8.49

Source: authors' computation using EViews 11

Note: * Indicates lag order selected by the criterion.

The estimation results presented in *Table 5* encompassed 43 observations, with a lag selection of 2 for the dependent variable, the natural log of RGDP, representing economic growth, and a lag of 1 for WHT (the price of wheat). All other variables were included in the model at the level. The R-square value indicated

that the explanatory variables accounted for 72 percent of the total variation in the dependent variable. Adjusting for the explanatory variable would result in a reduction of the R-square to approximately 66 percent. Additionally, the F-statistics, assessing the joint significance of the model series, demonstrated that the variables collectively incorporated in the model are statistically significant. Furthermore, the Durbin–Watson statistic, with a value of 1.95, implies the absence of autocorrelation in the model. Consequently, both economic and statistical insights can be derived from the estimation.

Table 5. *ARDL estimation output for economic growth and the selected commodities*

Regressand	LRGDP			
Variables	Coefficient	Abs [Coeff./ LRGDP(-1)]	Std. error	Prob. value
LRGDP(-1)	0.27**		0.13	0.04
LRGDP(-2)	-0.45***		0.13	0.00
LOLP	-0.04	0.16	0.04	0.34
LCOC	0.21***	0.77	0.06	0.00
LWHT	-0.21*	0.76	0.11	0.08
LWHT(-1)	0.19**	0.70	0.09	0.05
LSOY	0.35***	1.28	0.11	0.00
LPAL	-0.32***	1.18	0.08	0.00
C	18.55***	66.68	2.56	0.00
R²	72.24%		F-stat.	11.06***
Adj. R²	65.70%		DW-stat.	1.95

Source: authors' computation using EViews 11

Notes: ***, **, and * imply statistical significance at 1, 5, and 10 per cent respectively.

The long-run symmetric ARDL estimation indicates that all variables in the model are statistically significant, except for the oil price (LOLP), which bears a negative sign. Among the statistically relevant variables, both lag one and lag two of the dependent variables are significant, but the coefficients are less than one percentage point, with the lag two coefficients being negative. The cocoa price (LCOC) is statistically significant at a 1 per cent significance level and exhibits a positive sign. This variable aligns with theoretical expectations, where a percentage increase in cocoa price leads to a 77 basis point percentage (0.77 per cent) rise in economic outputs. The current year's wheat price shows a significant negative association with outputs, while the price of the previous period demonstrates a positive relationship. Additionally, the soybean price is positively linked to outputs, whereas the palm oil price has a negative association. Among all the regressors, the soybean price has the most substantial impact, showing a 1.28 per

cent increase with a percentage increment in soybean price. It is followed by the palm oil price with a 1.18 per cent impact, albeit negatively signed.

The results from the model series estimation, as obtained in this paper, aligned with the position of Nasir et al. (2019), who asserted that commodities' prices have a differential effect across economies. Also, within an economy, the selected commodities behave differently; this aligns with the findings of Ge and Tang (2020).

Table 6 reported the F-bounds test for the level relationships among the model series. The F-bounds estimation returned the F-statistic of 9.17, which is outside the bounds of the asymptotic level relation at 1 per cent for a finite sample at both 45 and 40 observations. Since the F-statistic of 9.17 is greater than the returned statistic at 1 per cent, it implies the rejection of the null hypothesis of no level relationship in the series for both the asymptotic and the finite sample observations. Since the hypothesis is already rejected at level, there is no need to consider the statistics for the relationship at the first difference again.

Table 6. *F-bounds test for levels relationship*

Test statistic	Value	Sig.	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
For estimation in Table 5			Asymptotic n = 1000		Finite sample n = 45		Finite sample n = 40	
F-statistic	9.17	10%	2.08	3	2.27	3.29	2.30	3.35
K	5	5%	2.39	3.38	2.69	3.82	2.73	3.92
		2.5%	2.7	3.73	--	--	--	--
		1%	3.06	4.15	3.67	5.01	3.65	5.25

Source: authors' computation using EViews 11

Table 7 shows a short-run symmetry ARDL estimation with the error correction coefficient. The short-run coefficient for wheat price exhibited a negative relationship with the output of 34 basis points. The ECM coefficient indicated correction of price diversion within a quarter, though the coefficient is explosive but statistically significant at a 1 per cent significance level.

The estimation results for both the long- and short-run asymmetric non-linear introgressive distributed lags are reported in Table 8. The estimation followed a stepwise regression model with a forward selection method and a p-value forward/backward (0.05/0.5) stopping criterion. The model estimation included 42 observations after adjustment, with 32 search regressors and 12 constantly included regressors. The R-squared of the model estimation showed that the explanatory variables account for 89 per cent variation in the explained variable. Possible series adjustments still account for the explained variable at 84 per cent. The F-statistic of 15.37 and the statistical significance at 1 per cent imply the joint relevance of the model series. Also, the Durbin–Watson statistic indicated a possible absence of autocorrelation in the model estimation.

Table 7. Short-run ARDL ECM estimation for economic growth and commodities

Regressand	D(LRGDP)			
Variables	Coefficient	Abs[Coeff./ LRGDP (-1)]	Std. Error	Prob. value
D(LRGDP (-1))	0.45***		0.11	0.00
D(LWHT)	-0.21***	0.34	0.07	0.00
CointEq (-1) *	-1.17***	0.004	0.13	0.00
R²	65.51%			
Adj. R²	63.79%		DW-stat.	1.95

Source: authors' computation using EViews 11

Notes: ***, **, and * imply statistical significance at 1, 5, and 10 per cent respectively. * p-value is incompatible with t-bounds distribution.

In the model series long-run estimation, the first lagged for the explained variable [LRGDP(-1)], negative decomposition of sums of oil price (LOLP_N), both partial decomposition of cocoa prices and soybean prices (LCOC_P, LCOC_N, LSOY_P, and LSOY_N), as well as the constant are the only statistically significant coefficients from the model series estimation. However, the partial decomposition of positive changes in the oil price and negative changes in palm oil price revealed a positive relationship with productivity but was not statistically significant. Meanwhile, the partial decompositions of wheat prices and positive changes in the palm oil price exhibited a negative relationship with the outputs, though not statistically significant. Factually, some of these variables did exhibit erratic behaviour due to the prevailing economic structure in the country.

Concerning the statistically significant variables, the modified coefficients, which are then returned coefficients divided by the coefficient of the first lag of the independent variable, revealed that a negative percentage change in the crude oil price would hurt the economy by 4 percentage basis points. This finding is contrary to the findings of Borozaan and Cipicic (2022), Cantavella (2020), Liu and Serletis (2022), Tumala et al. (2022), and Wong and Shamsudin (2017) in being asymmetric but in tandem with Charfeddine and Barkat (2020) in the sense that there is a stronger response to negative shocks on oil prices. A positive percentage change in the price of cocoa will boost the national output by 9 percentage basis points, and a negative change in the same commodity will reduce the output by 14 percentage basis points. A positive change in the price will reduce outputs by 15 percentage basis points, and a negative change will increase the outputs by 43 percentage basis points. This finding is in line with Dada (2018), Gruss (2014), and Tumala et al. (2022). The statistically significant variables discussed here followed a theoretical expectation except for the soybean price, which works reversely. Furthermore, in the short-run asymmetric estimation, a negative change in the soybean price hurts the economy by 53 per cent basis

points, and a positive change in the palm oil price equally hurts the economy by 49 per cent basis points.

In comparison, the positive change in the cocoa price boosts economic outputs by 41 percentage basis points. The performance of the price changes in palm oil behaves erratically in the short run, while the other two tally with the general expectation. This behavioural pattern could be attributed to the domestic consumption of the product and its relevance for industrial inputs. There is an interesting dynamic to the partial changes in the prices of these commodities, especially in cocoa and palm oil. We used the term interesting dynamics because a positive change in the prices of the two commodities hurt economic outputs and vice versa. This indicates that the domestic economy thrives on these commodities, and the positive change in price hurts consumption within the economy to the point that it can affect outputs. In contrast, the negative price change has the potential to adjust and expand outputs in the long run.

Table 8. *Asymmetric (NARDL) estimation output for economic growth and commodities*

Regressand variables	D(LRGDP) Coefficient	[Coeff./ LRGDP (-1)]	Std. error	Prob. value
LRGDP(-1)	-1.99***		0.14	0.00
LOLP_P(-1)	0.03	-0.02	0.08	0.67
LOLP_N(-1)	0.08**	-0.04	0.03	0.03
LCOC_P(-1)	-0.18**	0.09	0.09	0.05
LCOC_N(-1)	0.28***	-0.14	0.10	0.00
LWHT_P(-1)	-0.00	0.00	0.08	0.99
LWHT_N(-1)	-0.16	0.08	0.11	0.17
LSOY_P(-1)	0.30**	-0.15	0.13	0.03
LSOY_N(-1)	-0.86***	0.43	0.18	0.00
LPAL_P(-1)	-0.03	0.02	0.13	0.79
LPAL_N(-1)	0.31	-0.16	0.19	0.11
C	32.76***		2.44	0.00
DLRGDP(-1)	0.75***		0.10	0.00
DLSOY_N	-0.40**	-0.53	0.16	0.02
DLPAL_P(-2)	-0.37***	-0.49	0.12	0.00
DLCOC_P(-2)	0.30**	0.41	0.13	0.03
R ²	89.86%		F-stat.	15.37***
Adj. R ²	84.01%		DW-stat.	2.72

Source: authors' computation using EViews 11

Notes: ***, **, and * indicate statistical significance at 1, 5, and 10 per cent respectively. P-values and subsequent tests do not account for stepwise selection.

In terms of the price dynamics of soybeans, its behaviour reflects the level of domestic consumption, as the coefficients associated with the variable align with theoretical expectations. The coherence of the variable coefficients suggests that there is a lower level of domestic consumption regarding the commodity, and its industrial utilization is not extensive. Soybeans are predominantly an export-oriented commodity, so a positive price change contributes to improved economic outputs.

Table 9 reported the block examination of the long-run relationship among the model series. F-statistic and chi-square test statistics concurred with a long-run relationship among the model series for the long run. Likewise, for the short-run model series estimation, both F-statistic and chi-square test statistics affirmed the relationship among the model series. Both long- and short-run statistics supported the appropriateness of the pooling together of the model series, and the test statistics are both statistically significant at a 1 per cent significance level.

Table 9. *Wald test for long- and short-run asymmetry (NARDL) estimation*

	Long-run			
	F-stat		Chi-square	
Value	17.54***	Significant	157.89***	Significant
Df	(9, 26)		9	
	Short-run			
	F-stat		Chi-square	
Value	24.33***	Significant	72.99***	Significant
Df	(3, 26)		3	

Source: authors' computation using EViews 11

Notes: ***, **, and * indicate statistical significance at 1, 5, and 10 per cent respectively.

Results of the asymmetric long-run Wald test are reported in Table 10. The long asymmetry of each regressor in the model is tested with t-statistic, F-statistic, and chi-square. The three tests listed agreed with one another on each of the series tested. The test statistics, which is statistically significant at a 1 per cent significance level for both the cocoa price (LCOC) and the soybean price (LSOY), indicates that both series have an asymmetric effect on the economic outputs and that the long-run effects of both series are better examined using the non-linear estimation approach. Meanwhile, a linear approach would be sufficient in examining the effect of all other series in the model apart from cocoa and soybean prices. The development here backed up the finding of Ahmadi and Manera (2021), who asserted that there is little evidence of asymmetry between the crude oil price and economic outputs. However, contrary to the findings of Akinsola and Odhiambo (2020), Liu and Serletis (2022), and Wong and Shamsudin (2017), crude oil prices could not exhibit a non-linear relationship with the economic outputs.

Table 10. *Wald test for long-run asymmetry*

Variables	LOLP	LCOC	LWHT	LSOY	LPAL
t-stat [Prob.]	-0.50 [0.62]	-3.19*** [0.00]	0.99 [0.32]	5.13*** [0.00]	-1.24 [0.22]
F-stat. [Prob.]	0.25 [0.62]	10.21*** [0.00]	0.99 [0.32]	26.32*** [0.00]	1.55 [0.22]
Chi-square [Prob.]	0.25 [0.61]	10.21*** [0.00]	0.99 [0.31]	26.32*** [0.00]	1.55 [0.21]

Source: authors' computation using EViews 11

Notes: ***, **, and * indicate statistical significance at 1, 5, and 10 per cent respectively.

Post-Estimation Diagnostic Tests

Diagnostic tests after the model estimation, as reported in *Table 11*, indicated the absence of serial correlation in the estimation residual. However, only the F-statistic with a probability value of 0.06 accepted the null hypothesis of no serial correlation up to 2 lags. Similarly, the presence of heteroskedasticity in the series residual was rejected, as the three different test statistics, F-statistic, Obs*R-squared, and Scaled explained SS, accepted the null hypothesis of no heteroskedasticity in the residual in the series. Also, the normality test revealed in *Figure 2* confirmed the normal distribution of the estimation residual, reinforced by the Jarque–Bera statistic of 0.99 and the probability value of 0.60. The three subcategories of the post-estimation diagnostic tests discussed showed that the estimation coefficients are reliable and appropriate for policy inference.

Table 11. *Serial correlation and heteroskedasticity tests*

Breusch–Godfrey Serial Correlation LM Test	H ₀ :	No serial correlation at up to 2 lags		
F-statistic	3.00	Prob. F(2,24)	0.06	Accept the H ₀
Obs*R-squared	14.38	Prob. chi-square (2)	0.01	Reject the H ₀
Heteroskedasticity test	H ₀ :	There is no presence of heteroskedasticity in the residual.		
F-statistic	0.90	Prob. F(15,26)	0.57	Accept the H ₀
Obs*R-squared	14.38	Prob. chi-square (15)	0.49	Accept the Ho
Scaled explained SS	3.68	Prob. chi-square (15)	0.99	Accept the Ho

Source: authors' computation using EViews 11

Normality Test

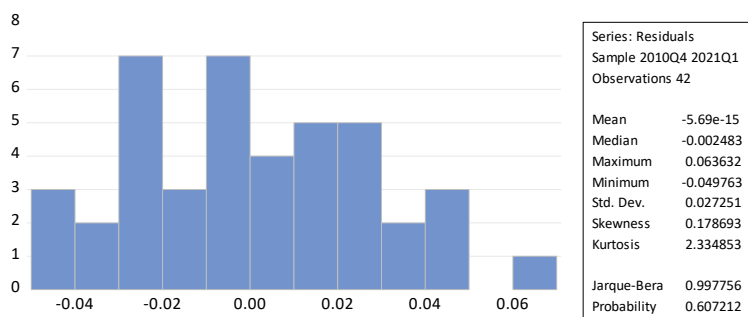


Figure 2. Normality test for residual distribution

Stability Tests

The charts in *Figure 3* are graphical stability test results associated with CUSUM and CUSUM square tests. The results in the two figures show stable recursive residuals because the residual line lies within the 5 per cent critical lines, indicating that the parameters in both models are stable. Also, the error variance is stable, as the linear line stays within the critical lines at a 5 per cent level, which equally indicates stable parameters. Thus, both models are reliable and feasible for a policy decision.

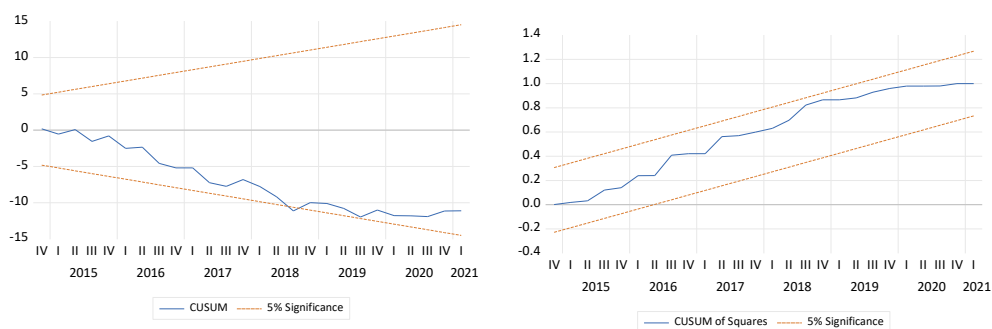


Figure 3. CUSUM and CUSUM Square charts for Model 1

5. Conclusion and Policy Implications

This paper asymmetrically examined the effect of selected commodities on Nigeria's economic growth. It used the Non-linear Autoregressive Distributed Lagged (NARDL) model. The estimation followed Shin et al. (2014) by decomposing the variables into positive and negative, which helps in circumventing the inherent inadequacies that reside in inferences from either extreme sides (short- or long-run), as the approach

is a transition between the two. The study used data extracted from the Central Bank of Nigeria's *Statistical Bulletin*, covering the period from 2010:1 to 2021:1. We found that the effect of the selected commodities' prices on the economic outputs is mixed, as some of the selected commodities were positively related to output, while some were not. Hence, the further investigation is necessary owing to the inconclusive findings. We found cocoa and soybean prices positively related to the outputs in the long-run symmetric estimation. Cocoa and soybean prices were found to be asymmetrically related to the output, but soybeans exerted a negative effect on the outputs with positive price changes and vice versa. Policy concerning the mass production of soybeans should be promoted and encouraged. Continued FGN support to farmers is favoured, just as a possible expansion to incorporate all areas through which dividends of these agricultural commodities could be fully harnessed. Also, crude oil prices, both negative and positive changes, were negatively related to economic output. The findings suggest a complex scenario in the sector, wherein the country is both exporting and importing concurrently. This complexity has affected the benefits associated with the adverse price change, emphasizing the necessity for a significant shift in deciding whether to function solely as an exporting or importing country rather than maintaining both simultaneously. Establishing a clear national position, whether the country functions as an exporting or importing economy, will aid in assessing the long-term impact of crude oil prices on the Nigerian economy.

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Exploring the Dynamic Interplay among Foreign Aid, Energy Usage, Economic Growth, and Carbon Emissions in Nigeria

Esther Olayinka ATOYEBI*

Department of Economics, Olabisi Onabanjo University Ago Iwoye, Nigeria
atoyebi.olayinka@oouagoiwoye.edu.ng

Jimoh Sina OGEDE

Department of Economics, Olabisi Onabanjo University, Ago Iwoye, Nigeria
sinaogede@oouagoiwoye.edu.ng

Soliu Bidemi ADEGBOYEGA

Department of Economics, Olabisi Onabanjo University, Ago Iwoye, Nigeria
adegboyega.soliu@oouagoiwoye.edu.ng

Ibrahim Abidemi ODUSANYA

Department of Economics, Olabisi Onabanjo University, Ago Iwoye, Nigeria
ibrahim.odusanya@oouagoiwoye.edu.ng

Abstract. In recent decades, Nigeria has emerged as a rapidly growing economy, while at the same time it faces pressing environmental concerns, particularly regarding rising carbon emissions. Although factors like foreign aid and energy usage contribute to economic prosperity, they just as well lead to increases in carbon emissions, causing concern about environmental degradation. This study investigates the complex links between foreign aid, energy usage, economic growth, and carbon emissions in Nigeria from 1990 to 2021. The autoregressive distributed lag analysis revealed mixed findings about how different economic elements relate to carbon emissions. While foreign aid, gross domestic product (GDP), and trade openness correlated positively but insignificantly, energy usage had an insignificant negative association with carbon emissions. Notably, financial development and remittances showed statistically significant inverse relationships with carbon emissions in the long run, and the speed of adjustment proved to be negative and significant in the short run. This research recommends policymakers to cut carbon dioxide while also acknowledging that the underlying dynamics are complicated.

Keywords: CO₂ emissions, energy consumption, economic growth, foreign aid, ARDL, Nigeria

JEL Classification: O13 Q43 Q54 O55

1. Introduction

Public awareness of the growing threat posed by climate change has increased (Ogede and Tiamiyu, 2023), and greenhouse gas emissions, notably carbon dioxide (CO₂) emissions, have been acknowledged as a key contributing factor. Literature has established that carbon dioxide (CO₂) emissions have a negative influence on human and sustainable growth (see Acheampong, 2021). However, despite the efforts of international institutions to control CO₂ emissions and safeguard the environment, emissions are still rising (International Energy Agency, 2018). Nigeria faces the dual task of fostering economic growth while also reducing emissions to lessen the effects of climate change. It is a developing country with a growing population and expanding economy. On the one side, Nigeria boasts a wealth of fossil fuel resources that have driven economic growth, including the ninth greatest proven crude oil reserves in the world (British Petroleum, 2020). However, just 40% of the population in Nigeria has access to power, and the country is also extremely vulnerable to the effects of climate change and environmental degradation (Abiodun, Lawal, Salami et al., 2013; World Bank, 2020).

Recent literature has examined various macroeconomic determinants of CO₂ emissions, with a focus on the impacts of energy usage, economic growth, remittances, trade openness, financial inclusion, income inequality, and institutional quality, among others (see Anwar et al., 2021; Chen and Taylor, 2020; Charfeddine and Kahia, 2019; Ertugrul et al., 2016; Jamil et al., 2022; Liu et al., 2022; Mirza et al., 2022; Ogede and Tiamiyu, 2023; Ogede, Oduola, and Tiamiyu, 2023; Sun et al., 2019; Wang, Yang, Lim, and Wang, 2023). For instance, Ogede et al. (2023) examined whether income inequality increases CO₂ emissions in sub-Saharan African countries from 2000 to 2018. Cross-sectional Autoregressive Distributed Lag (CS-ARDL) results showed that income inequality has a positive short- and long-run impact on emissions, indicating that pollution rises as the wealth gap widens. The square of income inequality negatively impacts emissions, though the magnitude varies by time frame. Interacting inequality with financial inclusion showed a continued positive effect on emissions in the short and long run. However, institutional quality was found to have a considerable negative effect when interacted, suggesting it significantly impacts the inequality-emissions nexus. Besides, using time series analyses and Fourier-Augmented Dickey–Fuller (FADF), Fourier Likelihood Maximum (FLM), and Fourier ARDL, Liu et al. (2022) reported that energy efficiency significantly reduces emissions in the long and the short term. The authors recommend policies to increase energy efficiency through investment, technology, and differential import tariffs. Also, Wang et al. (2023) argue that the impact of Foreign Direct Investment (FDI) on carbon emissions shifts from positive to negative at different income levels, with the turning point at a GDP per capita of \$541.87. They verified this using group regression robustness tests.

Pinar (2023), however, used dynamic panel generalized method of moments (GMM) to conclude that green aid fragmentation reduces effectiveness, mitigated by strong institutions. As a result, the research currently available provides contradictory data about what causes emissions in wealthy and other emerging nations.

Even though international aid has the potential to be a significant external source of development financing many developing nations like Nigeria, the role of foreign aid flows has received little attention. Few research, such as those by Kilama (2016), Bakirtas and Akpolat (2018), Kretschmer et al. (2013), and Alshubiri and Elheddad (2020), examined the relationship between foreign aid and CO₂ emissions; their findings were inconsistent among nations. Some theories suggest that aid, especially in education and health programmes, can enhance productivity, increase purchasing power, and subsequently lead to higher energy usage and CO₂ emissions. Investments in health and education facilitated by aid could potentially raise public awareness and reduce fossil fuel utilization (Hahn and Metcalfe, 2016). Although empirical research on this subject, especially country-specific studies, is scarce, conducting comprehensive case studies in diverse countries could provide deeper insights into the link between the variables (Yang et al., 2020; Zafar et al., 2022). The foregoing suggests that foreign aid might either secure carbon-intensive routes by subsidizing fossil fuel infrastructure or promote “green” growth through clean energy investments and climate finance. It is essential for sustainable development policy to quantify these effects. In 2021, Nigeria received \$3.36 billion in Official Development Assistance (ODA) for the Nigeria Energy Support Programme (NESP), a renewable energy project co-financed by the European Union and the German administration. The project aimed to improve investments in renewable energy and increase electricity access for marginalized rural communities, contributing to clean energy production and overall development in Nigeria. However, despite such aid, Nigeria still heavily relies on fossil fuels, which account for 74% of its total primary energy supply.

Therefore, examining the interactions between foreign aid, energy use, economic growth, and CO₂ emissions is essential while employing the necessary methodology in order to provide accurate conclusions. In order to better understand how foreign aid, energy use, economic growth, and CO₂ emissions interact dynamically in Nigeria, this study will examine this relationship. The driving force is the need to better understand how foreign aid affects emission trends while taking other important factors like energy use and economic growth into consideration. By employing recent time series data and strong econometric techniques, the study adds new evidence to the empirical literature about the relationships between aid, emissions, and growth for the largest economy in Africa. Specifically, the objectives are threefold: (i) to examine the impact of foreign aid on CO₂ emissions; (ii) to analyse the role of energy usage in driving emissions; (iii) to assess the growth–emissions relationship in Nigeria. Annual time series data over 1990–2021 are

utilized and analysed using advanced time series techniques such as the ARDL bounds testing approach. The results will provide valuable information about how well foreign aid works to change Nigeria's emission trajectory in the face of obstacles to expanding energy availability and economic growth. The study intends to educate decision-makers on how to create the best plans for utilizing foreign aid for sustainable development. Understanding the factors influencing CO₂ trends can help Nigeria meet its climate action pledges under the Paris Agreement given the country's increased global emission contribution. The following is a summary of the study's subsequent sections: The current literature is summarized in Section 2, the materials and techniques are described in Section 3, the results are presented and analysed in Section 4, and the conclusions are stated in Section 5.

2. Literature Review

The academic literature encompasses a growing body of research that examines the relationship between microeconomic variables and carbon emissions. This research explores various topics that transcend national borders. To start with, Yang et al. (2020) examined the effect of the inflow of remittances, energy consumption, and globalization on carbon dioxide (CO₂) radiation, exploring a dataset consisting of 97 nations worldwide between 1990 and 2016. The utilization of system GMM yielded the finding that transfers and energy consumption suggest a favourable link with CO₂ discharges, while globalization demonstrates a negative link with CO₂ emissions. The research splits the universal trial to two distinct subsamples: the first subsample consists of advanced republics, while the second subsample comprises evolving countries. However, the outcomes show similarity in both subsets. Neog and Yadava (2020) examine the link between CO₂ emissions and remittances in India and the asymmetrical correlation among inflow of remittances, financial expansion, and carbon discharges from 1980 to 2014 while employing a Non-linear Autoregressive Distributed Lag (NARDL) model. Their outcomes indicate that an optimistic exogenous influence on remittances is linked with a subsequent upsurge in carbon dioxide (CO₂) discharges. Conversely, a negative exogenous impact on remittances is linked to a decline in CO₂ discharges. The coefficient of financial development exhibits a positive direction, yet it loses its statistical significance.

Using data on China, Jafri et al. (2022) analyse the asymmetrical influence of remittances and FDI on CO₂ emissions by exploring the NARDL method. The time frame for this investigation spans from 1981 to 2019. According to the empirical findings of the NARDL model, a diminution in remittances is associated with the short-term and long-term positive impacts on CO₂ emissions. Findings suggest that alterations in FDI, whether positive or negative, have a favourable influence on CO₂ emissions. Furthermore, it was detected that an optimistic change in

FDI has a relatively better long-term impact on CO₂ emissions compared to an adverse change in FDI. The phenomenon of asymmetry is evident solely in terms of magnitude, rather than direction. In Nepal, Kishor and Bhattarai (2019) examined the link between economic progress, remittances, foreign aid, and CO₂ emissions. The empirical results indicate that an upsurge in remittances and foreign aid is correlated with a reduction in CO₂ emissions. Conversely, financial development and higher income levels are found to be correlated with an upsurge in CO₂ discharges. The aforementioned findings underscore the significance of market mechanisms in effectively modifiable financial development and promoting higher revenue levels as a means to control CO₂ emissions, all the while ensuring that competitiveness is not compromised.

In another development, Mahalik et al. (2021) investigated the comparative efficacy of foreign energy aid inflows and total foreign aid with carbon emissions in India from 1978 to 2014. It incorporates remittance inflows, FDI, economic progress, globalization, and energy usage as added features within a CO₂ production function. The research investigated the usage of the ARDL bounds estimation to assess the occurrence of a statistically significant long-term association link between the variables under consideration. It is noteworthy that there exists an observed link between energy usage, globalization, and foreign aid inflows with a notable reduction in CO₂ discharges. Conversely, inflows of remittances, foreign energy aid inflows, FDI, and economic progress are found to have an inducing impact on CO₂ emissions. From the standpoint of climate mitigation policy, in an alternative progression, Saliba et al. (2022) evaluated the impacts of sources of renewable energy and remittances on carbon emissions, considering the influence of technological advancements, globalization, and economic development with data spanning from 1990 to 2019. The research applied bounds testing methodology to study the link between CO₂ and the regressors, revealing significant long-term associations. The study also applied frequency-domain causality, which examines causality across several frequencies. Moreover, the findings from the ARDL model specify that there exists a helpful link between CO₂ production and economic growth in the long and short term. Conversely, the variables of green energy, remittances, and globalization exhibit an adverse association with CO₂ emissions, suggesting that they have a mitigating influence on ecological pollution. In conclusion, the utilization of the frequency domain causality approach unveiled that various features, such as renewable energy, economic advancement, globalization, remittances, and technological innovation, possess the ability to forecast long-term CO₂ emissions. The robustness of these findings was determined using the Difference-in-DOLS and FMOLS regression methods.

Further, Farooq (2022) used Estimated Generalized Least Squares (EGLS), Two Stage Least Squares (2SLS), System Generalized Methods of Moments (SGMM), and Fully Modified Ordinary Least Squares (FMOLS) models to explore how

governance affects FDI, foreign aid, and CO₂ emissions in Asia. The study found that FDI increases emissions through industrialization, while foreign aid and governance reduce emissions by promoting cleaner technology and regulating industry. However, foreign aid was found to undermine governance and its emission-reducing impact. The author recommends governance measures to curb FDI-related emissions. Liu et al. (2022) examined the impact of the efficiency of US energy on CO₂ emissions alongside trade, growth, and population. Using time series analyses, Fourier-ADF, Fourier-LM, and Fourier ARDL, they found that energy efficiency significantly reduces emissions in the long and short term. The authors recommend policies to increase energy efficiency through investment, technology, and differential import tariffs. Also, recent studies have examined the relationship between FDI, foreign aid, and CO₂ emissions using various econometric techniques. For instance, Wang, Yang, Li, and Wang (2023) used panel threshold estimation for 67 countries to find that the impact of FDI on carbon emissions shifts from positive to negative at different income levels, with the turning point at a GDP per capita of \$541.87. They verified this using group regression robustness tests. Pinar (2023), however, used dynamic panel GMM methodology for 92 countries and found mixed results regarding the emission-reducing impact of green aid. The study found that green aid fragmentation reduces effectiveness, mitigated by strong institutions.

In Nigeria, for example, Cosmas et al. (2019) performed an econometric analysis to explore the macroeconomic factors that stimulate carbon dioxide (CO₂) releases in Nigeria from 1981 to 2016 and adopted both the ARDL and the NARDL techniques. The results derived from the analysis of the environment–economy nexus challenge the credibility of the Environmental Kuznets Curve (EKC) and reveal the existence of an N-shaped affiliation in Nigeria. The analysis reveals that there exists a strong interrelation between changes in CO₂ emissions and GDP per capita – specifically the impact of changes in GDP per capita on CO₂ production is substantial. Additionally, there are signs of a bi-directional causal relationship between energy consumption and GDP per capita, with energy usage, in turn, leading to an upsurge in CO₂ emissions. Akinlo (2022) employed NARDL to analyse data spanning the period of 1980–2018 to ascertain the effects of fluctuations in remittances on environmental deterioration in Nigeria. The findings show that the variables exhibit a sustained and interdependent relationship over an extended period. Research findings indicate that there exists an asymmetric relationship between remittances and ecological footprint (EFP), which serves as a metric for assessing environmental degradation. This asymmetry is observed both over the extended period and in short-term contexts. However, when considering CO₂ emissions as a measure of environmental deterioration, the asymmetric connection with remittances is only evident in the long-term perspective. The study additionally discovered that the influx of remittances has a contributory

effect on environmental degradation in Nigeria over an extended period. Ekesiobi et al. (2022), however, utilized the autoregressive distributed lag procedure to argue that FDI has a causal impact on carbon discharges. Furthermore, there is a reciprocal relationship between international trade and carbon emissions, where both variables exert influence on each other. The empirical results obtained from the ARDL procedures depict that both FDI and international trade have a significant adverse impact on carbon emissions in the short term. In the long term, international trade and FDI have a beneficial impact on Nigeria's carbon footprint, thereby reinforcing its status as a long-term polluter haven.

The foregoing review of the extant literature suggests that remittance inflows and higher GDP per capita tend to increase emissions, while FDI, trade openness, and financial development can have mixed effects depending on the country context. Causality appears to run in both directions between emissions and economic growth indicators like GDP per capita. Hence, more research is needed on the specific mechanisms linking microeconomic factors to emissions beyond broad correlations, through channels like energy mix, technology, and composition of economic activity. Studies incorporating such granular analyses would provide sharper policy implications beyond general emissions–growth relationships.

3. Methodology and Sources of Data

3.1. Data

This study aims to investigate the impact of aid received, economic progress, and energy usage on CO₂ emissions while considering the influence of financial development, trade openness, and remittances. The research utilizes annual time series data from the period of 1990–2021 in Nigeria due to its significance as the most densely populated black nation in Africa and the largest economy on the continent, as well as the availability of reliable data. The measurement of CO₂ emissions is represented by metric kg per capita. Foreign aid (AID) is estimated using net official development assistance and official aid received (current US\$). Energy usage (ENCON) is measured by percentage of renewable energy consumption to final energy consumption, and GDP per capita growth (annual %) is employed to gauge the economic growth, as previously used in related studies by Nasir et al. (2019), Kaidi et al. (2019), and Steenblik, Jones, and Lang (2012). Trade openness is introduced as a variable, calculated by dividing the total of imports and exports by GDP (TRDOP). This ratio is a widely used indicator of trade openness in existing studies such as Siddiki (2002), King and Levine (1993), and Murinde and Eng (1994). Financial expansion is approximated by domestic credit to the private sector (DCP), following the methods of Rani and Kumar (2018) and

Afolabi (2022). Remittances (REM) are measured as total remittances received (% of GDP). To simplify estimation, data on CO₂ emissions, AID, and ENCON were converted into natural logarithmic form to ensure stationarity in variance. For a comprehensive understanding of the variables used in the study, please refer to *Table 1* for the explanation and sources.

Table 1. *Description of variables*

Abbreviation	Description	Source
Carbon dioxide emissions (CO)	CO ₂ emissions (metric tons per capita)	World Development Indicator
Foreign Aid (AID)	Net official development assistant (Current US\$)	World Development Indicator
Energy Usage (ENCON)	% of renewable energy consumption to final energy consumption	World Development Indicator
Economic Growth (GDP)	GDP per capita (constant 2015 US\$)	World Development Indicator
Trade Openness (TRDOP)	% of trade to GDP	World Development Indicator
Financial Development (FD)	Domestic credit to the private sector (% of GDP)	World Development Indicator
Remittances (REM)	% of total remittances to GDP	World Development Indicator

Source: authors' compilation (2023)

Model Specification

The model for the implication of foreign aid, energy usage, growth, trade openness, financial expansion, and remittances on carbon emission is stated as:

$$CO_2 = F(AID + ENCON + GDP + FDEV + TRDOP + REM),$$

where CO_2 is the carbon emission (a proxy for CO measured by metric kg per capita), AID is a delegation for foreign aid, advancement in the economy by GDP per capita growth, β_0 is the constant term, β_1 , β_2 , β_3 , and β_4 are the coefficients of the model, and ε_{t1} stands for the error term. *TRDOP* represents trade openness (import + export/GDP), domestic credit to the private sector (% of GDP), proxied for financial expansion, while remittance is a proxy of personal remittance received % of GDP. The adopted empirical strategy involves the estimation of the baseline equation through the ARDL procedure. ARDL techniques have been widely utilized in the field of econometrics for a considerable period. Their application has become increasingly accepted in recent years, particularly as a

means of analysing cointegrating connections (Adegboyega and Odusanya, 2014). Two significant contributions in this context are the works of Pesaran, Shin, and PSS (2001) – specifically Pesaran et al. (2001) and Pesaran and Shin (1998). The authors contend that ARDL techniques possess distinct advantages due to their capacity to effectively address cointegration while demonstrating resilience against the misrepresentation of integration orders of pertinent variables. The dynamic relationship is specified as:

$$CO_{2t} = \beta_0 + \beta_1 AID_t + \beta_2 ENCON_t + \beta_3 GDP_t + \beta_4 FDEV_t + \beta_5 TRDOP_t + \beta_6 REM_t + \varepsilon t_1$$

Further, the study aimed to analyse the impact of the dynamic interactions between foreign aid, energy usage, economic growth, trade openness, remittances, and financial progress on carbon emissions in Nigeria. Descriptive statistics were used to present and summarize the data effectively. Additionally, data normality was confirmed by examining means and Jarque–Bera values (Gujarati and Porter, 2010). Hence, to assess stationarity, the study conducted unit root tests using the ADF and Philips–Perron methods. Subsequently, ARDL estimation techniques were employed to investigate the variables' cointegration.

4. Results and Discussion

Descriptive Statistics

Table 2 presents the results of the descriptive statistics. The findings show that the mean and median values of all variables fall in the range of their maximum and minimum values. This suggests a high probability of a normal distribution for all features, namely carbon emission, aid, energy usage, growth in the economy, financial development, trade openness, and remittances. The Jarque–Bera statistics support this inference, as the series adheres to a normal distribution. Furthermore, the lack of statistical significance at the 5% level for all p-values of the series further confirms the acceptance of the alternative hypothesis, which states that each variable follows a normal distribution.

Table 2. *Descriptive statistics*

	CO ₂	AID	ENCON	GDP	TRDOP	FD	REM
Mean	-0.398	20.585	6.595	1.636	0.361	10.274	3.370
Median	-0.399	21.099	6.607	1.809	0.365	9.395	3.819
Maxi	-0.087	23.159	6.666	12.27	0.532	19.625	8.333
Mini	-0.710	18.839	6.522	4.507	0.163	4.957	0.018
Std. dev	0.177	1.325	0.042	3.848	0.093	3.539	2.349
Skewness	0.142	0.064	-0.253	0.452	-0.157	0.821	0.179

	CO ₂	AID	ENCON	GDP	TRDOP	FD	REM
Kurtosis	1.698	1.517	1.769	3.378	2.465	3.352	1.880
Observations	32	32	32	32	32	32	32

Source: authors' compilation (2023)

Notes: foreign aid (AID), energy usage (ENCON), economic growth (GDP), remittances (REM), financial development (FD), trade openness (TRDOP), and carbon emissions (CO₂).

Test of Multicollinearity

To evaluate the existence of multicollinearity among the predictor variables – specifically aid, energy consumption, economic progress, openness in trade, financial development, and remittances –, a correlation matrix was generated. The correlation matrix is presented in *Table 3*. The analysis demonstrates that there is a lack of link between the variables, thus establishing the study's outcomes as highly reliable. *Table 3* also presents the outcome of the correlation matrix, indicating that the factors produce both positive and negative correlation coefficients. The absence of multicollinearity among the variables can be inferred from the correlation coefficient being less than 0.95, as noted by Baltagi, Bun, and Sarafidis (2015) and Wooldridge (2007).

Table 3. *Correlation matrix*

Variables	CO ₂	AID	ENCON	GDP	TRDOP	REM	FD
CO₂	1.000						
AID	-0.814	1.000					
ENCON	-0.710	0.820	1.000				
GDP	0.045	0.014	0.031	1.000			
TRDOP	0.326	-0.353	-0.262	0.374	1.000		
REM	-0.803	0.890	0.655	-0.001	-0.184	1.000	
FD	-0.812	0.580	0.538	0.066	-0.229	0.658	1.000

Source: authors' compilation (2023)

Notes: foreign aid (AID), energy usage (ENCON), economic growth (GDP), remittances (REM), financial development (FD), trade openness (TRDOP), and carbon emissions (CO₂).

Results in *Table 4* indicate that the factors exhibit stationarity at levels and the first difference. The empirical outcome revealed both the non-stationary characteristics of the factors and the covariance structure of the analysed dataset. We employ the ARDL technique to estimate the association of the factors of interest. The selection of the estimation strategy is crucial in this research, as it aligns with the observed patterns in the data. The determination of the most suitable lag duration is accomplished by utilizing the Schwartz information criteria. The process includes determining the lag duration value that minimizes the information criterion, specifically the Schwartz Criteria (SC), while simultaneously ensuring that the model does not display autocorrelation. The presentation includes the determination of the optimal lag length, as shown in *Table 5*.

Table 4. *Unit root test*

Variables	Level				First difference			
	Intercept		Trend and intercept		Intercept		Trend and intercept	
	ADF PP		ADF PP		ADF PP		ADF PP	
CO ₂	-1.232	-1.083	-2.888	-2.962	-5.921**	-6.854**	-5.788**	-6.728**
AID	-0.907	-1.091	-3.185	-2.325	-5.393**	5.227**	-5.287**	-5.019**
ENCON	-1.406	1.215	-2.681	-2.370	-5.407**	7.275**	-5.313**	-7.083**
RGDP	-3.767**	3.892**	-3.680**	3.812**	-9.376**	20.114**	-9.154**	-20.989**
TRDOP	-2.809***	-2.809	-3.342	-3.304	-5.422**	-9.957**	-5.436**	-17.837**
FD	-2.567	-1.718	-3.773**	2.114	-5.054**	5.983**	-5.026**	-6.023**
REM	-2.069	-1.980	-2.470	-2.490	-5.685**	-7.047**	-5.641**	-7.889**

Source: authors' compilation (2023)

Note: ***, **, and * stand for 10%, 5%, and 1% respectively. Foreign aid (AID), energy usage (ENCON), economic growth (GDP), remittances (REM), financial development (FD), trade openness (TRDOP), and carbon emissions (CO₂).

Table 5. *Lag length selection*

Lag length	SC
0	7.403
1	5.762*
2	7.788

Source: authors' compilation (2023)

Notes: ***, **, and * stand for 10%, 5%, and 1% respectively.

Bounds Test

The study employs the bounds testing procedure as proposed by Pesaran et al. (2001) to inspect the existence of extended period links among the variables. F-test is adopted to assess the assumption of the absence of co-movement among the factors in comparison to the hypothesis of its presence, which is represented as:

$H_0: \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = 0$, i.e. there is no cointegration among the variables.

$H_1: \beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 \neq \beta_6 \neq 0$, i.e. there is cointegration among the variables.

Table 6. *Bounds test results*

F-statistics	1%		5%		10%	
4.993	Lower bound	Upper bound	Lower bound	Upper bound	Lower bound	Upper bound
	2.88	3.99	2.27	3.28	1.99	2.94

Source: authors' compilation (2023)

Notes: ***, **, and * stand for 10%, 5%, and 1% respectively.

Based on the conclusions of the bounds test, as shown in *Table 6*, it is suggested to compare the F-statistic value with the critical value of Pesaran at the conventional significance level. Narayan (2005) detailed that the critical values outlined in Pesaran et al's (2001) study do not apply to a small number of sample sizes, as they are based on the assumption of huge sample sizes. Narayan (2005) allows critical values for sample sizes ranging from 30 to 80 observations. The observed values in this study fall within the range of 1.99–2.94 for a significance level of 10%, 2.27–3.28 for a significance level of 5%, and 2.88–3.99 for a significance level of 1%. The null hypothesis is not rejected based on the F-statistic of 4.993, which exceeds both the lower and upper bound critical values. Therefore, it can be concluded that all factors in the model exhibit co-movements in the extended period within Nigeria.

Table 7. *ARDL long-run estimates (Pesaran et al., 2001; Narayan, 2005); dependent variable: CO2*

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LAID	0.002	0.045	0.040	0.968
LENCON	-0.141	0.782	-0.180	0.858
GDP	0.002	0.005	0.330	0.744
TRDOP	0.123	0.302	0.407	0.688
FD	-0.017	0.007	-2.338**	0.029
REM	-0.054	0.023	-2.310**	0.031
C	0.806	4.535	0.177	0.860
R-squared	0.748			
Adjusted R-squared	0.720			
Durbin-Watson stat	2.402			
F-statistic(Prob)	33.564**			

Source: authors' compilation (2023)

Notes: ***, **, and * for 10%, 5%, and 1% respectively. Foreign aid (AID), energy usage (ENCON), economic growth (GDP), remittances (REM), financial development (FD), trade openness (TRDOP), and carbon emissions (CO2).

Table 7 indicates that the explanatory variables of the model account for 72.08% of the variation in the regressand variable over the long term. The rest, 27.92% of the variation, was determined by factors outside of the model. The statistical significance of the model was confirmed by the F-statistic (33.56) at a significance level of 5%. The statistical analysis reveals that the model exhibited a positive serial correlation, as evidenced by the Durbin–Watson statistic of 2.402, which is within the acceptable range of 1.5–2.5, as established by previous research (Dufour and Dagenais, 1985; Durbin, 1960). The findings suggest that over the long term, the foreign aid received has a positive impact and is statistically irrelevant at a 5% level of significance. This suggests that an increase of a certain percentage in official aid and assistance

received will result in a corresponding 0.018 per cent increase in carbon emissions in Nigeria. Furthermore, energy consumption exhibits an adverse and statistically insignificant correlation at the 5% level. The aforementioned statement suggests that an upsurge of a certain percentage in energy usage will lead to a reduction of 0.141 per cent in carbon emissions. The coefficient of growth in economy and trade liberalization points to a positive direction, yet it loses its statistical significance with carbon emissions in Nigeria. Meanwhile, the statistical analysis reveals that both financial development and remittances exhibit an adverse and inconsequential correlation with carbon emission, suggesting that an increase of a certain percentage in remittance and financial development will result in a corresponding 0.05 per cent and 0.01 per cent reduction, respectively, in carbon emission in Nigeria.

Table 8. *ARDL short-run estimates; dependent variable: CO2*

Variable	Coefficient	Std. error	t-statistics	Prob.
D(TRDOP)	0.436	0.091	4.766**	0.000
D(FD)	-0.003	0.004	-0.852	0.403
D(REM)	-0.011	0.005	-2.133**	0.045
ECM(-1)	-0.701	0.095	-7.343**	0.000

Source: authors' compilation (2023)

Notes: ***, **, and * stands for 10%, 5%, and 1% respectively. Foreign aid (AID), energy usage (ENCON), economic growth (GDP), remittances (REM), financial development (FD), trade openness (TRDOP), and carbon emissions (CO2).

Findings suggest that over a short-term period, there exists a positive and significant (5%) level of correlation between openness in trade and carbon emission in Nigeria. Furthermore, it is noteworthy that financial development exhibits an adverse and statistically insignificant correlation at a 5% level of significance, while remittances exhibit an adverse and significant association with carbon emission, which implies that a rise in remittances in Nigeria will result in a reduction of 0.01 in carbon emission.

The results of the short-run effect of interplay among foreign aid, energy usage, economic growth, and carbon emissions in Nigeria are presented in *Table 8* above. Negative effects were revealed in the short term, which were found to be statistically significant at the 5 per cent level. Also, a relatively short transition period results in relatively small changes; even where there are imbalances, the return to equilibrium has been relatively high, with a value of 0.701 (70.1%) being registered in the first year.

Figure 1 demonstrated the normality stability test that indicates a normal distribution with the probability value of 0.337. Also, the results in *figures 2–3* depicted the CUSUM and CUSUM of squares, whose lines fall within the critical bounds of 5 per cent significance. This suggests that the series exhibits structural stability.

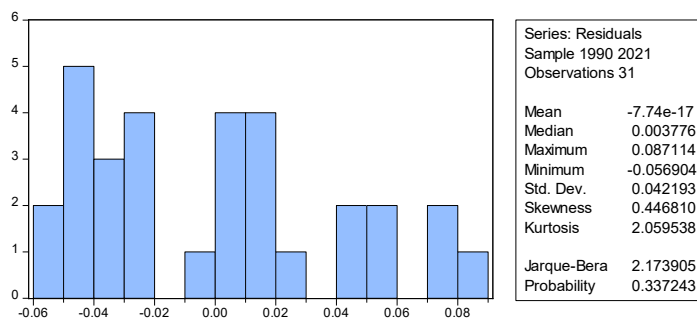


Figure 1. Normality test

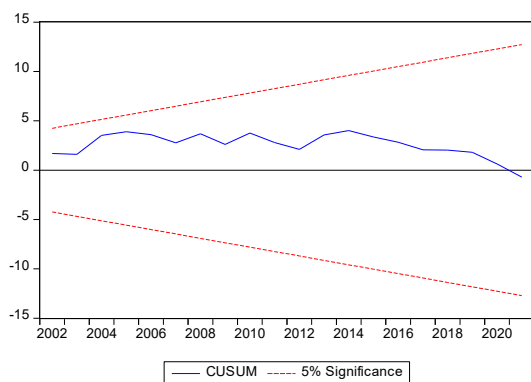


Figure 2. CUSUM stability test

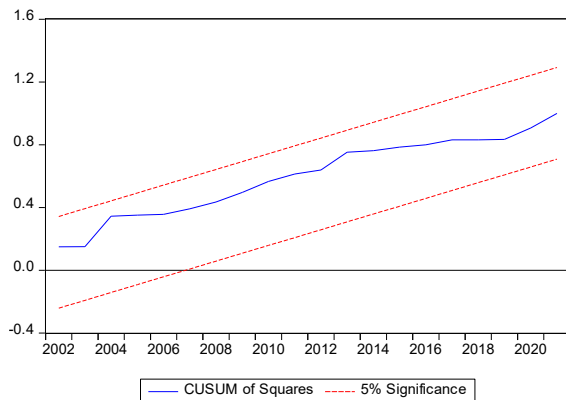


Figure 3. CUSUM of squares

5. Conclusions and Policy Recommendations

The relationship between energy use, economic growth, and carbon emissions has been extensively researched in the Nigerian academic discourse, taking into account elements such as financial development, trade openness, and remittance inflows. Foreign aid and its relationships with other variables are not being examined sufficiently in current research, which is one obvious gap in the field. To address this, our study used data from the World Development Indicator of the World Bank, spanning the years between 1990 and 2021 and using an Autoregressive Distributed Lag estimate approach. The results of the present study point to a positive correlation between foreign aid received and carbon emissions over an extended period in Nigeria. It is crucial to remember that this association loses its statistical significance beyond a certain point. In a similar vein, we have discovered that economic expansion and trade liberalization have no statistically significant impact on carbon emissions in Nigeria. These results contrast with the findings of Kishor Sharma and Badri Bhattarai (2019) and Mahalik et al. (2021), who reported a negative and statistically insignificant correlation between energy consumption and CO₂ emissions. Moreover, a noteworthy and adverse association was observed between financial progress, remittances, and carbon emissions. In the short term, trade openness in Nigeria had a positive and statistically significant influence, while remittances showed a statistically significant negative correlation with carbon emissions. Specifically, an increase in remittances corresponded to a decrease of 0.011 in carbon emissions. However, financial development had an adverse and statistically irrelevant influence on CO₂ in the short term.

The results of this study offer fascinating new insights into the complex interactions between many variables and carbon emissions in the context of Nigeria. These ramifications highlight the necessity of specialized policy interventions and shed light on the challenges associated with attaining sustainable development. First, despite losing statistical significance, the positive correlation between foreign aid and carbon emissions that has been found warrants further investigation. Foreign aid can be helpful in boosting economic growth, but it must be carefully considered for any potential effects on carbon emissions. Policymakers must carefully evaluate the type of help received and how it fits with the objectives of sustainable development. In order to evaluate the proposed projects based, for example, on their environmental impact, social benefits, and compatibility with emission reduction goals, a thorough sustainability assessment framework must be created. It is also practical to incorporate evaluation criteria such as carbon footprint, resource efficiency, and emission reduction potential. It is also crucial to set up systems for the continual evaluation and monitoring of the success of emission-reducing activities.

The necessity for comprehensive policy responses is highlighted by the statistically insignificant impact of trade liberalization and economic growth on carbon emissions.

There is no guarantee that merely increasing commerce or economic activity will reduce emissions. To decouple growth from emissions, a more comprehensive approach is needed. Such a mechanism would encourage environmentally friendly production and trade practices to reduce the environmental impact of the growing trade activity. Last but not least, the research showing a negative correlation between remittances, financial development, and carbon emissions suggests that some components of financial development could not be environmentally friendly. Therefore, it proposes that the stakeholders should take advantage of the discovered inverse relationship between remittances and carbon emissions and create strategies to encourage beneficiaries of remittances to finance green initiatives, ultimately cutting carbon emissions. Government entities and all other stakeholders should make sure that financial development is in line with sustainability goals and should promote investments in green technologies and environmentally friendly projects, given the negative correlation between financial progress and carbon emissions.

Nevertheless, further research should delve into the underlying mechanisms involved, considering variables such as the quality of institutions, regulatory measures within the financial sector, and the influence of specific industries on economic expansion and financial advancement.

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Multilateral Development Banks in Emerging Countries – The Beginning of the Transformation of the Multilateral Financial System

Zoltán EPERJESI

Department of Economics, Wekerle Sándor Business School, Budapest, Hungary
e-mail: eperjesiwsuf@gmail.com

Abstract. In the twenty-first century, two multilateral development banks were set up at the initiative of emerging countries to promote the concept of development finance for emerging and developing countries, breaking away from the Bretton Woods institutional system based on the dominance of the US and Western states. China has played a very significant role in the establishment of both the New Development Bank and the Asian Infrastructure Investment Bank. The New Development Bank established by the BRICS countries (Brazil, Russia, India, China, the South African Republic) is the first multilateral development bank in the world in which the five founding countries have equal voting shares at the time of its establishment and which is truly focused on the needs of emerging and developing countries. No Western developed country has a stake in this bank. Although China is the largest shareholder in the Asian Infrastructure Investment Bank, it has been joined by a number of advanced industrialized countries, and its operating mechanisms are similar to those of the Bretton Woods financial development institutions. Both new financial institutions will create competition for the Bretton Woods system of international development finance institutions, which has been in place since 1944, with the New Development Bank most likely to rival the International Bank for Reconstruction and Development, while the Asian Infrastructure Investment Bank could gain a foothold in the operational area of the Asian Development Bank, which was established in the 1960s.

Keywords: BRICS countries, multilateral development banks, infrastructure financing, emerging economies, global development-financing architecture

JEL Classification: F02, F53

1. Introduction

We can distinguish four different waves of multilateral development finance institutions (MDBs), each of which can be linked to a specific event in world history and politics. The first wave of multilateral development banks took place in the 1940s, at the end of the Second World War. The International Bank for Reconstruction, created at the Bretton Woods Conference on the initiative of the United States of America, had as its primary task to finance the reconstruction of the European continent following the devastation of the Second World War. However, the Marshall Aid, also initiated by the US, took over the role of the organization responsible for the reconstruction of Europe, and the International Bank for Reconstruction repositioned its main focus of operations under a new name (International Bank for Reconstruction and Development), and from then on it concentrated on the developing world (Zhu, 2019: 130).

In the 1960s, decolonization, i.e. the dismantling of the colonial system, led to the second wave of multilateral development finance institutions, with the creation of a number of multilateral development banks operating at the regional level (Asian Development Bank, African Development Bank, Inter-American Development Bank, Latin American Development Bank, Islamic Development Bank).

The third wave of multilateral development banks dates back to the early 1990s, when the Cold War ended, the Soviet Union collapsed, and the former socialist countries of Central and Eastern Europe embarked on the path of the multi-party democratic system and market economies. The major Western European powers proposed the creation of the European Bank for Reconstruction and Development (EBRD), and in parallel the European Union's development bank, the European Investment Bank (EIB), extended its operations to the Central and Eastern European countries' region (Wang, 2017: 113).

The fourth wave of international development banks arrived following the 2008 global economic and financial crisis. For decades, the World Bank, dominated by US and Western influence, neglected financing infrastructure development and focused on poverty alleviation and good governance (Wang, 2019: 223). Emerging economies have led to a major shift and shift of power in the world's political and economic structure. The GDP of the BRICS countries as a share of world GDP increased from 8% to 22% between 2000 and 2019, while the GDP of the G7 group (USA, Canada, UK, France, Germany, Japan, Italy) decreased from 65% to 45% of world GDP (Wang, 2019: 222).

Table 1. *The chronology of the establishment of multilateral development banks*

Period of time	Decisive international events	Establishment of the multilateral development banks
1940s	end of the Second World War	IBRD
1960s	decolonization	ADB, AfDB, IDB, IsDB, CDB, IDA, IFC
1990s	end of the Cold War	EBRD, extension of EIB financing
2010s	intense co-operation of the emerging economies	NDB, AIIB

Source: Jiejun Zhu (2019): Borrowing country-oriented or donor country-oriented? Comparing the BRICS New Development Bank and the Asian Infrastructure Investment Bank. p. 131.

Notes: abbreviations: IBRD: International Bank for Reconstruction and Development; ADB: Asian Development Bank; AfDB: African Development Bank; IDB: Inter-American Development Bank; IsDB: Islamic Development Bank; CDB: Caribbean Development Bank; IDA: International Development Association; IFC: International Finance Corporation; EBRD: European Bank for Reconstruction and Development; EIB: European Investment Bank; NDB: New Development Bank; AIIB: Asian Infrastructure Investment Bank).

Table 1 shows that two new multilateral development banks were established in the 2010s, which were not spurred by developed Western countries but by emerging countries having a focus on the developing world. The two new international financial institutions, the New Development Bank and the Asian Infrastructure Investment Bank, aim to become an alternative to the Bretton Woods international financial system and to change the framework for global development finance. Emerging economies want to see a rethinking of the disproportionate distribution of voting rights among member states in the multilateral financial institutions created after the Second World War. The establishment of new multilateral development banks to compete with the old Bretton Woods global financial institutions can also be seen as part of Chinese foreign policy to counterbalance the US dominance of existing international institutions by creating parallel structures (Reisen, 2015a: 274). In establishing the Asian Infrastructure Development Bank, the US tried to dissuade several friendly states from joining, citing environmental standards, the opacity of state contracting, and the lack of expropriation protection for local populations. An important question is whether the newly established international financial institutions can exert any meaningful influence over the organizations that have been in a dominant position since the end of the Second World War. The Asian Infrastructure Investment Bank and the New Development Bank established by the emerging countries dispose of sufficient investment funds, so they appeared as real challengers to the international financial system set up after the Second World War (Reisen, 2015b: 297).

Table 2. *The Bretton Woods multilateral development institutional system*

Description	Voting weight (%)				Number of directors					
	USA	other G7 members	other non-borrowing countries	borrowing developing countries	USA	other G7 members	other non-borrowing countries	borrowing developing countries	Total	president
IMF	17	28	17	38	1	6	6	11	24	non-borrowing country
World Bank	16	27	18	39	1	6	8	9	24	non-borrowing country
IADB	30	16	4	50	1	4	0	9	14	non-borrowing country
ADB	13	27	15	45	1	4	1	6	12	non-borrowing country
AfDB	7	21	12	60	1	4	1	12	18	borrowing country
EBRD	10	47	30	13	1	6	12	4	23	non-borrowing country

Source: Birdsall 2003 (https://www.researchgate.net/publication/228420747_Global_Economic_Governance_and_Representation_of_Developing_Countries_Some_Issues_and_the_IDB_Example – p. 23).

Notes: abbreviations: IMF: International Monetary Fund, IADB: Inter-American Development Bank, ADB: Asian Development Bank, AfDB: African Development Bank, EBRD: European Bank for Reconstruction and Development.

Having a look at *Table 2*, the disproportion of the voting weight and the number of directors can easily be assessed.

I focus in my study on the hypothesis that the hegemony of the USA over the world economy is increasingly challenged by the emerging countries' striving for a multi-polar world order and world economy better suiting their development needs and expectations. The bipolar world order – based on the competition of the USA and the Soviet Union after the Second World War – transformed into a unipolar world order led by the USA after the collapse of the socialist regimes in Eastern Europe. More than sixty years had passed after the Second World War until a new phenomenon appeared in the world order. This new phenomenon is called multi-polar world order. The major emerging countries – Brazil, Russia, India, China, South African Republic – gathered and set up new international organizations, such as the New Development Bank, articulating their wishes and needs that are in line with their position played in the world economy. The Asian Infrastructure Investment Bank initiated by China focuses first of all on the financing of infrastructure projects in Asia, but its structure reflects the structure of the well-established Bretton Woods institutions. In section two, I present and compare the BRICS countries, which are in all aspects – economically, culturally, and socially – rather heterogeneous. These countries do not necessarily aim to reach the level of integrity of the European Union. The emerging and the developing countries cannot reshape the existing multilateral financial organizations. That is why they decided to set up their own multilateral organizations paying attention

to their long-term financial needs and economic interests. These institutions will serve furthermore as a counterpole to the Bretton Woods institutions.

The study is composed of seven sections. The general profile and most important attributes of the heterogeneous BRICS group of countries (Brazil, Russia, India, China, the South-African Republic) are presented in section 2. I deal in section 3 with the increasing ambitions of the emerging and developing countries to reform the international financial system that better meets their development finance needs. A special emphasis is laid on the infrastructure finance of crucial importance for the emerging and developing countries within this section. The two new multilateral developments established in the 21st century are compared in section 4. The New Development Bank is characterized by a funding and lending model based on the ownership structure, while the Asian Infrastructure Investment Bank follows the financing model of the old Bretton Woods institutions. The financing of the New Development Bank is presented in section 5. I present the operations of the Asian Infrastructure Investment Bank focusing on climate finance, cross-border infrastructure development, and private sector finance in section 6. The study is closed by the conclusions formulated in section (7).

2. The General Profile of the BRICS Group of Countries

The acronym BRICS stands for the economic cooperation of five emerging countries: Brazil, Russia, India, China, and South Africa. All five countries have significant regional and global influence – e.g. China and Russia are members of the UN Security Council, and all five countries are members of the G20, the world's largest economies. The combined population of the five countries accounts for 40% of the world's total population. In 2011, the five countries formed the BRICS Forum, an independent international organization to strengthen trade, political, and cultural cooperation among BRICS member countries. Jim O'Neill, chief economist at the US multinational financial services firm Goldman Sachs, first used the acronym BRIC in 2001, predicting that the economic performance of the group of Brazil, Russia, India, and China would overtake the current richest countries by 2050 (Net 1).

Analysing *Table 3*, we may ascertain that China's GDP per capita showed the strongest growth over the period of 20 years under study. The world GDP amounted to USD 84.71 trillion in 2020. The US GDP amounted to USD 20.94 trillion, accounting for 24.71% of the total world GDP. The combined GDP of the five BRICS countries amounted to USD 20.79 trillion in 2020, which was 24.55% of the world GDP. The GDP of the BRICS member countries in 2020 was as follows: China: 14.86 billion USD; India: 2.67 billion USD; Russia: 1.48 billion USD; Brazil: 1.45 billion USD; Republic of South Africa: 0.33 billion USD (Net 3).

Table 3. GDP per capita of the BRICS countries 2000–2021

Description	Number of population (million)	GDP per capita (2000, USD)	GDP per capita (2021, USD)	Growth rate of GDP (%)
Brazil	211.76	3 772.05	7 563.56	201%
Republic of South Africa	59.31	3 039.04	6 950.43	229%
India	1 378.62	451.11	2 282.97	506%
China	1 411.00	951.16	12 358.80	1299%
Russia	146.17	1 899.41	12 198.21	642%
Total	3 206.86	10 112.77	41 353.97	

Source: Net 2: <https://www.statista.com/statistics/741745/gross-domestic-product-gdp-per-capita-in-the-bric-countries/>

Table 4. General comparison of the BRICS countries

Country	Population (in million)	Productivity	Life expectancy (years)	Level of urbanization (%)	Economic sectors			Unemployment rate (%)	Export (billion USD)	Foreign trade balance (billion USD)
					Agriculture (%)	Industry (%)	Services (%)			
Brazil	211.76	1.71	76.08	87.07	5.89	17.7	62.8	13.69	209.18	42.84
Russia	146.17	1.5	71.34	74.93	4	29.83	56.13	5.59	333.37	93.73
India	1 378.62	2.18	69.89	34.93	18.23	24.53	48.44	8	276.41	-96.79
China	1.411	1.7	77.1	63.89	7.7	37.8	54.5	4.24	2 589.95	523.99
Republic of South Africa	59.31	2.36	67.9	67.35	2.53	23.42	64.57	29.22	93.18	14.86

Source: own compilation in accordance with Net 4: <https://www.statista.com/study/14028/bric-countries-statista-dossier/>; <https://www.statista.com/statistics/455931/urbanization-in-south-africa/>; <https://www.statista.com/statistics/371233/south-africa-gdp-distribution-across-economic-sectors/>; <https://www.macrotrends.net/countries/ZAF/south-africa/trade-balance-deficit>

Studying *Table 4*, we can see the big differences and heterogeneity among the BRICS countries concerning population, life expectancy, and the composition of their economies. Although all five countries have achieved significant economic growth over the past two decades, it is legitimate to ask whether or not the BRICS group of countries can be considered a single group in social, economic, and geopolitical terms. We are talking about an extremely heterogeneous group of countries that do not share a common ideology, culture, or even geographical

proximity. While the economies of China and India continue to grow, Russia, Brazil, and the Republic of South Africa are in decline.

3. The Context for the Establishment of the New Development Bank and the Asian Infrastructure Investment Bank in Their Respective Multilateral Development Environment

The political alliance of the BRICS countries gives new impetus to the gradual transformation of the current international order. The trend shows that the hegemony of the Western countries, which appeared to be enduring after the break-up of the socialist camp in 1989, is being challenged by globalization and the ever-changing balance of power. In any case, the truth is that the governments of the BRICS countries have no revolutionary ambitions but are primarily seeking to reform the international financial system. They are a long way from challenging the very foundations of the neoliberal global economic system. Nevertheless, their aspirations are based on the need to strengthen the voice and representation of emerging and developing countries.

The BRICS countries established the New Development Bank in 2014 on the initiative of India, while China initiated the signing of the statutes of the Beijing-based Asian Infrastructure Development Bank in 2015 by 50 countries wishing to join (Cooper, 2017). The BRICS, officially known as the New Development Bank, was established in Brazil at the sixth summit of the group of countries. The Shanghai-based bank has an equity capital of USD 50 billion, to which the five founding member states contributed a total of USD 10 billion in capital and USD 40 billion in guarantees (Reisen, 2015a: 274). Brazil, India, Russia, China, India, Russia, and South Africa each hold 100,000 shares of the NDB's 514,980 registered shares, with 19.42% of the voting rights. Meanwhile, Bangladesh, the United Arab Emirates, and Egypt joined the bank in 2021, having subscribed 5.12% of the subscribed capital of the bank. Each of the five founding countries disposes of 18.98% of the subscribed capital (NDB Annual Report 2021: 12). Bangladesh contributed USD 188 million and the United Arab Emirates USD 111 million to the Bank's paid-up capital. The Bank primarily finances large infrastructure investments. China is a major financier of both multilateral development banks.

The greater the inequality in the voting shares of the BRICS and other emerging countries in international development banks, the greater the pressure to participate in decision-making processes commensurate with their economic weight. The BRICS countries hold 13.87% of the World Bank's subscribed capital and 13.23%

of the voting share, while the G7 group of countries has 43.71% of the capital and 41.19% of the voting share (Reisen, 2015a: 275).

The extent of the shortage of infrastructure development loans at concessional rates, with long maturities, and initial grace periods is driving the demand for new multilateral bank (BRICS, AIIB) credit facilities. The extent to which development banks, dominated by the US and the developed countries of Western Europe, transfer policy leverage to emerging economies depends on this demand (Griffith-Jones, 2014: 2). The shift in the centre of gravity of the global economy towards East Asia is yet to be felt in the governing bodies of multilateral development banks or in changes in decision-making mechanisms. The discontent of emerging countries is leading to the creation of new global and regionally-based development finance institutions, further dividing the multilateral development finance architecture. New shadow institutions competing with the Bretton Woods system reduce the existing system's value of quota reform. In 2014, when the new multilateral financial institutions were established, the BRICS countries accounted for 46% of the world's population and 22% of the world GDP. The population and GDP of the BRICS countries are not in line with their voting weight in the World Bank. The G7, which was created in 1975 to serve as an informal forum for the leaders of the world's most advanced industrialized countries (Canada, France, Germany, Italy, Japan, the United Kingdom, the United States), accounted for only 10% of the world's population and 33% of its GDP in 2020, suggesting that their share of the World Bank's registered capital and voting power is quite over-represented (Reisen, 2015a: 275).

The quota system of the International Monetary Fund (IMF), the contributions of individual member states and their voting weight in relation to their role in the world economy are even more unbalanced than the composition of the World Bank's executive board. The BRICS countries have only 10% of the voting power in the IMF. The European Union, on the other hand, has 27% of the voting power, while its share of GDP in the world economy is only 18%. In addition, the IMF is traditionally headed by a European president, while the World Bank is headed by a US president. In 2010, a decision was taken in principle to reform the Bretton Woods institutions, such as doubling the IMF's capital stock to achieve a positive weighting of voting power in favour of poorer member countries, but this was not ratified due to the refusal of the US Congress (Reisen, 2015a: 275). European countries have also blocked the reform of the international financial system, so the EU continues to be over-represented in the IMF, the World Bank, and regional development banks.

The BRICS countries, seeing that the US and the Western developed countries do not support an increase in the political influence and voting power of the emerging economies, do not feel the urge to take more responsibility in the world economy and to produce more global public goods. The Asian Development Bank, dominated by the US and Japan, has particularly skewed voting shares and quota

allocations. OECD member states provide 59% of the Bank's registered capital and hold over 64% of the voting rights. China and India, by contrast, hold 11% of the voting rights. The US and Japan are the Bank's largest shareholders, with 15.6% each at the end of 2020. In contrast, China and India held only 6.4% and 6.3% of the shares respectively. The skewed share ratios are illustrated by the fact that China's GDP has consistently exceeded Japan's GDP in USD terms since 2010. The Asian Development Bank has been headed by a Japanese president since its inception. The policy orientation of the Development Bank has always been in line with that of Japan's main ally, the US. Both states have done their utmost to ensure that the dominant Asian emerging powers, China and India, do not gain additional ownership and voting rights. A direct negative consequence of the distorted system of representation and ownership is that it reduces the amount of capital that can be raised and the amount of credit that can be disbursed. Financing difficulties are evident both in the Asian Development Fund (ADF), which is meant to finance the poorest Asian member countries, and in lending to the middle-income member country. Japan's role and influence in the development bank cannot be sustained in the long term, as Japanese public finances are under increasing pressure from the country's ageing society (Y. Sawada, 2014: 55).

The World Bank and the Asian Development Bank have a decisive influence on the field of global energy governance in Asia, and they play a crucial role in introducing new energy technologies, procedures, and services. However, the two multilateral development banks did not succeed in harmonizing the environmental, social, economic, and geopolitical aspects of the global energy governance competing with each other (Nakhoda, 2011: 120).

All multilateral donors tend to allocate more aid to countries with lower per capita incomes and to less populous countries. The development banks concentrate on economic development needs rather than human development needs given that big infrastructure projects and the promotion of economic growth are often on the top of their agenda for development assistance (Neumayer, 2010: 23).

The emergence of parallel international financing systems is reinforced by the fact that emerging as well as developing countries continue to see their position in international development finance institutions – established and dominated by Western developed countries – as unlikely. In the case of the World Bank, for example, all member state shareholders should contribute to the reform of voting rights and quotas. Even a veto by one member state would thwart the initiative.

3.1. Problems of Infrastructure Financing

In the past twenty years, just under 4% of world GDP has been invested in infrastructure. While the share of infrastructure development in advanced industrialized countries was only 2.5%, emerging countries spent 5.7% of their

GDP on infrastructure. The development lending and lending capacity of the New Development Bank (NDB) and the Asian Infrastructure Investment Bank (AIIB), both of which offer concessional financing, will determine how much of the political influence and development lending of the established Western-led Bretton Woods financial institutions and the regional multilateral development banks, also under Western influence, will be lost to new international competitors. The World Bank estimates infrastructure financing needs in emerging and developing countries at 7% of a country's GDP. Calculations prepared for the 2013 meeting of the G24 Intergovernmental Group on International Monetary and Development Affairs (G24) suggest that between USD 1 and 1.5 billion per year would be needed to fight global poverty, build drinking water and sanitation networks, and tackle the consequences of climate change (Bhattacharya, M. Romai 2013). China has a number of construction companies that still have plenty of capacity to carry out projects abroad. The two new international development banks represent an excellent symbiosis for capital providers and capital borrowers.

The establishment of new multilateral development banks is certainly a positive progress for global development, as they will greatly contribute to the financing of the missing infrastructure projects. The new development banks will provide emerging countries with a much stronger voice than the Bretton Woods institutions. The new situation may also help the Western industrialized countries, seeing their monopoly in the field disappear, to give developing countries a greater say in the World Bank Group and in regional international development financial institutions.

For the multilateral development financial institutions dominated by the US and Western European countries, the potential loss of creditor status is a major concern. The supply of new alternative development loans is reducing the compatibility of existing loan contracts and encouraging a shift towards new lending institutions. For this reason, both old and new international development banks have an interest in maintaining long-term loan repayment morale, and it is advisable for these financial institutions to include cross-default clauses in their various loan contracts.

4. Comparison of the New Development Bank (NDB) and the Asian Infrastructure Investment Bank (AIIB)

Created in the 21st century, what both development banks have in common is that they were established by emerging economies. The lack of infrastructural investments arising in the developing countries and the desire of the emerging countries in the global governance due to their position in world economy to represent their interests provided the basis for the establishment of the two multilateral development banks in the 21st century (Shelepov, 2017: 128).

The New Development Bank, created by the BRICS countries, is mainly characterized by a funding and lending model based on ownership, while the Asian Infrastructure Investment Bank (AIIB) continues to operate on a donor-country basis, i.e. a disparity model, similar to the International Bank for Reconstruction and Development or the African and Asian Development Banks. Following the accession of several European non-continental developed countries to the AIIB multilateral development bank, China, under pressure from international – mainly European and US – credit rating agencies, decided to make the AIIB a truly “Western-style internationalized” development bank like the existing one. The equal shareholding (5 x 20%) of the five shareholding member countries of the NDB is explained by the attempt to avoid competition for leadership between China and India. This has created equality between shareholding member countries, one of the Bank’s most defining characteristics (NDB General Strategy 2017-21, 2017: 10). Both multilateral development banks were created by emerging economies to finance infrastructure investment and contribute to global governance reform. However, the two banks operate under different operational mechanisms. While the ownership structure of the NDB is the determining factor for borrowing, the AIIB is a development bank that is inclusive of developed countries outside the continent and draws heavily on international best practices developed by the Bretton Woods institutions. China’s commitment and dedication to the reform of multilateral development financial institutions has been strongly reinforced over the past decades (Picciau, 2019: 143). In the case of the NDB bank, all shareholder member states are both capital contributors and borrowers, and the five founding shareholder member states have equally shared in the bank’s capital up until 2020.

To be fair, the NDB bank has in the meantime also taken on some smaller member states. In the case of the AIIB bank, there is no question of equal ownership by the shareholding member states, some shareholders contribute to the bank’s share capital but do not borrow from the bank, and its operating mechanism is the same as that of the previously established World Bank Group and some of the major regional development banks.

The NDB development bank mostly uses the country-specific systems of individual member states, as well as borrowers, in environmental and social areas, thereby also utilizing and developing the capacities of member states. In addition, one of the most distinctive features of the New Development Bank is that it does not apply political conditionality in its borrowing compared to traditional Bretton Woods multilateral financial institutions (United Nations Office for South-South Cooperation, 2021: 10). Whereas the NDB bank primarily uses the money and capital markets of the debtor member state, the AIIB bank uses the international capital markets for its various financing operations and makes loan amounts available to the debtor member state in US dollars. The NDB builds partnerships primarily with local financial institutions, the country’s national development bank and commercial banks, while the AIIB

bank strengthens its links mainly with existing multilateral development banks. The operating models of the two IFIs under review reflect the different approaches of emerging economies to global economic governance. The AIIB bank's operating mechanism is characterized mainly by minor efficiency-enhancing changes based on a review of the functioning of existing multilateral banks, while the NDB bank embodies a real paradigm shift, the donor-state-first approach being replaced by an orientation that prioritizes the borrowing countries. In the short term, the AIIB will find it easier to obtain higher ratings from international rating agencies, thus improving its international reputation. In the longer term, however, the NDB bank can provide a more significant institutional alternative for developing countries to reform global economic governance.

Developing countries are lagging far behind in terms of infrastructure investment, whereas the example of the newly industrialized countries of South-East Asia (the small tigers) clearly shows that infrastructure investment is essential for sustainable economic development. The African Development Bank (AfDB) included in its 2011 report that only one third of the rural population on the African continent has direct access to road networks, less than 40% of the population has access to electricity, only 5% of agricultural land is under irrigation, only 34% of the population has access to adequate healthcare, and 35% of the population does not have access to clean drinking water (Kaberuka, 2011). In 2011, D. Kaberuka, President of the AfDB Bank, estimated that the African continent would need to spend USD 93 billion per year on infrastructure investment between 2011 and 2020 to bring its infrastructure network up to the level of middle-income countries (Zhu, 2019: 131). The main reason – why multilateral development banks provide little funding for infrastructure development in the developing world – is that the decision-making mechanisms of multilateral development banks are determined by representatives of developed countries (Zhu, 2019). In this light, the two newest international development banks embody new ideas and approaches to the involvement of developing countries in global economic governance. International development policy is currently dominated mainly by a liberal, neoliberal approach that generalizes the development policies of developed Western countries around the world. In a lesser known speech in 1998, J. Stiglitz, the World Bank's chief economist, spoke of the need to diversify thinking on development policy, which was received very positively by representatives of developing countries (J. Stiglitz, 1999).

Former World Bank Vice-President X. Zhu expressed his belief that emerging economies should actively contribute new development policy ideas and knowledge to the mainstream policy agenda. The main role of the NDB is to provide a new development policy direction for developing countries. International development banks established by emerging countries tend to focus on infrastructure development and sustainable development. The level of development of the countries concerned varies, so different approaches to development need to be applied to them.

The multilateral development banks established in the past century were founded by developed countries and have been effective in contributing to the development of developing countries through project finance and technology transfer, but the truth is that these financial institutions have often been used as diplomatic tools by developed industrial countries to achieve their own goals and interests (Wei, 2016: 35). Hence, mainly the NDB and the AIIB banks can be seen as institutionalized advocacy organizations in developing countries, acting as strategic compasses against the opportunistic attitude and approach of developed countries. These new development finance institutions allow developing countries to partially exit from institutions dominated by the developed world, where their comments and suggestions are not listened to. The two banks under review also play a major role in addressing the common problems of emerging economies.

In November 2008, Indian Prime Minister Manmohan Singh proposed at the G20 summit in Washington that infrastructure investment in developing countries should be stepped up, but the multilateral development banks present completely ignored the proposal. The Indian Prime Minister proposed at the fourth BRICS summit in New Delhi in 2012 that a multilateral development bank (MDB) should be set up under the leadership of developing countries, a proposal that was endorsed by the leaders of the other BRICS countries.

At this meeting, the BRICS leaders decided that there was a real need for a multilateral financial institution to provide financial resources to BRICS and other emerging and developing countries for their infrastructure and sustainable development projects, complementing the existing international development finance institutions. India and China were the two key players in the establishment of the NDB Bank. India was the initiator of the idea, while China had very substantial foreign exchange reserves and vast experience in infrastructure financing. Although both countries agreed to set up a development bank, their preferences differed greatly. India was most concerned with the interests of the borrowing countries when it set up the bank and saw the new financial institution as a financier of its own infrastructure development. India had traditionally relied on the World Bank to finance its infrastructure development, but it faced a new situation when it was no longer eligible for IDA financing. It is therefore not surprising that India was the main advocate of the NDB. Even after the global economic crisis of 2008, India was always the country that, in contrast to China, was working on alternative development financing strategies (Cooper, 2017: 275). India proposed from the outset that the new bank should have a share capital of USD 10 billion to be contributed equally by the five founding countries. China did not block this proposal, but it showed a marked reluctance to accept equal shareholding.

China's main preference in establishing the new bank was to give priority to donor countries. China wanted to be a new major donor country with a better understanding of the needs of borrowing developing countries, based on more than 30 years of

experience with the World Bank and the Asian Development Bank. In the long term, China sees the NDB bank as an international development finance institution with a strong interest in strengthening sustainable development in developing countries, which provides a huge new market for China (Chin, 2014: 366).

China was concerned about the Bank's efficient functioning due to the equal allocation of shares among the BRICS member states. In terms of quota allocation, two types of allocation can be distinguished, one based on GDP and capital contributions and the other on political equality (one country one vote). The NDB is the only multilateral development bank in the world that uses equal voting rights for member countries (Cooper and Farooq, 2015: 32). Besides equal voting rights and equity shares as a pioneering governance innovation, the use of country-specific systems for each member country is another institutional innovation that benefits member countries. China has made three proposals for the operation of the NDB bank, which have been implemented. First, China has succeeded in getting the bank to be based in Shanghai. A very important objective was to enable the bank to use the local capital markets to raise debt through bond issues to recapitalize the bank. The choice of Shanghai proved to be perfect, as it is one of the most prominent financial centres in the BRICS countries. China's second proposal to increase the total core capital of USD 10 billion to USD 100 billion has also come true. At the same time, in order to reduce the burden on the BRICS countries, which have significantly less foreign currency reserves than China, it was also decided that the amount of core capital to be paid in per country should be USD 10 billion. China's third proposal to India was that the bank should finance not only the BRICS countries but also the countries of the developing world. To counter China's influence, with the NDB headquarters in Shanghai, India insisted that the Bank's first chairman be an Indian.

Table 5. *Indian, Chinese, and BRICS proposals concerning the NDB*

Description	Quota allocation	Capital base	Headquarters	President	Scope of lending
Indian proposal	according to the principle of equality	10 billion USD	New Delhi	first president from India	BRICS countries
Chinese proposal	according to GDP size	100 billion USD	Shanghai	first president from China	all of the developing countries
BRICS proposal	according to the principal of equality	10 billion USD as paid in capital and 100 billion USD as authorized capital	Shanghai	first president from India	all of the developing countries

Source: Jiejun Zhu (2019): Borrowing Country-Oriented or Donor Country-Oriented? Comparing the BRICS New Development Bank and the Asian Infrastructure Investment Bank, p. 135.

Table 5 shows unambiguously the distinct initiatives of India and China concerning the establishment of the New Development Bank. Many years of development experience have shown that strengthening the systems of each emerging and developing country and bringing them up to an acceptable international standard is all the more important because the push for donor countries to adopt their own system-specific operational mechanisms undermines the autonomous management of their own development projects. Country-specific systems developed at their own international level take a significant burden off the shoulders of donor countries, as they do not have to deal with the various policy issues, especially procurement and procurement legislation, which greatly facilitate donor country co-financing in developing countries. The development of their own systems is also of great importance for developing countries, as they can improve the efficiency of government spending in a meaningful way, and not only in the case of donor funding. For example, from India's perspective, the use of borrower countries' own administrative systems contributes greatly to strengthening the country's development autonomy, while China also benefits from this concept, as the use of countries' own operational systems improves the NDB Bank's leverage and reputation in the developing world. The New Development Bank sees the best way forward through developing the debtor countries' own systems, as this will best serve their long-term development and capacity building. It is for this reason that the NDB Bank examines in advance the environmental, social, asset management and procurement systems of debtor countries and uses them if they meet the Bank's criteria. A difficulty for the NDB Bank is that it does not have a single set of rules for environmental and social aspects for each of the borrowing countries. If, under pressure from developed countries, the NDB applies high standards similar to those of the World Bank, this will provide greater certainty, but the NDB is committed – building on the experience of its founding countries – to ensuring that debtor countries can manage their projects most effectively if they have control over their own development concept and various policy operating mechanisms. In developing the NDB's vision, a high priority has been to develop close links and cooperation with international organizations, national governments, and development banks operating at the national level (Mukherjee, 2022: 21).

In contrast to the NDB, the Asian Infrastructure Investment Bank is a new multilateral development bank initiated by China, which aims first and foremost to increase its international legitimacy and attract European co-financiers. Political pressure from European countries for the new Asian development bank to be multilateral in nature and expectations from US credit rating agencies have prompted the China-dominated AIIB to operate on a donor-country orientation model (a "disparity model"), similar to existing multilateral financial institutions. The idea of establishing an AIIB bank was first raised by Chinese President Xi Jinping during his visit to Indonesia in October 2013. South, South-East, and

Central Asian countries welcomed the idea positively, while non-Asian developed countries, mainly in Europe and North America, were pessimistic about it. Two questions were raised at the outset about the new international bank: firstly, whether we are really talking about a Chinese bank and, secondly, whether the new financial institution would lower the high standards applied by existing multilateral development banks in terms of governance structure, environmental and social standards, transparency, and procurement policies (Harpaz, 2016: 15). From a geo-economic perspective, many feared that China would use the AIIB bank to export excess industrial capacity and strengthen the international acceptance of the Chinese currency. The Chinese economy had very significant excess capacity in the steel, energy, and construction sectors, where domestic profitability was declining. It was reported that China initiated to establish the AIIB bank for the purpose of generating new business opportunities and foreign market access for Chinese heavy industry (Sun, 2015: 27). From a geopolitical perspective, the AIIB bank was thought to become the financing bank for the “one belt one road” project and part of Chinese foreign policy. In October 2014, nineteen mainly developing countries from West, South, and Southeast Asia (Bangladesh, Brunei, Cambodia, Cambodia, Kuwait, Laos, Kazakhstan, Malaysia, Mongolia, Myanmar, Nepal, Oman, Pakistan, Philippines, Qatar, Singapore, Sri Lanka, Thailand, Qatar, Uzbekistan, Vietnam) signed a Memorandum of Understanding (MoU) with China and India (Zhu, 2019: 137). Japan, Russia, South Korea, and Australia adopted a wait-and-see approach at the beginning. Japan and the US repeatedly underlined their concerns that the AIIB was not engaged enough to use internationally accepted standards of transparency and regulations of other multilateral development banks. The United Kingdom became the first truly dominant country to join the Bank in 2015. The British Finance Minister George Osborne reported that the United Kingdom intended to play a key role in ensuring the Bank’s high standards of transparency and governance. The British accession encouraged and accelerated applications for membership from Germany, France, Italy, Switzerland, Russia, South Korea, Brazil, and Turkey. At the end of 2015, fifty-seven countries had already joined the AIIB, of which thirty-seven were Asian and twenty from other continents. The rapid and unexpected increase in the number of shareholding member states – especially those from Western Europe – has posed a serious challenge for the Bank. In case the Bank would have concentrated on developing countries in Asia and their financial needs, and China would have controlled it, the Bank’s international legitimacy and influence would have remained very limited. The accession of the Western European countries clarified the issue, and the AIIB became a multilateral development bank dominated by donor countries recognized in the international financial and capital markets such as the International Bank for Reconstruction and Development and the Asian Development Bank (IBRD, ADB).

China's top priority has always been to ensure that the new bank actively contributes to infrastructure investments in Asia, providing an opportunity to exploit China's industrial capacity. Profit motives drove the European countries' accession and the desire to maintain internationally recognized best practices and environmental, social, and procurement standards in addition to the preference of their own infrastructure development companies in Asia.

After lengthy multilateral negotiations, the Asian Infrastructure Investment bank finally became a "new-age" multilateral development bank, along the lines and characteristics of the World Bank and the Asian Development Bank, except that the AIIB bank managed to implement some institutional innovations, such as a focus on infrastructure investment, a system of non-local board members, and global procurement and recruitment procedures. The main difference between the AIIB and the NDB banks is that the AIIB is a donor-dominated "North-South" development bank, like the former multilateral banks, while the NDB is a "South-South" development bank based on an equal shareholder structure (Zhu, 2019: 136). The AIIB bank, unlike the World Bank and the Asian Development Bank, which mostly finance their projects through capital contributions from member states, finances projects by borrowing on the international capital markets. Because of its link to the international capital markets, the AIIB has to apply high international standards and legislation, as applied by other multilateral development banks, in order to reduce the cost of borrowing. The AIIB has been co-financed from the outset by the World Bank, the Asian Development Bank, and the EBRD, and it has applied a set of environmental and social criteria very similar to those of these banks in order to increase its low-risk project lending and enhance its positive international reputation. Both of the two youngest multilateral development banks set up their climate finance targets after 2020. The New Development Bank strives to provide 40% within its overall funding for climate and environment protection targets in the period between 2022 and 2026. The Bank's climate finance activity reached 10% within the entire loan portfolio in 2021. The Asian Infrastructure and Investment Bank expects to reach 50% for climate protection goals within its loan volume by 2025. The bank reached a share of 29% within its loan portfolio disbursed for climate projects (Neunuebel, Thwaites, and Choi, 2022: 3).

5. Financing of the New Development Bank (NDB)

In 2021, the NDB financed a total of 74 projects worth USD 29.1 billion, an increase of 19.1% compared to the previous year. Loans to sovereigns accounted for 88% of the financing portfolio, with loans to non-sovereigns accounting for

12% of the total portfolio. In 2021, the Bank sought to achieve geographical balance in its portfolio across the founding member states. The emergency loans against the negative impact of the COVID-19 virus have brought the volume of lending to each founding member state into balance in terms of size. The Bank's regional branches established in South Africa, Brazil, and Russia also played a key role in expanding banking operations among the member states (NDB annual report 2021: 37). NDB's loan portfolio to Russia, Brazil, and South Africa increased from 32.4% in 2017 to 50.6% in 2021. With the addition of new members, the Bank aims to further diversify its funding geographically. Lending in local currency will continue to be one of the NDB's main and defining features and policies. Lending in the national currency of each member state increased from 21.1% to 23.3% of the Bank's total portfolio between 2020 and 2021. More than 70% of NDB-approved loans to China were disbursed in RMB (NDB Annual Report, 2021: 37). The Bank also lent in other currencies (EUR, CHF) to better meet customer needs. In 2021, the largest share of approved loan transactions (371%) was in EUR, 31.8% in RMB and 31.1% in USD. 31.6% of the Bank's total loan portfolio was allocated to COVID-19 epidemic recovery programmes, followed by transport infrastructure, urban development, and green energy project finance with 21.2%, 14.8%, and 13.5% shares respectively (NDB Annual Report, 2021: 4). In 2021, the NDB approved a total of ten projects with a total value of USD 5.060 billion. In 2021, the Bank's portfolio included 74 financing projects with a total value of USD 29.143 billion. The economic protection against the COVID-19 virus represented the largest share of Bank financing (89.7% – USD 9.201 billion). This was followed by the Bank's transport infrastructure financing at 21.2% (USD 86.185 billion) and renewable energy investments at 13.5% (USD 3.921 billion). Urban development projects accounted for 14.8% of the Bank's financing, irrigation and water management projects for 6.7% (USD 1.958 billion), and multi-sector projects for 5.3% (USD 1.552 billion) in 2021. Social infrastructure development projects accounted for 3.5% (USD 1.010 billion), environmental efficiency project finance for 2.4% (USD 700 million), and digital infrastructure development for 1% (USD 300 million) in 2021 (NDB Annual Report, 2021: 4).

6. Financing of the Asian Infrastructure Investment Bank (AIIB)

Efforts to create a global shared prosperity based on “South-South” cooperation, i.e. solidarity, have been arranged in the past mostly through bilateral channels. A good example is China, which strengthened its cooperation with certain African countries in a very significant way, establishing the multilateral Forum on China-

Africa Cooperation (FOCAC), which primarily served as an umbrella organization for China's bilateral relations with Africa. China has taken on the role of the main advocate of South-South cooperation, paving the way for the creation of an international financial institution specialized in financing infrastructure investments initiated by China (Abdenur, 2015: 3).

The Beijing-based multilateral development financial institution started operations on 16 January 2016 with fifty-seven member states, twenty of which were not located in Asia. By the end of 2021, the number of member states had risen to one hundred and five, of which eighty-eight were full members and seventeen were candidate countries (AIIB Annual Report, 2021: 14). Hungary joined the AIIB in the summer of 2017, which is expected to further expand Hungary's international financial and external economic connectivity in a dynamically developing region (Net 5). In addition to Hungary, Poland, Romania, Croatia, and Serbia from the Central and Eastern European region have also joined the Bank. The Bank's member countries account for 85% of the world's population and 65% of world GDP. The mission of the Development Bank is to finance the environmentally, socially, and financially sustainable infrastructure of the future. The AIIB's market position is defined by three distinct priorities: climate finance, cross-border infrastructure development, and private sector finance. In 2021, the AIIB financed a total of 51 projects across different economic sectors (green infrastructure, infrastructure network development and regional cooperation, technology development, private capital mobilization) for a total of USD 9.93 billion (AIIB Annual Report, 2021: 12). Energy, transport, and urban development projects were among the most financed sectors.

Table 6. *The number of the member countries of the AIIB 2021*

Year	Number of approved member countries	Number of regional member countries	Number of non-regional member countries
2016	57	37	20
2017	84	48	36
2018	93	50	43
2019	102	50	52
2020	103	50	53
2021	105	51	54

Source: https://www.aiib.org/en/news-events/annual-report/2021/_common/pdf/2021_AIIBAnnualReport_web-reduced.pdf – p. 14.

Table 6 provides us a transparent overview of how intensely the number of the regional and non-regional member countries of the Asian Infrastructure Investment Bank increased over the course of the five years under study.

Table 7. *Approved and disbursed credits of the AIIB*

Year	Annual approved investments (billion USD)	Disbursements (billion USD)
2016	1.69	0.01
2017	2.5	0.79
2018	3.31	0.62
2019	4.54	1.48
2020	9.98	6.23
2021	9.93	4.62
Total	31.95	13.75

Source: https://www.aiib.org/en/news-events/annual-report/2021/_common/pdf/2021_AIIBAnnualReport_web-reduced.pdf – p. 14.

Table 7 shows the steady demand for the credit lines of the Asian Infrastructure Investment Bank.

7. Conclusions

An analysis of the context in which the NDB and the AIIB banks were established and of their operating mechanisms shows that in the case of the New Development Bank, India was the initiator and had to fight with China for a long time to take the lead until it was agreed that the founding member states would have equal ownership and that the new development bank would focus on development concepts in developing countries. The NDB bank will be “South-South”, i.e. it will be specifically dedicated to the development interests of emerging and developing countries. In the case of the Chinese-initiated AIIB bank, on the other hand, China placed much more emphasis on the Bank’s excellent rating by US rating agencies and its international recognition and legitimacy, so with the accession of Western European countries, the Bank’s dominance by donor countries was no longer in question. For emerging countries, there is a serious dilemma between choosing a governance and development model based on international best practices, dominated by the “old traditional” donor countries, or a governance and development model based on the dominance of borrowing emerging and developing countries. On the one hand, it is easier for the AIIB to obtain a higher debt rating and issue bonds on more favourable financial terms in the international capital markets, while the NDB bank’s equal equity ownership structure provides a greater opportunity to present an alternative to the Bretton Woods global financial institutions and reform the current global development finance architecture. The NDB Bank is the first development bank in the world established by emerging and developing countries that does not include any developed country among its members, at least not in the initial phase. This phenomenon is a hallmark of

the transformation of the institutional architecture of international development finance. The relationship between the borrowing countries and the donor countries is a new type of “South-South” cooperation in the case of the New Development Bank and a new, but old, “North-South” cooperation in the case of the Asian Infrastructure Investment Bank. There is still a lack of trust between the emerging economies, as can be seen in the relationship between China and India. Another key factor is the ability of developed countries, given their structural strength, to influence the legitimacy of new international institutions through market pressure. Global governance can only become truly “global” if the emerging economies achieve a level of development that enables them to counterbalance and balance “Western” hegemony.

It is essential to mention that China plays a leading role in both new multilateral development banks. Through the establishment of the NDB and the AIIB, China has been able to play a key role in a development bank based on old Western operating mechanisms (AIIB) as well as in a hitherto unknown development bank focusing on development finance for emerging and developing countries. With the establishment of the NDB bank, emerging and developing countries see China as a mentor for their voice and global development policy vision, while the 30.8% stake in the Asian Infrastructure Investment Bank, established in parallel with the regionally based Asian Development Bank, assures China that it finally has an international development bank based on the Bretton Woods model that cannot be bypassed. China can thus become both a financier of developing countries and a developer of infrastructure at the global level, while at the regional level, on the Asian continent, it can also create a competitive environment for the Asian Development Bank.

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Interaction Effects of Agricultural Output Price and Agricultural Productivity on Industrialization in Sub-Saharan Africa

Anu Keshiro TORIOLA*

Department of Economics, Hallmark University, Ijebu-Itele, Nigeria

*e-mail: aktoriola@hallmarkuniversity.edu.ng

Oluwaseyi Adedayo ADELOWOKAN

Department of Economics, Olabisi Onabanjo University, Ago-Iwoye, Nigeria

e-mail: seyiadelowokan@gmail.com

Abstract. This study explores the interactive role of agricultural output price in the agricultural productivity and industrial output nexus. The data used are on sub-Saharan African countries as listed in the World Bank database of the World Development Indicators and Food and Agriculture Organization from 1995 to 2022. The results from the system-generalized method of moments estimation demonstrate that the agricultural output price increases the effect of agricultural productivity on industrial output. This result then shows that with a better agricultural output price, there will be a significant positive effect of agricultural productivity on the industrial output in sub-Saharan Africa. Thus, the study advocates the adoption of a counterbalanced agricultural output price policy in the form of subsidy through minimum price guarantee and government direct purchase to make the price stable and attractive for the teeming population and investors while also ensuring the affordability of the output for consumers across all income groups in the region.

Keywords: agricultural output price, industrialization, interaction effect, sub-Saharan Africa, system-generalized method of moments

JEL Classification: Q10, Q11, L60, C23

1. Introduction

The economies of many developing countries, including sub-Saharan Africa (SSA), are characterized by an unprecedented drift of workers out of the primary-agrarian sector to industry and services, with services receiving the larger share. This low share of industry in employment compared to services (referred to as

de-industrial productivity) in SSA has culminated in a decline in agricultural produce, the range of agricultural produce, and its volume of exports (Rodrik, 2016).

Data published by *Africa's Pulse*, a World Bank Group, in 2019 on the structural transformation in SSA revealed that the service sectors with a lower share of employment compared to the agricultural sector has the highest value added in terms of productivity, while agriculture with the highest share of employment has the least value added. Meanwhile, the proportion of industry in total employment and value added is the lowest among the three sectors (World Bank, 2019). Consequently, industrial productivity in the region has been weak and uneven (World Bank, 2021). Thus, features of de-industrialization, such as declining output, rising input costs, and dearth of factories, prevail across most economies in SSA. This has positioned the region's ranking as one of the least in the share of global manufacturing (United Nations Industrial Development Organization, 2020).

The debate in the literature is whether lowering agricultural output price can help extract surplus from agriculture for rapid industrialization (Fardmanesh, 2017; Tomek and Kaiser, 2014). Meanwhile, low pricing of agricultural products in the market creates favourable price incentive for manufactured goods at the expense of agricultural products (Tomek and Kaiser, 2014). This disparity in output price between the two sectors has been attributed as the core reason for the sectoral disparity in productivity and the resultant decline in the role of agricultural sector in favour of the industrial sector (Dastagiri and Bhavnaga, 2019). Since there is linkage and interdependence between agriculture and industry via the supply of raw materials and food from the agricultural sector to the industry and, in return, the provision of manufactured and agro-allied products by industry for agricultural use, changes in agricultural prices will have effect on industrial growth (Guda, Dawande, Janakiraman, and Rajapakshe, 2021).

According to Rattso and Torvik, (2003), the price of agricultural products negatively affects output in the sector, while the output is positively related to the price in industry due to nominal wage response (Xie and Wang, 2017). Thus, government intervention in the agricultural sector, particularly in developing countries, through the use of incentive policies – specifically output price support – is expected to have implications for the dynamics of agricultural production and subsequently industrialization in economies undergoing rapid transitions. This price support involves government intervention to maintain minimum prices for agricultural commodities, ensuring profitability for farmers (Lin and Huang, 2021; Guda, Dawande, Janakiraman, and Rajapakshe, 2021). Among numerous agricultural support incentives, the output price support, or subsidy, offers more beneficial effects in enhancing the total income of farmers (Tang, Wang, and Zhao, 2023).

In the extant literature, there is a paucity of studies on the interaction effects of agricultural output price on industrial output in sub-Saharan Africa (Mendes,

Bertella, and Teixeira, 2014). The few available evidence not only covered a limited number of SSA countries with conclusions that may not apply to all the countries in the region (Rodrik, 2016; Nguimkeu and Zeufack, 2019) but also ignored the important interactive role of agricultural output price in analysing industrial productivity. Also, while some studies provide evidence of de-industrial productivity in SSA, several other studies argue that it is too early to submit that the region's industrial productivity potential can no longer be realized (Kruse, Mensah, Sen, and Vries, 2021). This study aims to offer an additional insight into the literature based on the inconclusive evidence of existing studies on the effect of agricultural productivity on industrial productivity. This study addresses this lacuna by examining how agricultural output price through its interaction with agricultural productivity impact industrial output in sub-Saharan Africa.

This study investigates the interaction effect of agricultural output price and agricultural productivity on industrialization in sub-Saharan Africa. The specific objectives of the study are to investigate the effect of agricultural output price on industrialization, determine the effect of agricultural productivity on industrialization, and examine the interaction effect of agricultural output price and agricultural productivity on industrialization in sub-Saharan Africa.

This study contributes to the literature by demonstrating with the use of empirical literature and statistical data the intricate relationship between agricultural productivity, industrial output, and agricultural output prices in SSA. Thus, the study provides a more comprehensive understanding of economic development in SSA and underscores the importance of the competitiveness in the agricultural sector and strategic agricultural output pricing for broader economic development. The study also offers empirical support for the idea that adjusting output prices can lead to a reallocation of resources from agriculture to industry, fostering industrial growth.

This empirical analysis sheds light to the forces that power agricultural labour exits and the reasons why the agricultural sector remains the largest employer of labour and why the income of rural dwellers, who are predominantly farmers, remains so low. The analysis of the effect of agricultural output price will help policy makers in introducing attractive pricing policies with a view to stabilizing prices of agricultural output and ensuring an adequate production and supply of food. The study would inform policies capable of enhancing the welfare of the general consumers through improved access to locally made manufactured products and food supply that can be well compared to international market prices through an effective pricing redistributive policy. This research will promote awareness and serve as a source of valuable information for future analysis of agricultural output prices in sub-Saharan Africa in the field of development economics, especially industrial economics and agricultural economics as well as microeconomics.

The rest of the study is organized as follows. Section 2 presents a literature review followed by Section 3 on methodology. In Section 4, the focus is on results and discussion, while in Section 5 the conclusions and recommendations are presented.

2. Literature Review

Industrialization can be conceptualized as a social and economic process that brings about a transformation of the society from a traditionally purely agrarian economy into a modern advanced and more socialized economy. Industrialization is the prominence of a process involving a range of industrial plants opened by several entrepreneurs over a slower timescale in local economies and changing the outlook of regional economy (Simandan, 2009). Although industrialization can occur for a variety of causes – because it has no single cause –, its consequences vary widely across geographical regions and historical times. The English Industrial Revolution took into account factors that have been ignored hitherto such as genetic changes and urbanization, while for all other cases of industrialization the imitation factors that contributed to the process of industrialization are capitalism and modernization.

On the other end, agriculture is sometimes limited to only the cultivation of crops, with animal domestication excluded, but it generally covers both (Harris and Fuller, 2014). The price of agricultural output is, in theory, the price one pays for that item at their farm gate or village site (Chandrasekhar, 2013). Agricultural product prices are significantly more volatile than other non-farm products and services (Fitria, Harianto, Priyarsono, and Achسانی, 2019). Consequently, a change in the expected price of the farmers will lead to a relatively lower change in supply in the shorter term or in the long run; as such, price is inelastic. Despite the fact that agricultural product prices are more volatile than many other prices, the average of a group of prices (indexes) is less volatile. This is known as the fixed-flex model (Andrews and Rausser 1986).

Output price support involves government intervention to maintain minimum prices for agricultural commodities, ensuring profitability for farmers (Lin and Huang, 2021). According to Guda, Dawande, Janakiraman, and Rajapakshe (2021), output price support represents the minimum price at which the government commits to purchasing a unit of a particular crop from farmers. The determination of this price involves considerations of production costs, demand–supply dynamics, and the need to incentivize farmers.

Several theories abound: the Kaldor model of manufacturing sector and three-sector hypothesis, circular cumulative causation theory by Myrdal. The Kaldor (1967) model of manufacturing sector and economic development is relevant to

this study because the model based on the experience of Western Europe explains that agricultural modernization is a precondition to achieving a continuous rise in industrial output. That is, industrial productivity is determined by growth in agricultural modernization, which provides the source of food supply and labour that is needed in the non-agricultural sector. Furthermore, the model believed that as the industrial sector progresses, growth in productivity in other sectors, including agriculture, the service sectors, and the economy at large, will increase via the positive spillover effect in the form of technological advancement and complementary markets in the service sector. The three-sector hypothesis of structural shifts is relevant to this study because it has separated economy into two categories: the technological advancing segment and the non-progressive unit. These units are differentiated, as the progressive sector uses more technology, while the non-progressive uses more labour. As such, cost disease affects the non-progressive sector more because wage rate and output growth are higher in the progressive sector, which is the industrial sector. Thus, output and price are consequently favourable in the sector compared to agriculture.

In the literature, most previous studies on agricultural productivity and industrial productivity linkage concentrated on one particular side of the coin. While some of the studies focused their attention on the effect of agricultural productivity on industrial productivity, evidence also abounds in studies focused on the reverse side of the issue. Although there are sparse studies on the role of agricultural support incentives in agricultural productivity, the role of agricultural output price has been largely ignored in the analysis of the linkage relationship between the two sectors.

On the linkage between agricultural productivity and industrial productivity, Subramaniam and Reed's (2009) study employed a Vector Error Correction Modelling to examine the connections between various sectors, namely agriculture, manufacturing, service, and trade in Poland and Romania. They found that these sectors in both countries exhibited similar patterns over the course of the study, indicating interdependency in their growth rates. Notably, a long-term relationship was established between industry, services, and trade and trade sectors and agriculture. In Poland, the industrial sector had a positive impact on agriculture, while the service sector showed mixed results. In Romania, the industrial sector had an adverse effect on agriculture, but the service sector made a positive contribution. Short-term results indicated that the service sector played a significant role in the Polish economy, positively affecting other sectors, while the industrial sector had a negative impact. A similar pattern was observed in the Romanian economy, although the results were not statistically significant. As expected, the role of agriculture in the short run was not significant in its impact on other sectors, except for a direct influence on industry in Romania.

Using a system of simultaneous equations, Onakoya (2013) explored the relationships between services, oil and gas, the manufacturing and agricultural

sectors. The study revealed that the intersectoral relationships are complex and bidirectional. Interactions and linkages between sectors generated externalities and spillover effects. Furthermore, the study found that the role of agriculture was unidirectional, with capital mainly flowing towards oil and gas, tertiary services and industry. Interactions between sectors were sometimes detrimental. Waniko (2016) empirically investigated the causal nexus between agricultural sector components and other sectors in Nigeria's economy, using vector error correction and data spanning from 1981 to 2012. The research found that agriculture and industry have a causal relationship in the long run.

Shifting the focus towards agricultural support incentives and their impact on agricultural productivity, Su, Heerink, Oosterveer Tan, and Feng (2021) conducted a research to investigate the effects of the Minimum Grain Procurement Price Programme on households' use of chemical fertilizers and pesticides. Their study utilized panel data regression techniques and found that the programme had a negative effect on chemical fertilizer and pesticide use. While higher grain prices resulting from the programme increased agrochemical use, the study identified counteracting effects, as the programme further inspired areas for expansion, resulting in the use of lesser agrochemical per unit of land. The direct negative effect of the procurement price of rice on fertilizer and pesticide use was found to be significant.

In a similar vein, Lin and Huang (2021) conducted an empirical analysis to determine how government policies in agriculture affect land rental prices. They looked at three main policies: agricultural tax, agricultural subsidy, and output price support. Their findings showed that when the government removed agricultural tax on cultivated land and introduced price support policies, land rental prices went up significantly. However, the impact of agricultural subsidies given to contract holders or owners on land rental prices was not significant. Another study by Tang, Wang, and Zhao (2023) explored the effects of input and output farm subsidies on farmer welfare, income inequality, and consumer surplus. Using a game-theoretical model, they found that both subsidy types reduced overall income inequality, but they had different effects. The input subsidy decreased income inequality among farmers, while the output subsidy increased it. Farmers with low yields preferred the input subsidy, while those with high yields favoured the output subsidy. Overall, the output subsidy was more effective in increasing total farmer income, while the input subsidy was better at reducing income disparities and improving consumer surplus.

Also, von Cramon-Taubadel and Goodwin (2021) employ a comprehensive review of new advancement in the transmission of price in the market of agricultural products, focusing on spatial and vertical linkages. The methodological approach involves the use of increasingly nonlinear time-series models to understand spatial market linkages. The study finds that spatial market integration is a crucial

aspect of agricultural markets, influencing the relationships between prices in different geographical locations. Adeeth Cariappa, Acharya, Adhav, Sendhil, and Ramasundaram (2022) investigate the effects of the 2019 coronavirus lockdown on the price of agricultural commodity and consumer behaviour in India. The study employs time series approach based on data collected from seven hundred and twenty-nine consumers and two hundred and twenty-five farmers and a synthesis of literature on food loss and waste. The findings highlight significant price increases for certain commodities post-lockdown, consumer behaviour shifts, and disruptions in farmers' ability to dispose of produce. Despite panic purchases leading to initial food wastage, the study emphasizes the resilience of the Indian agriculture.

3. Methodology

The ex post facto research design was applied in this study. The research design was deemed appropriate because the main goal of this analysis is to explore the nexus and explain why and how the independent variables best predict variations in the dependent variable based on the use of empirical data.

In order to investigate the interaction effect of agricultural output price and agricultural productivity on industrial output in sub-Saharan Africa, this study adapted the model used in the study conducted by Dholakia and Sapre (2013), where they used two dynamic regression equations to estimate the responsiveness of the growth of agricultural and total output to changes in relative output prices. As a modification to the model, since the present objective is the interaction effect of agricultural output price and agricultural productivity on industrial output, a single dynamic equation was employed as follows:

$$Y_{lit} = \alpha Y_{lit-1} + \beta Y_{Ait} + \rho P_{Ait} + \delta P_{Ait} \times Y_{Ait} + \sum_{j=1}^J \gamma_j Z_{jit} + \theta_i + \varepsilon_{it},$$

where i , the cross-sectional identifier, stands for i^{th} country and t , the time identifier, for the i^{th} year; θ_i is the country-specific fixed effect, Y_{lit-1} is the lagged value of Y_{lit} of country i at time t , Y_{lit} is the industrial productivity proxy by the industrial value added of country i at time t , Y_{Ait} is agricultural productivity of country i at time t , P_{Ait} is the price of agricultural output of country i at time t , $P_{Ait} \times Y_{Ait}$ is the interaction term of country i at time t , and Z is a vector of control variables (Gujarati, 2004; Asiedu, 2013). The data is on forty-eight (48) cross-sectional units (i) over the period of twenty-eight (28) years from 1995 to 2022 (t).

The data employed in this study covers forty-eight (48) sub-Saharan Africa (SSA) countries as listed in the World Bank 2022 data on sub-Saharan Africa (World Bank, 2022). Twelve (12) countries comprising Comoros, Congo, Dem. Rep., Eswatini,

Gabon, Lesotho, Liberia, Mauritania and Sao Tome, Uganda, Sudan, South Sudan, Somalia, and Principe were excluded from the analysis due to unavailability of data on agricultural output price and capital employed in agriculture for the selected years. Consequently, the number of countries used in the region of sub-Saharan Africa is 36. The selection of sub-Saharan Africa as the focus of this study stems from the disparities in the distribution of benefits of the transition process among countries in this region. Some countries have achieved more success in this transition compared to others, as highlighted by Subramaniam and Reed in 2009. Furthermore, the transition process in sub-Saharan Africa is notably slower compared to other developing regions. Many of these countries continue to have a significant portion of their workforce employed in the agricultural sector, which distinguishes them from industrialized countries, as noted by the World Bank in 2019.

The data used in this study was sourced from the World Bank's World Development Indicator and the Food and Agricultural Organization. The dataset spans a period of 28 years, covering the years from 1995 to 2022. This extended timeframe allows us to build upon the analysis of structural transformation in SSA presented by the World Bank in 2019. Specifically, it offers insights into the patterns of structural transformation in the region, particularly in terms of the movement of labour from one sector to another. For more detailed information about the data sources and units of measurement, refer to *Table 1*.

Table 1. *Variable description and sources of data*

SN	Variables	Description Symbol	Operational Definition	Sources
1	Agricultural productivity	Y_{Ait}	Agriculture, value added	World Development Indicators (2022)
2	Industrial productivity	Y_{Iit}	Industry, value added	World Development Indicators (2022)
3	Agricultural output price	P_{Ait}	Agriculture producer price index	Food and Agricultural Organization (2022)

Source: authors' compilation (2023)

Theoretically, a positive or negative relationship is expected between agricultural output price and agricultural productivity in the economy because agricultural output price, being the price faced by producers, reflects the incentives for production and investment. When the relationship is negative, it implies that agricultural output price provides no or less incentive to produce more output, and when it is positive, the price provides incentives for production. The lagged value of agricultural productivity is also expected to have a positive relationship with agricultural productivity. The interaction term is expected to have a negative effect on industrial productivity because it measures the farmers' total income for

any productive time period, and as such a rise in farmers' income will raise current production, thereby shifting resources against industry, but a decline in farmers' income is expected to shift resources in favour of industry.

By its very nature, this study involves the analysis of panel data because it aims to analyse movement over the time of subjects across successive states, countries, or conditions. In the analysis, the study applies three procedures consisting of the pre-estimation, estimation, and post-estimation of the model. In pre-estimation, the study uses the normality test (Jarque–Bera), the test for multicorrelation (correlation matrix), the unit root test (Levin, Lin, and Chu (2002), Augmented Dickey–Fuller and Phillips–Perron tests proposed by Maddala and Wu (1999) and Choi (2001)), and the panel cointegration test (Pedroni's (1999) methodology). Both the system GMM estimator proposed by Blundell and Bond (1998) and Konya (2006) and the causality test will be employed in the actual estimation, while the tests for serial correlation, validity of instruments and OLS and within group (fixed effects) tests will be used for the post-estimation.

The system-generalized method of moments (GMM) estimator proposed by Blundell and Bond (1998) will be used to analyse models one, two, and three because it makes use of more instruments compared to differenced GMM and provides a more efficient estimator through the use of additional moment conditions to offset the poor instruments problem. It is also less biased than the difference GMM estimator because it is a weighted sum of the difference and the level estimator, and these biases move in opposite directions (Gujarati, 2004; Hayakawa, 2007).

4. Results and Discussion

The estimation approach employed in the study was informed on the basis of the preliminary tests that were undertaken to help attain this aim of the study. To check the accuracy of the estimates, post-estimation tests using the Wald test, normality test, and Arellano–Bond Serial (ABS) correlation test were also conducted.

4.1. Preliminary Analysis

This preliminary analysis, which includes a descriptive analysis, a multicollinearity test, and a unit root test, is presented in *tables 2, 3, and 5*.

As can be observed by the higher-than-one ratio between the standard deviation and mean of the variables, the descriptive statistics summary in *Table 2* reveals that YI, YA, and PA values varied significantly over time and between countries. As a result, it is possible that the distribution of the variables across nations and times is neither symmetrical nor bell-shaped. In other words, the Jarque–Bera statistics will be near zero. The significant level of variability in the dataset is confirmed by

the high standard deviation of the variables: 7.79, 0.86, and 0.89 for YI, PA, and YA respectively. Because of the heterogeneity properties implied by the standard deviation, the appropriateness of the SGMM dynamic panel approach is justified.

Table 2. *Descriptive statistics*

	YI	PA	YA
Mean	0.353	0.089	0.122
Median	0.057	0.045	0.049
Maximum	230.514	20.892	18.144
Minimum	-0.998	-0.999	-0.994
Std. Dev.	7.788	0.858	0.893
Skewness	29.376	19.305	14.324
Kurtosis	868.439	438.996	253.476
Jarque–Bera	27589306	6721398	23781.2
Probability	0.000	0.000	0.0000
Observation	880	842	898

Source: authors' compilation (2023)

Notes: YA: agricultural productivity; PA: agricultural output price. The variables remain as defined in *Table 1* in Section 3.

Despite the region's abundant agricultural resources, the average agricultural productivity (YA) value, which is 12%, is low. Additionally, the mean is skewed towards the minimum value (Min. = -0.9943; Mean = 0.1215; Max. = 18.1435), indicating that agricultural output across the time period and nations is often poor.

The average agricultural output price (PA), which is 9%, is likewise quite low. Meanwhile, the low agricultural output price will have an impact on total harvest, yields, or production in future periods, making the sector less desirable for capital investment and employment, which will then have a negative impact on the supply of raw materials to industry. Another indication of the low value of agricultural production price across nations and time periods is the fact that the mean tends towards the minimum value (Min. = -0.9995; Mean = 0.0892; Max. = 20.8920).

Due to the fact that their means are higher than the median, YI, YA, and PA have a long right tail (i.e. positively skew). Additionally, these variables exhibit kurtosis values larger than three, indicating leptokurtic behaviour. The probability value of the Jarque–Bera statistics for the variables YI, YA, and PA is less than the crucial value of 0.05. This indicates that these variables do not follow a normal distribution.

Given the linear nature of the link between the variables in the model, it was determined that the Pearson's correlation technique was appropriate for this investigation (i.e. continuous-level variables). The findings of the correlation analysis are reported in *Table 3* below.

Table 3. *Correlation matrix*

	YI	PA	YA
YI	1.000		
PA	-0.029	1.000	
YA	0.092	-0.092	1.000

Source: authors' compilation (2023)

Notes: YA: agricultural productivity; PA: agricultural output price; YI: capital employed in agriculture.

The correlation coefficient between YI and YA shows a positive sign, as demonstrated in *Table 3*. This shows that there is a positive correlation between industrial output and agricultural productivity. These facts suggest that as agricultural productivity increases, so will industrial output and vice versa.

Contrary to expectations, the YI and PA and the YA and PA correlation coefficients are negative. This finding indicates that agricultural output price has an inverse relationship with agricultural productivity and industrial output. The negative correlation between industrial output and agricultural output prices in SSA indicates that the negative association between agricultural output price and agricultural productivity lead to a negative association with industrial output. That is, an adverse association between agricultural output price and agricultural productivity will also lead to a negative association between agricultural output price and industrial output.

Table 4. *Lag selection*

	LR	FPE	AIC	SC	HQ
0	-2033.435	NA	0.649	8.106	8.091
1	-1675.968	709.260	0.163	6.799	6.738
2	-1631.840	87.031	0.142	6.735	6.628
3	-1624.626	14.141	0.143	6.817	6.665
4	-1620.002	9.010	0.145	6.910	6.712
5	-1617.695	4.466	0.149	7.012	6.768
6	-1611.486	11.951	0.151	7.099	6.808
7	-1606.378	9.770	0.153	7.189	6.853
8	-1604.119	4.293	0.157	7.292	6.909

Source: authors' compilation (2023)

Notes: * indicates the lag order selected by the criterion; LR: sequential modified LR test statistics; FPE: Final Prediction Error; AIC: Akaike Information Criterion; HQ: Hanan-Quinn Information.

Since the use of a simple correlation coefficient in the case of two explanatory variables of 0.8 as a rule of thumb to detect multicollinearity can lead to misleading results, detecting multicollinearity even where it does not exist, the study focuses primarily on whether or not there is a perfect collinearity (Gujarati and Poter, 2009;

Wooldridge, 2010). Since no pair of variables displays complete collinearity and the correlation coefficients are less than 0.8, there is no tendency for the estimates to be skewed. *Table 4* displays the outcome of the lag order selection criterion.

According to the results provided in *Table 4*, the maximum number of two (2) lags that met the requirements of the LR, FPE, AIC, and HQ criteria was shown to be adequate.

For robustness, three (3) panel data unit root tests were used: Levine, Lin, and Chu-LLC (2002), Augmented Dickey–Fuller Fisher (ADF-Fisher), and Phillips–Perron Fisher (PP-Fisher). No trend and intercept, intercept simply, and trend and intercept were all given in the specification. The individual nation heterogeneity (individual unit root) and the individual country common or homogeneous aspects are both addressed by built-in methods in both tests. *Table 5* presents this finding.

Table 5. *Panel unit root*

Spec.	Vari- ables	LLC-t statistics		ADF-Fisher chi-square		PP-Fisher chi-square		Order
		Level	First Diff.	Level	First Diff.	Level	First Diff.	
No trend and intercept	YI	-18.421*** (0.000)	-36.073*** (0.000)	424.948*** (0.000)	834.989*** (0.000)	3.7409 (0.000)	817.533 (0.000)	I(0)
	YA	4.301 (1.000)	-5.381*** (0.000)	17.772 (1.000)	70.528 (0.329)	13.189 (1.000)	610.172*** (0.000)	I(1)
	PA	3.504 (0.999)	-5.022*** (0.000)	27.527 (0.999)	55.410 (0.497)	23.005 (1.000)	734.984*** (0.000)	I(1)
With intercept only	YI	198.042 (1.000)	154.572 (1.000)	330.667*** (0.000)	639.551*** (0.000)	946.216 (0.000)	1032.660*** (0.000)	I(0)
	YA	-3.214*** (0.001)	29.290 (1.000)	64.727 (0.521)	48.470 (0.948)	29.351 (1.000)	476.034*** (0.000)	I(0)/I(1)
	PA	-1.819** (0.035)	20.731 (1.000)	38.913 (0.960)	50.706 (0.675)	49.015 (0.983)	638.028*** (0.000)	I(1)
With intercept and trend	YI	222.150 (1.0000)	174.07 (1.000)	256.532*** (0.000)	628.454*** (0.000)	3380.580*** (0.000)	6561.58*** (0.000)	I(0)
	YA	32.714 (1.0000)	46.532 (1.000)	31.7220 (0.999)	33.395 (0.997)	80.840 (0.223)	356.127*** (0.000)	I(1)
	PA	22.171 (1.000)	30.118 (1.000)	38.461 (0.965)	55.864 (0.480)	100.802** (0.014)	949.022*** (0.000)	I(0)

Source: authors' compilation (2023)

Notes: ***, **, and * denote significance at 0.01, 0.05, and 0.10 critical values respectively. YI: industrial output; YA: agricultural productivity; PA: agricultural output price.

According to the findings presented in *Table 5*, agricultural productivity (YA) and agricultural output price (PA) are stationary at first difference, while industrial output is stationary at level based on the three panel unit root tests and the specifications used.

4.2. Empirical Results

System-generalized method of moments (SGMM) is used to estimate the model to determine the interaction effect of agricultural output price and agricultural productivity on industrial output. The outcome produces a GMM-type instrument based on Arellano and Bond (1991) that solely uses internal instruments based on the lag one of all exogenous variables as the standard instrument. *Table 6* reports the outcome.

Table 6. *Dynamic system GMM estimates*

Variables	Dependent variable: Agricultural productivity (YA)			
	Coefficient	Std. Error	t-statistics	Probability
Lag of industrial output Y_{lit-1}	-0.007***	0.001	-4.808	0.000
Agricultural output price P_{Ait}	0.001***	1.691	-87.409	0.000
Interaction of agricultural output price and agricultural productivity $P_{Ait} * Y_{Ait}$	0.002***	2.480	83.246	0.000
F-test of joint significance	F = 2.6411			
Arellano bond for AR(1) in first difference	Z = -2.106**, pr < z = 0.035			
Arellano bond for AR(2) in first difference	Z = -0.699, pr < z = 0.484			
Hansen J-test of overriding restrictions	Pr > chi(2) = 0.497			
Number of instrument	36			
Number of countries	36			
Number of observations	702			

Source: authors' compilation (2023)

Notes: ***, **, and * denote significance at 0.01, 0.05, and 0.10 critical values respectively.

In the results summarized in *Table 6*, although both the lag of industrial output and that of agricultural output price proved to be significant in the model, the main consideration is on the coefficient of the interaction between agricultural output price and agricultural productivity. The interaction effect of agricultural output price on the relationship between agricultural productivity and industrial output can be stated as follows:

$$\frac{\Delta YI}{\Delta YA} = \beta_1 + \beta_2 \overline{P_A},$$

where β_1 is the coefficient of PA, β_2 is the coefficient of the interactive term (i.e. the coefficient of PA * YA), while $\bar{P}_A$ is the mean value of PA displayed in *Table 6*. The result of the computation is given as:

$$\frac{\Delta YI}{\Delta YA} = 0.001 + 0.002(0.0892) = 0.003.$$

This shows that, on the average, with agricultural output price, a percentage increase in agricultural productivity would increase industrial output by 0.0003 percentage points. This implies that agricultural output price increases the effect of agricultural productivity on industrial output. This then shows that with a better agricultural output price, there will be a significant positive impact on industrial output, as the positive effect of the variable on its own on agricultural productivity is capable of promoting industrialization. This result is particularly interesting, as it provides credence to the key argument in this study that the price factor, especially agricultural output price, is capable not only of enhancing productivity in agriculture but also of achieving industrialization, especially in developing countries like SSA, which are at the early stages of development and are predominantly mono-product economies exporting only primary commodities, with agricultural product constituting the bulk of such exports. The result conforms to Preobrazhensky's (1926) first premise (P1) that a price policy in the form of a lower output price, which forced a reallocation of resources from agriculture to industry, will necessarily promote industrialization and subsequently raise national income in the short term and promote growth in the longer term. Nonetheless, such policies in the view of Martin and Warr (1990) may also impoverish the rural population and frequently lead to food shortages.

Table 6 also shows that the number of the model's instrument, which is thirty-six (36), is less than the number of observations, which is seven hundred and two (702). As a result, the estimates are free of the issue of instrument proliferation, which may lead to the overfitting of endogenous variables and may reduce the effectiveness of Hansen's test to determine the validity of the instruments (Roodman, 2009). Also, the AR(2) coefficients ($Z = -0.6999$, $pr < z = 0.4839$) are not statistically significant at the 5% level; there is no evidence of second-order auto-correlation in the model specification. Finally, *Table 6* shows that the instrument sets are not overidentified according to Hansen's statistics ($Pr > \chi^2(2) = 0.4966$), which is not statistically significant at the 5% level.

5. Conclusions and Recommendations

The results of the SGGM estimation for the interactive role of agriculture output price in the agricultural productivity and industrial output nexus demonstrates that a percentage increase in agricultural productivity would increase industrial

output by 0.0003 percentage points. This result implies that agricultural output price increases the effect of agricultural productivity on industrial output. This result then shows that with a better agricultural output price, there will be a significant positive impact of agricultural productivity on industrial output in SSA. In line with Tomek and Kaiser (2014), this study supported the premise that low agricultural output price has adverse implications for productivity in the sector and may worsen rural dwellers' welfare and standard of living and thereby translate to shortages in food production (Martin and Warr, 1990). Besides, evidence also shows that higher agricultural output price, which is favoured by the findings from this study, can be an obstacle to industrialization through high costs of industrial input supplies from agriculture (Fardmanesh, 2017). Thus, findings suggest that government intervention in the agricultural sector, particularly through output price support, becomes imperative.

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The result conforms to Preobrazhensky's (1926) first premise (P1) that a price policy in the form of a lower output price that forced a reallocation of resources from agriculture to industry will necessarily promote industrialization and subsequently raise national income in the short term and promote growth in the longer term. Nonetheless, such policies in the view of Martin and Warr (1990) may also impoverish the rural population and frequently lead to food shortages. The result corroborates the findings reported by Xie and Wang (2017) that changes in grain yield production in China are influenced by changes in agricultural product prices. It is also consistent with the findings of Miecinskiene and Lapinskaite (2014) that changes in commodity prices in the global market, especially the prices of aluminium, cocoa, coal, and oil, determine the changes in the aggregate price level in Lithuania. It is also in tandem with the result reported by Huka, Rouja, and Mchopa (2014) that price fluctuations in agricultural productivity are barriers to small-scale farmer growth, resulting in capital loss and farmers' shifting to other production activities. The findings also align with the result of Thiele (2003) that pricing policies, macroeconomic distortions, and certain non-price factors have a long-run relationship with agricultural productivity. It is also in line with Akanegbu's (2015) finding that agricultural price distortions have a major and negative effect on agricultural production.

The contribution of this study is manifold. The study's focus on SSA economies, often characterized by mono-product exports, predominantly agricultural, makes

it highly relevant to the region's economic development challenges. It contributes to the understanding of how pricing mechanisms affect resource allocation and sectoral shifts, providing region-specific insights into this global economic transition. By exploring how agricultural price levels affect wage costs in industries, the study uncovers essential dynamics often overlooked in previous research. This study sheds light on the ongoing transition of workers from the primary-agrarian sector to industry and services in SSA. This transition is a critical aspect of the region's economic development, and the research contributes to a deeper understanding of this shift. It recognizes the continued dependence of the majority of the population in SSA on agriculture for their livelihoods. The study employs rigorous sophisticated econometric technique, specifically the SGGM estimation; as such, the study adds a valuable quantitative dimension to the existing literature, allowing for more precise conclusions and policy recommendations.

By demonstrating the amplifying effect of agricultural output prices on the relationship between agricultural productivity and industrial output, this study provides valuable policy implications. Policymakers can use these findings to design strategies that promote agricultural productivity and ensure stable output prices, which can, in turn, foster industrialization and economic growth. The findings inform strategies aimed at balancing sectoral growth and enhancing overall economic productivity. Additionally, the study suggests potential areas for future research, guiding scholars towards unexplored avenues in the field.

The study is limited by data availability and relies on the accuracy and dependability of the secondary sources from where the data are collected, including the Food and Agricultural Organization and the World Bank database for the World Development Indicators. The issue of data availability limited the scope of the study to the period of 1995–2022, and the countries covered were limited to thirty-six (36) out of the forty-eight sub-Saharan African countries. However, these limitations are not necessarily a threat to the result of the findings given the coverage of a substantial number of countries in the region and the sufficiency of the number of years.

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Poverty, Education, Income Inequality Nexus in South Africa: A Multivariate Approach

Mercy T. MUSAKWA,¹ Nicholas M. ODHIAMBO²

¹Department of Economics, University of South Africa, South Africa
e-mail: tsile.musa@gmail.com

²Department of Economics, University of South Africa, South Africa
e-mail: odhiambo@unisa.ac.za / nmbaya99@yahoo.com

Abstract. This study investigated the causal relationship between poverty, income inequality, and education in South Africa, using annual data from 1990 to 2020. The main objective of the study was to establish the causal relationship between the three variables to provide insight to policymakers. Two poverty proxies were used, namely household consumption expenditure and infant mortality rate. Using the autoregressive distributed lag (ARDL) approach to cointegration and error correction model (ECM)-based causality analysis, the study found the causality between poverty, income inequality, and education to vary depending on the poverty proxy used. Based on these findings, it is recommended that South Africa should continue with a three-pronged policy focus on poverty, inequality, and quality education.

Keywords: inequality, Human Development Index, household consumption expenditure, autoregressive distributed lag, South Africa, poverty, education

JEL Classification: I24; I32; I38; C32

1. Introduction

South Africa has battled with poverty and inequality since its declaration of independence (Leibbrandt, Wegner, and Finn, 2011). The past political regime that favoured certain races to others contributed largely to the currently experienced inequality. Though the government has put in place programmes to redress these challenges, poverty levels and inequality have not decreased as expected (Leibbrandt et al., 2011). The government has put in place social safety nets aimed at redistributing wealth to the poor and closing the inequality gap. Several studies have examined how poverty can be alleviated in South Africa using different macroeconomic variables such as remittances (Gupta, Pattilo, and Wagh, 2009;

Nahar and Rashad, 2017; Tsaurai, 2018), foreign aid (Masud and Yontcheva, 2005; Calderon, Chong, and Gradstein, 2006), and economic growth (see Adam Jr, 2003; Zhu, Bashir, and Marie, 2022). These studies found inconclusive results, where the country of study, methodology, and measures of poverty were identified as some of the factors causing varied findings. Separate studies have also investigated the link between poverty alleviation and inequality (Chaudhary et al., 2010; Awan et al., 2011). Despite the findings in the existing literature, the fact remains that more must be done to find a lasting solution to inequality and poverty in South Africa. According to a study done by Tregenna and Tsela (2012), South Africa has a high level of inequality. The main source of inequality was found to be earnings, which require intentional government policies to redress.

This study adds value to the current literature by examining the causal relationship between education, inequality, poverty, and unemployment using the Autoregressive Distributed Lag approach to cointegration and ECM-based Granger causality approach. The ARDL approach was selected due to its numerous advantages. Among the few studies that explored the relationship between poverty and inequality, panel data was used. Given the multidimensional aspects of poverty measurement, this study employs household consumption expenditure and infant mortality rate as measures of income and health poverty respectively. This study departs from these studies by using annual time series data for South Africa. This allows an analysis of the causal relationship specifically related to South Africa without pooling data from different countries together. Although statistical techniques are used in panel data analysis to take care of in-group and between-group variation, it is expected that results from this study will be more informative in a poverty–inequality–education nexus.

According to Leibbrandt et al. (2011), South Africa continues to battle with the challenge of rising income inequality since its declaration of independence. Even National Development Plan 2030 highlights unemployment growth, poverty, and inequality as the major challenges facing the country (National Planning Commission, 2022). These factors make South Africa a suitable African country to analyse the relationship between poverty, inequality, and education. The results of this study will contribute to policy formulation aligned with poverty alleviation and redress high inequality in South Africa. This is even more important given South Africa's commitment to the Sustainable Development Goals (SDGs) on poverty alleviation and inequality.

The rest of the study is divided as follows: Section 2 outlines the literature review and is divided into subsection 2.1, which covers country-based literature, and subsection 2.2 touching on a review of related literature. Section 3 highlights the estimation techniques, Section 4 discusses the data analysis and the discussion of results, while Section 5 concludes the chapter.

2. Literature Review

2.1. Poverty, Inequality, and Education Dynamics in South Africa

For decades, the eradication of poverty has been a global goal expressed in the Millennium Development Goals and SDGs. Under the SDGs, poverty reduction is captured in Goal 1: End poverty in all its forms everywhere (Statistics South Africa [StatsSA], 2017). South Africa is among the signatories to the SDG and is expected to roll out policies that aim to meet the targets set out under Goal 1. Reducing poverty and closing inequality has been a concern for South Africa expressed in the country's economic policy documents – from the Reconstruction and Development Programme to the current National Development Plan (NDP) 2030 (StatsSA, 2018). The government's approach to poverty reduction is three-pronged. First, there is the economic empowerment of the poor through the provision of opportunities with programmes such as the public works programme, black economic empowerment, and SMME support. Second, there is a provision of basic services such as education, housing, and health to the poor. Third, there is the provision of social safety net that aims to redistribute income through several grants, namely disability, pension, foster care, care dependency, child support, and social relief (StatsSA, 2017). In March 2021 alone, R18.44 million grants were paid that benefited 11.45 million recipients (Parliament Budget Office, 2022). According to the StatsSA (2022a) analysis of the Living Conditions Survey 2014/15, approximately 49.2% of the adult population was living in poverty below the upper-bound poverty line. The provinces with the largest population living in poverty are Limpopo, Eastern Cape, KwaZulu-Natal, and Northwest (StatsSA, 2022a). *Table 1* reports poverty measured by poverty headcount and poverty severity, as well as trends in income poverty measured by poverty headcount and poverty gap.

Table 1. *Poverty headcount and poverty severity in South Africa: 1990–2020*

Year	Poverty Gap (\$2.15 per day)	Poverty Gap (\$3.65 per day)	Poverty Gap (\$6.85 per day)	Poverty Headcount (\$2.15 per day)	Poverty Headcount (\$3.65 per day)	Poverty Headcount (\$6.85 per day)
1993	12	25	42.7	33.5	52.1	71.1
2000	14.3	27.7	45.7	36.8	55.4	74.3
2005	9.3	22.3	41.7	28.3	51.2	71.8
2008	5.4	15.4	32.8	18.7	39.3	62.1
2010	5.5	15.1	31.9	18	37.9	60.9
2014	6.9	16.6	33.4	20.5	40	61.6

Source: World Bank (2023)

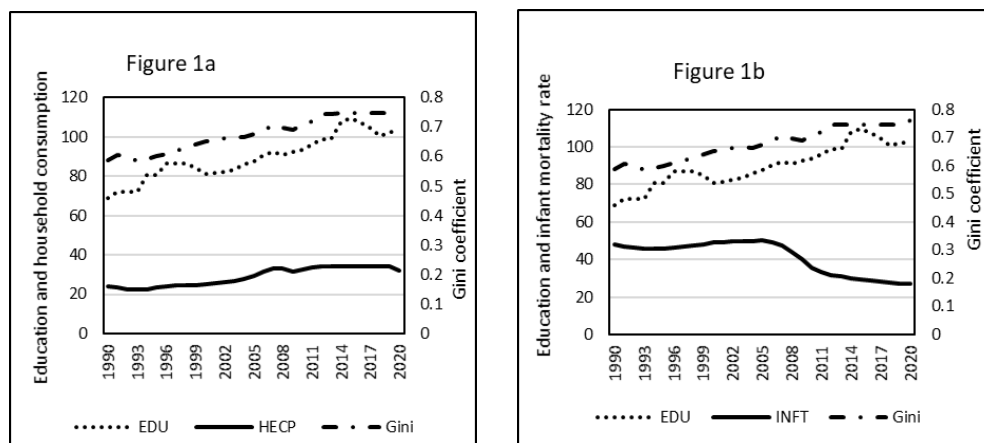
South Africa recorded a decrease in poverty measured by poverty headcount and poverty gap across all the poverty lines from 2000 to 2010 (World Bank, 2023). However, the country experienced a surge in poverty levels across all the measures captured in *Table 1* from 2014 (World Bank, 2023). This points to a need for the government to strengthen policies aimed at poverty alleviation in South Africa incorporating the effects of external shocks to the success of the policies implemented.

Inequality is related to the difference in the share of something (income or expenditure) among persons or access to opportunities (Trapeznikova, 2019). This includes several elements such as wealth, consumption, health, education, employment, and income, among other variables. The National Development Plan acknowledges that South Africa is still a highly unequal society (National Planning Commission, 2022). This has exacerbated the severity of poverty, with most of the poor in South Africa continuously alienated from participating in economic development. This has been a challenge despite the government policy on improving access to education through some non-fee-paying institutions of learning, among other support structures. Under the NDP, South Africa aims to reduce inequality in income per capita from 0.7 to 0.6 by 2030 (StatsSA, 2017). This is in line with SDG Goal 10: Reduce Inequality within and among countries (United Nations, 2022).

Wage inequality was found to be a major source of inequality, while education was found to play an important role in bridging the inequality gap (Van der Berg, 2010). According to Keeton (2014), income inequality continues to widen due to inequalities within the workplace and a huge gap between the employed and the unemployed sitting at 32.5% in the fourth quarter of 2021 (StatsSA, 2022b). These developments are also reflected in the Gini index, which increased from 59.3% in 1993 to 63% in 2014 (World Bank, 2022). The inequality report released by Statistics South Africa jointly with the Southern Africa Labour and Development Research Unit and Agence Française de Développement indicated a fall in most inequality measures, with notable variations between provinces (StatsSA, 2019).

Education, like poverty, is ingrained in the SDGs, captured under Goal 4, which calls for inclusive, quality, and equitable education that affords lifelong opportunities. This policy stance is also reflected in the Constitution, which states that every citizen has the right to education. The overarching objective of the National Education Policy Act is to make education accessible to all South Africans. Education plays a crucial role in poverty alleviation by enhancing human capital that is required in the job market. It increases the ability of the poor to earn high income and demand for their labour in the market. The ability of the poor to enhance themselves through education leads to an increase in access to social services and a better living standard. This consequently leads to poverty reduction. It is important to point out that the more educated the poor are, the more the inequality gap between the poor and the rich closes, especially in South

Africa, where income plays an important role in the livelihoods of households (Keeton, 2014). South Africa has made great strides in education, with gross secondary enrolment increasing consistently from 68% in 1990 to 103% in 2020 (World Bank, 2022). This improvement in gross enrolment was also registered in gross primary school enrolment. The figures show evidence of progress made in education although tertiary institutions have not registered high enrolment rates. *Figure 1a–b* shows the trends in the Gini coefficient, poverty captured by infant mortality rate and household consumption expenditure and education.



Source: World Bank (2023)

Figure 1. Trends in poverty, inequality, and education: 1990–2020

Figure 1 reports education, inequality measured by the Gini coefficient and poverty – captured by household consumption expenditure and infant mortality rate. South Africa experienced a steady increase in household consumption expenditure though the figures remain depressed throughout the study period (World Bank, 2023). Infant mortality rate, on the other hand, drastically decreased from 2008, a reflection of government efforts to make health accessible to everyone. Secondary school enrolments also increased during the study period, while the GINI coefficient continued to increase over the study period. The growth in the Gini coefficient reflects widening inequality in South Africa despite government effort to redress the results of the past political regime. This points to the inadequacy of policies that have been implemented to address inequality in South Africa.

2.2. Review of the Related Studies

There is still no consensus on the best measure of poverty, which is a multi-dimensional phenomenon that captures multiple facets, such as income poverty, health, and education. Some tend to prefer multidimensional measures of poverty

like the Human Development Index, while others settle for income poverty measures. There are multiple theories on poverty, among them the cultural theory of poverty and the structural theory of poverty (Jordan, 2004; Ogbeide and Agu, 2015). Cultural poverty involves poverty inherited due to a lack of resources to send children to school, access to health and the laziness to work and improve one's welfare or lack of skills that are required in the market (Jordan, 2004; Ogbeide and Agu, 2015). Structural poverty centres on the economic structure of the economy that favours those who are well off (Jordan, 2004; Ogbeide and Agu, 2015). Income inequality can be measured using multiple dimensions that include income outcomes or access outcomes. On income measures, the most common measures are the Gini index and the Lorenz curve. Income measures may be broken down further into income, wealth, and pay inequality (Trapeznikova, 2019). In this study, inequality is measured by the Gini coefficient.

Most of the studies in the literature explored the impact of education and level of income on poverty. In this section, literature on poverty, inequality, and education will be outlined. Due to a dearth of literature on the causality between the variables of interest, studies that examined the impact and causal relationship among the three variables will be reviewed.

Adeleye et al. (2020) carried out a comparative analysis of 58 sub-Saharan African countries and Latin American countries to establish if growth reduces poverty and if the interaction of economic growth and inequality alters its impact on poverty. Using data from 2000 to 2015 and pooled ordinary least squares, fixed effects and system GMM, the study found that the growth of inequality intensified poverty. Inequality was found to reduce the impact of economic growth on poverty, especially in high-income and upper-middle-income countries, but not in lower-middle and low-income countries. Khemili and Belloumi (2018) also examined the relationship between poverty and inequality using 1970 to 2013 data for Tunisia. Using ARDL and Toda and Yamamoto's modification of the Granger causality test, the study found a positive relationship between income inequality and poverty in the long run and a positive relationship between inequality and growth to poverty. In the same study, a unidirectional causality was also confirmed from economic growth to poverty.

Akanbi (2016) analysed the long-run relationship and causality between growth, poverty, and inequality using panel data for nine South African provinces from 1995 to 2012. The study found a long-run relationship between poverty and inequality and a unidirectional causal flow from income poverty to income inequality. In the same spirit, Ogbeide and Agu (2015) examined the causality between poverty and inequality in Nigeria, using the Gini coefficient as a measure of inequality and national poverty lines as a measure of poverty. A study found a bidirectional causality between poverty and inequality, a unidirectional causality from unemployment to inequality, and a unidirectional causality from life expectancy

to inequality. The study found no causality between poverty and unemployment. De Janvry and Sadoulet (1999) used data from 1970 to 1994 for 12 Latin American countries to analyse the role of aggregate income on changes in urban and rural poverty and inequality. The study found income growth to be effective in reducing poverty if educational levels are sufficiently high and the starting poverty levels are not too high. Thus, Latin American countries cannot rely on income growth to eradicate inequality.

Clentine and Garidzirai (2020) investigated the causal relationship between education, poverty, and economic growth using South African data from 1984 to 2015. Employing a trivariate Granger causality analysis, the study found that a 1% change in education minimizes poverty by 0.027%. Afzal et al. (2012) examined the relationship between education, poverty, and economic growth in Pakistan using data from 1971 to 1972 and from 2009 to 2010. Using the ARDL model, the study found that education had a positive impact on economic growth and a bidirectional causality between economic growth and education, poverty and economic growth, and poverty and education, confirming that education leads to poverty reduction; and economic growth is a necessary variable to poverty alleviation. Citak and Duffy (2020) investigated the causal relationship between education and poverty in Turkey. Using the instrumental variable estimation and two-stage least squares (2SLS) regression, the study found that the higher the education of the household head, the higher the income per capita.

Studies that have examined the impact of education on poverty confirm the mitigating effect of education on poverty. Nasution et al. (2015) investigated the impact of social capital on poverty in Indonesia and found education to play an important role in increasing the probability of social participation, which in turn reduces poverty. The same results were found by Chaudhary et al. (2010) and Awan et al. (2011) in a study on Pakistan. Naito and Nishida (2012) examined the effects of inequality on education policy and economic growth. High initial inequality was found to have a negative effect on education expenditure, which consequently reduced economic growth.

3. Estimation Techniques

This study uses the ARDL approach to cointegration and the ECM-based Granger causality test to analyse the causality between poverty, inequality, and education. The ARDL approach was developed by Pesaran and Shin (1999) and further expanded by Pesaran, Shin, and Smith (2001). The ARDL model was selected because of several advantages. The approach allows the analysis of a combination of variables integrated of different orders – variables integrated of order zero $I(0)$ or integrated of order one $I(1)$ (Pesaran et al., 2001; Odhiambo, 2020). However,

the approach falls away if the order of integration is greater than one. Another advantage of this approach is that the results from this approach are in short- and long-run time frames. These results are formative to policymakers, as guidance is given on short- and long-run policy focuses.

The study employs two models. Model 1 captures poverty measured by household consumption expenditure, and Model 2 captures poverty measured by infant mortality rate.

4. Variables

Poverty is captured by household consumption expenditure (HCE) and infant mortality rate (INFT), which are used as proxies for poverty capturing income poverty and health poverty respectively. Household consumption expenditure has been used in several studies as a proxy for poverty (see Musakwa and Odhiambo, 2022; Magombeyi and Odhiambo, 2017, 2018a; Kaidi et al., 2018; Rehman and Shahbaz, 2014; Ravallion, 2001). Infant mortality rate has been used in several studies to capture health poverty. Some of the studies that used infant mortality rate as a proxy for poverty include Musakwa and Odhiambo (2020), Magombeyi and Odhiambo (2018b), Abosedra et al. (2016), Van Multzahn and Durrheim (2008). Education (EDU) is captured by gross secondary enrolment, following the findings by Citak and Duffy (2020) that higher education is more important in poverty alleviation and inequality. The Gini coefficient is used to capture inequality in this study. The study added one intermittent variable, namely unemployment, to form a multivariate causality framework. *Table 2* reports variable description.

Table 2. *Variable description*

Variable	Description	Notation	Source
Poverty	Household consumption expenditure as a percentage of GDP	HCE	World Development Indicators
	Infant mortality rate	INFT	World Development Indicators
Income inequality	Gini Coefficient	INEQ	Worldwide Inequality Database
Education	Secondary school gross enrolment	EDU	World Development Indicators
Unemployment	Unemployment measured by strict unemployment definition	UNE	World Development Indicators

The study is divided into two models, where Model 1 captures household consumption expenditure as a proxy for poverty while other variables remain the same, and Model 2 captures infant mortality rate as a proxy for poverty and the rest of the variables remain unchanged.

ARDL model specification for the multicausality model is given in equations (1)–(4).

Cointegration Model (POV, EDU, INEQ, UNE):

$$\begin{aligned} \Delta POV_{mt} = & \varphi_0 + \sum_{i=1}^n \varphi_{1i} \Delta POV_{mt-i} + \sum_{i=0}^n \varphi_{2i} \Delta EDU_{t-i} + \sum_{i=0}^n \varphi_{3i} \Delta INEQ_{t-i} + \sum_{i=0}^n \varphi_{4i} \Delta UNE_{t-i} \\ & + \beta_1 POV_{mt-1} + \beta_2 EDU_{t-1} + \beta_3 INEQ + \beta_4 UNE_{t-1} + \mu_{1t} \end{aligned} \quad (1)$$

$$\begin{aligned} \Delta EDU_t = & \varphi_0 + \sum_{i=0}^n \varphi_{1i} \Delta POV_{mt-i} + \sum_{i=1}^n \varphi_{2i} \Delta EDU_{t-i} + \sum_{i=0}^n \varphi_{3i} \Delta INEQ_{t-i} + \sum_{i=0}^n \varphi_{4i} \Delta UNE_{t-i} + \beta_1 POV_{mt-1} \\ & + \beta_2 EDU_{t-1} + \beta_3 INEQ + \beta_4 UNE_{t-1} + \mu_{2t} \end{aligned} \quad (2)$$

$$\begin{aligned} \Delta INEQ_t = & \varphi_0 + \sum_{i=0}^n \varphi_{1i} \Delta POV_{mt-i} + \sum_{i=0}^n \varphi_{2i} \Delta EDU_{t-i} + \sum_{i=1}^n \varphi_{3i} \Delta INEQ_{t-i} + \sum_{i=0}^n \varphi_{4i} \Delta UNE_{t-i} + \beta_1 POV_{mt} \\ & + \beta_2 EDU_{t-1} + \beta_3 INEQ + \beta_4 UNE_{t-1} + \mu_{3t} \end{aligned} \quad (3)$$

$$\begin{aligned} UNE_t = & \varphi_0 + \sum_{i=0}^n \varphi_{1i} \Delta POV_{mt-i} + \sum_{i=0}^n \varphi_{2i} \Delta EDU_{t-i} + \sum_{i=0}^n \varphi_{3i} \Delta INEQ_{t-i} + \sum_{i=1}^n \varphi_{4i} \Delta UNE_{t-i} + \beta_1 POV_{mt-1} \\ & + \beta_2 EDU_{t-1} + \beta_3 INEQ + \beta_4 UNE_{t-1} + \mu_{5t} \end{aligned} \quad (4)$$

POV_m is measured by household consumption expenditure (HCE) in Model 1 and infant mortality rate per 1,000 live births (INFT) in Model 2; the rest of the variables remain the same in each model; EDU = education measured by gross secondary school enrolment; INEQ = inequality measured by the Gini coefficient; UNE = unemployment measured by the strict definition of unemployment; φ_0 is a constant; $\varphi_1 - \varphi_4$; $\beta_1 - \beta_4$ are coefficients; $\mu_1 - \mu_4$ are error terms.

The cointegration test determines if variables included in a model have a long-run relationship. Each variable enters the equation as a dependent variable. For those equations where cointegration is confirmed, long-run causality is captured by the error correction term, while short-run causality is captured by the F-statistics in each equation. For those models where long-run relationships could not be confirmed, only the F-statistic is used to determine short-run causality. The Granger causality models for Equations (1)–(4) are specified in Equations (5)–(8) as follows:

$$POV_{mt} = \varphi_0 + \sum_{i=1}^n \varphi_{1i} \Delta POV_{mt-i} + \sum_{i=1}^n \varphi_{2i} \Delta EDU_{t-i} + \sum_{i=1}^n \varphi_{3i} \Delta INEQ_{t-i} + \sum_{i=1}^n \varphi_{4i} \Delta UNE_{t-i} + \vartheta_1 ECM_{t-1} + \mu_{1t} \quad (5)$$

$$EDU_t = \varphi_0 + \sum_{i=1}^n \varphi_{1i} \Delta POV_{mt-i} + \sum_{i=1}^n \varphi_{2i} \Delta EDU_{t-i} + \sum_{i=1}^n \varphi_{3i} \Delta INEQ_{t-i} + \sum_{i=1}^n \varphi_{4i} \Delta UNE_{t-i} + \vartheta_2 ECM_{t-1} + \mu_{2t} \quad (6)$$

$$INEQ_t = \varphi_0 + \sum_{i=1}^n \varphi_{1i} \Delta POV_{mt-i} + \sum_{i=1}^n \varphi_{2i} \Delta EDU_{t-i} + \sum_{i=1}^n \varphi_{3i} \Delta INEQ_{t-i} + \sum_{i=1}^n \varphi_{4i} \Delta UNE_{t-i} + \vartheta_3 ECM_{t-1} + \mu_{3t} \quad (7)$$

$$UNE_t = \varphi_0 + \sum_{i=1}^n \varphi_{1i} \Delta POV_{mt-i} + \sum_{i=1}^n \varphi_{2i} \Delta EDU_{t-i} + \sum_{i=1}^n \varphi_{3i} \Delta INEQ_{t-i} + \sum_{i=1}^n \varphi_{4i} \Delta UNE_{t-i} + \vartheta_4 ECM_{t-1} + \mu_{5t} \quad (8)$$

5. Data Sources

The study used annual time series data from 1990 to 2020 to examine the causality between poverty, education, and inequality in South Africa. Data on education (EDU), poverty (POV) proxied by household consumption expenditure per capita (HCE), infant mortality rate (INFT), and unemployment (UNE) were obtained from the World Development Indicators database. The Gini coefficient was retrieved from the Worldwide Inequality Database.

6. Empirical Results

A test for unit roots was done on all the variables in Model 1 and Model 2 to avoid spurious regression associated with non-stationary variables. Stationarity is when the mean, covariance, and variance of variables specified in a model remain constant over time. It is also important to confirm the stationarity of the variables when using the ARDL approach, although it is not essential. If any of the variables are integrated of order two or higher, the ARDL approach falls away. However, a combination of variables integrated with order 0 and order 1 are acceptable when using this approach. Unit root results are reported in *Table 3*.

Table 3. *Stationarity results*

Variable	Dickey–Fuller Generalized Least Square (DF-GLS)				Phillips and Perron (PP) Root Test			
	Variables in Levels		Variables in First Difference		Variables in Levels		Variables in First Difference	
	Without Trend	With Trend	Without Trend	With Trend	Without Trend	With Trend	Without Trend	With Trend
HCE	-0.523	-1.781	-2.748**	-3.123*	-0.660	-1.350	-3.621**	-3.504*
INFT	-0.623	-1.881	-2.746**	-2.895*	-0.660	-1.350	-3.621**	-3.504*
INEQ	0.3669	-2.504	-4.215***	-4.808***	-0.431	-2.380	-5.090***	-4.829***
EDU	-0.4735	-2.320	-4.825***	-5.094***	-1.554	-2.205	-4.978***	-4.960***
UNE	-1.276	-1.939	-4.192***	-4.232***	-1.445	-1.472	-4.063***	-4.022**

Notes: *, **, and *** denote stationarity at 10%, 5%, and 1% significance levels respectively.

Results presented in *Table 3* show that all the variables in Model 1 and Model 2 are stationary in first difference. The next step is to check for the long-run relationship among the variables in Model 1 and Model 2. Cointegration results are presented in *Table 4*.

Table 4. *Cointegration results*

Dependent Variable	Function	F-Statistic	Cointegration Status
Panel A: Model 1			
HEC	F(HCE INEQ,UNE,EDU)	9,2170***	Cointegrated
INEQ	F(INEQ HCE,UNE,EDU)	3.5138	Not Cointegrated
EDU	F(EDU HCE,UNE,INEQ)	1,3195	Not cointegrated
UNE	F(UNE INEQ,HCE,EDU)	4.3216**	Cointegrated
Panel B: Model 2			
INFT	F(INFT INEQ,UNE,EDU)	4.961**	Cointegrated
INEQ	F(INEQ INFT,UNE,EDU)	2.601	Not Cointegrated
EDU	F(EDU INFT,UNE,INEQ)	2.408	Not cointegrated
UNE	F(UNE INEQ,INFT,EDU)	1.126	Not Cointegrated
Asymptotic Critical Values (unrestricted intercept and no trend)			
Critical Values	1%	5%	10%
	I (0)	I (1)	I (0) I (1)
	3.74	5.06	2.86 4.01 2.45 3.52

Notes: *, **, and *** denote stationarity at 10%, 5%, and 1% significance levels respectively.

Results reported in *Table 4* confirm cointegration in some of the functions in Models 1 and 2. For Model 1, the HEC and UNE functions were found to be cointegrated at 1% and 5% level of significance, respectively, while in Model 2 the INFT function was found to be cointegrated at 5% level of significance. To proceed with the analysis, long-run and short causality relationships are tested

for those functions where cointegration was confirmed. In those functions where no cointegration was confirmed, only the short-run causality is tested. Causality results are reported in *Table 5*.

Table 5. *ECM-based causality results for models 1 and 2*

Panel 1 Model 1: Household Consumption Expenditure as a Measure of Poverty					
	ECM t-statistics				ECM (t-stat)
	ΔHCE	$\Delta INEQ$	ΔEDU	ΔUNE	
ΔHCE	-	2.451 [0.108]	0.133 [0.719]	2.616* [0.095]	-0.589** [-2.748]
$\Delta INEQ$	10.507*** [0.002]	-	1.514 [0.230]	7.195** [0.013]	-
ΔEDU	3.878* [0.077]	5.432** [0.042]	-	2.404 [0.141]	-
ΔUNE	9.570*** [0.002]	8.660*** [0.007]	0.356 [0.556]	-	-0.393*** [-4.866]
Panel 2 Model 2: Infant Mortality Rate as a Measure of Poverty					
	$\Delta INFT$	$\Delta INEQ$	ΔEDU	ΔUNE	ECM (t-stat)
$\Delta INFT$	-	6.187* [0.020]	6.482** [0.018]	5.568** [0.095]	-0.091*** [-5.396]
$\Delta INEQ$	0.541 [0.469]	-	5.114** [0.026]	0.377 [0.545]	-
ΔEDU	4.351* [0.049]	5.309** [0.042]	-	0.215 [0.648]	-

Notes: *, **, and *** denote stationarity at 10%, 5%, and 1% significance levels respectively.

The results reported in *Table 5*, Panel 1, where household consumption expenditure was used as a poverty measure, a unidirectional causal flow from poverty to education was confirmed in the short run at 5% level of significance. Results confirmed the importance of household consumption expenditure on the level of education. The higher the household consumption expenditure, the higher the access to education. In other words, the lower the poverty levels, the more likely households can invest in human capital, which is important in getting better-paying jobs (Cingano, 2014; Keeton, 2014; Van der Berg, 2010). A distinct unidirectional causal flow from household consumption expenditure to inequality was confirmed in the short run at 1% level of significance. This finding confirms the importance of the level of household consumption expenditure on the inequality gap. Lower household consumption expenditure fosters the widening of the income gap, while the opposite is true with high household consumption expenditure. Thus, a low

household consumption expenditure worsens inequality, as more households lack the capability to access social services that can change their living standards. The study also found a unidirectional causal flow from inequality to education in the short run. The study confirmed the importance of the negative influence inequality has on education level and quality. It is not surprising that South Africa sits with high structural unemployment and a mismatch between what is covered in the education curriculum and what the market requires.

When poverty was measured by infant mortality rate, a bidirectional causality was found between poverty and education in the short run and a unidirectional causality from education to inequality in the long run. According to the findings of the study, poverty causes lower education, which in turn worsens poverty. This finding is consistent with the phenomenon that poor people in South Africa are trapped in a vicious cycle of poverty because the lack of education that reduces chances of getting better-paying jobs. Afzal et al. (2012) found the same results in a study on Pakistan. The study also found a unidirectional causal flow from inequality to poverty in both the long run and the short run. Results confirm the challenge that South Africa is facing due to high inequality and consequently high poverty levels. The government needs to solve high poverty levels by also focusing on closing the inequality gap, where the poor get poorer, and the rich get richer. Another bidirectional causality was found between inequality and education in the short run at 1% level of significance. Accordingly, poor families have no access to quality education, as they are unable to pay for the service, thus trapping generations in deprivation and poverty. These results are not unique to South Africa alone, as Akanbi (2016) and Ogbeide and Agu (2015) found the same results in separate studies on the South African provinces and Nigeria respectively.

Other results reported in *Table 5*, Panel 1, where household consumption expenditure was used as a measure of poverty, confirmed: i) a bidirectional causality between unemployment and inequality in the short run and a unidirectional causal flow from income inequality to unemployment in the long run; ii) a bidirectional causality between poverty and unemployment in the short run and the long run; iii) no causality between unemployment and education. Results reported in *Table 5*, Panel 2, where infant mortality rate was used as a measure of poverty confirm: i) a unidirectional causal flow from inequality to unemployment in the short run; ii) a bidirectional causality between unemployment and poverty in the short run and a unidirectional causal flow from unemployment to poverty in the long run; iii) a unidirectional causal flow from education to unemployment. This finding emphasizes the importance of education in lifting most South African population from poverty and dependence on government, where secure, better-paying jobs imply high income to cater for social services or opening businesses.

The government needs a three-pronged policy that tackles education, poverty, and inequality to reduce poverty and inequality levels in South Africa. This

intervention provides a permanent solution to poverty and helps to eradicate the main cause of poverty and not just its symptoms.

7. Conclusions

This study investigated the nexus between poverty, inequality, and education in South Africa, using annual data from 1990 to 2020. Using two proxies of poverty, the household consumption expenditure and infant mortality rate, it succeeded in capturing income and health poverty respectively. The study used the ARDL approach and the ECM-based Granger causality test. The findings of the study revealed that when household consumption expenditure was used as a proxy, 1) a unidirectional causal flow was found to prevail from poverty to education in the short run, 2) a unidirectional causality from poverty to inequality was found in the short run, and 3) a unidirectional causal flow from inequality to education was found to predominate in the short run.

The results confirmed the importance of poverty in access to education and closing the inequality gap. When infant mortality rate was used as a poverty proxy, the study found: 1) a bidirectional causality between education and inequality in the short run and a unidirectional causal flow from education to poverty in the long run; 2) a unidirectional causal flow from inequality to poverty in the short and long run; 3) a bidirectional causality between inequality and education in the short run. Based on the findings of this study, it can be concluded that there is a close causal relationship between inequality, poverty, and education. This suggests a coordinated policy approach from all fronts to ensure that the challenge of poverty and inequality is eliminated. The National Development Plan pointed out poverty and inequality as challenges among the triple challenges, for which a concoction of policies was formulated. However, according to the findings of the study, a coordination of policies across poverty, inequality, and education will allow South Africa to enjoy the mutually beneficial effect of each variable individually and as a group. It is therefore recommended that the government should continue to strengthen policies on education, poverty, and inequality with a view to benefiting from the reinforcing effects among the policies. It is also recommended that a continuous review of the policies and desired outcomes is done to ensure that policies serve the purpose they were designed for and take new developments at a national and global level into account.

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COVID-19 or the Conflict: Examining the Catastrophic Effect on the Stock Markets of G-20 Economies

Mahesh DAHAL*

Department of Commerce, PDUAM, Tulungia – 783383, India
e-mail: maheshdahal118@gmail.com

Joy DAS

Department of Commerce, Nagaland University, Kohima Campus Meriema,
Nagaland – 797004, India
e-mail: joy.kxj@gmail.com

Paulami RAY

Academic Associate, Finance and Accounting Area, Indian Institute of Management
Bangalore, Bengaluru, Karnataka – 560076, India
e-mail: paulamiray18@gmail.com

Abstract. The present study attempts to capture the stock market reactions of G-20 nations, arising because of COVID-19 and the conflict between Russia and Ukraine. To achieve its objective, the present study employed event study methodology and paired sample t-test on the index return of the G-20 nations. The study found that for the G-20 nations, the impact of COVID-19 is more severe as compared to the conflict. The region-wise analysis showed that for COVID-19, the stock markets of all regions except Europe responded negatively, and during the conflict all regions displayed significant negative returns except America.

Keywords: COVID-19, conflict, G-20 nations, stock market, event study methodology

JEL Classification: G14, G12

1. Introduction

In 2019, amidst intensifying geopolitical tensions driven by the United States–China trade war, Brexit, and the fear of recession looming over the horizon, the novel coronavirus outbreak emerged in the world like a bolt from the blue that

has caused havoc in public health, in the financial and socio-economic scenario globally. As the coronavirus disease (COVID-19) outbreak escalated from a regional emergency in China to a global catastrophe, nations around the world felt an increasing need to close down the economy to be able to get it running again. On 11 March 2020, the WHO (World Health Organization) declared the coronavirus outbreak a pandemic (WHO, 2020; Cucinotta and Vanelli, 2020), following which governments all over the world adopted unprecedented measures to limit the spread of the disease.

To curb the spread of the disease, several countries paused all major economic operations, and the repercussions of these severe measures were seen as several economies experienced historic disruptions in their labour and financial markets. Stock prices are considered a leading economic indicator, as they reflect changes in the economy long before other economic indicators (Bodie et al., 2013), and amid such uncertainties financial markets exhibited high volatility (Baker et al., 2020). Following the announcement of 11 March 2020, stock markets around the world experienced a massive plunge. The SandP 500, NASDAQ, and FTSE100 indices lost close to 10% (Stevens et al., 2020), while BSE Sensex and Nifty declined by more than 8% (Ananda, 2020); this “bloodbath” continued in the European markets too, as the stocks plunged as much as 11% (Carvalho and Adinarayan, 2020), all in a single day. However, the stocks of different sectors had varying reactions to COVID-19 depending on the impact that the outbreak had had on the operations of the business (Mazur et al., 2021).

Declining stock prices show that uncertainty and fear lead investors to behave irrationally, and consequently stock prices exhibit unexpected movements (Isidore and Christie, 2018). Thus, studying stock price movements can reveal a great deal about investors’ sentiments and reactions to an event. In this vein, there has been substantial work examining the dynamics of the stock market concerning such “black swan events” in the past and also the coronavirus pandemic in particular (Bannigidadmath et al., 2022; Chowdhury et al., 2022; He et al., 2020; Mishra and Mishra, 2021; O’Donnell et al., 2021).

While the world economy was still gradually recovering from the aftermaths of the COVID-19 pandemic, it was hit with the news of Russia’s invasion of Ukraine on 24 February 2022 (Zinets and Vasovic, 2022; Ellyatt, 2022). This invasion ended up in an intense geopolitical conflict whose consequences have spattered across economies and markets globally (Umar et al., 2023; Umar et al., 2022; Alam et al., 2022). Even though it is only expected that rising geopolitical tensions will lead to plunging stock prices, the diverse nature of the markets concerning their geographical location and economic strength makes some nations more resilient than others (Agyei et al., 2022; Będowska-Sojka et al., 2022; Bossman et al., 2023; Bounbou and Yatié, 2022). While Russia invaded Ukraine, several Western countries, such as the United States, the members of the European Union, and the

United Kingdom, imposed economic sanctions on Russia, which were expected to result in a substantial contraction of the Russian economy (Pestova et al., 2022). Being the largest country and a major exporter nation, Russia plays a significant role in the global markets, and the economic sanctions imposed on it were expected to have an impact on global markets. Similarly, Ukraine, too, enjoys the status of being an important exporter to many nations (Gill, 2022).

It is also evident from previous literature that war is one such black swan event that influences financial markets globally (Rigobon and Sack, 2005; Leigh et al., 2003; Yousaf et al., 2022). As geopolitical and military conflicts lead to an increase in uncertainty about the future of the companies among investors, the fear leads to irrational behaviour among them, which results in variations in stock prices (Leigh et al., 2003; Choudhry, 2010; Brune et al., 2015).

Now that economic globalization has brought financial markets and financial systems of different regions closer, it has also amplified the degree of interdependency among economies. For investors, this helps in diversifying the financial risks; yet it also increases the chances of a particular financial market's risk, this way jeopardizing the stability of the global financial system (Silva et al., 2016). However, in periods of crisis and uncertainty, the intensity of the consequences in developing economies is expected to be much lesser as compared to advanced economies due to the under-developed economic system in developing markets (Naeem et al., 2023). Also, the exceptional growth potential presented by the emerging markets in recent years has drawn significant investors from the developed markets to include assets from emerging markets in their portfolios (Naeem et al., 2022; Bossman and Agyei, 2022b; Gubareva and Umar, 2020).

Given the dynamics of these markets, analysing the impact that black swan events like conflicts and pandemics can have on equity markets of nations from different economic classes and geographical locations is an important step for asset allocation, risk management, and policy formulation.

Black swan events are extremely rare, and due to the varying nature of such events, financial markets may react differently each time. Additionally, every event of such nature may or may not induce a reaction of the same intensity from global financial markets. Motivated by these issues, the current study aims to present a comparison between the stock market response to the crisis of the COVID-19 pandemic and to the Ukraine–Russia conflict on emerging and developed markets. The findings provide significant information that help gain a better understanding of the investors' behaviour towards such events. The study also aims to demonstrate the varying responses of the financial markets to such black swan events depending on the inherent nature of the market. The G-20 countries were selected for the study, as these account for around 85% of the Gross World Product and approximately 80% of global trade (Liu et al., 2017; Zhang et al., 2020). Thus, the drastic changes experienced by the global financial markets because of the above-mentioned

events can be effectively represented by this group of emerging economies and developed nations.

The rest of the article is organized as follows. Section 2 presents an extensive literature review followed by section 3 comprising all the information regarding data and methodology. Section 4 discusses the findings of the study and provides an in-depth interpretation followed by section 5, which concludes.

2. Literature Review

The COVID-19 outbreak originated in China but has rapidly made its way into different other nations, triggering a global public health crisis (Wang et al., 2020). Later, on 11 March 2020, the outbreak was declared a pandemic by the World Health Organization (WHO, 2020). Lockdowns imposed in the majority of the countries to curb the spread of the disease generated demand- and supply-side shocks and brought the world economy to a standstill (Eichenbaum et al., 2020; Gormsen and Koijen, 2020; Fetzner et al., 2021). The impact of the measures was evident from the disruptions in the real and financial sectors of the affected countries (Banco De Espana, 2020). The financial markets of developing and advanced economies exhibited high volatility and downturns (Anh and Gan, 2021; Narayan et al., 2020; Zhang et al., 2020). Panic and negative sentiments of the investors and other market participants are believed to be the main triggers of the negative stock market performance amid the pandemic (Mishra and Mishra, 2021; Mishra et al., 2020). It has also been observed that an increase in the number of COVID-19 cases directly influenced market volatility (Haroon and Rizvi, 2020; Mishra et al., 2020; Al-Awadhi et al., 2020). Recent studies have also focused on analysing the reasons behind the plummeting stock prices in COVID-19-stricken countries. The studies of Baker et al. (2020), Scherf et al. (2022), and Ashraf (2020a) observed that government-imposed restrictions on movement and pauses in economic operations had a direct impact on the falling stock prices. However, a surge in the number of positive cases of COVID-19 and the number of deaths due to COVID-19 were seen to be affecting stock market movements negatively (Anh and Gan, 2021; Khan, et al., 2020). Sharif et al. (2020) find that the decline in oil prices amid the pandemic is also responsible for the stock market volatility during that period. Taking into consideration the extent of the COVID-19 pandemic, researchers have made numerous attempts to gauge the impact of COVID-19 on the financial markets. Ashraf (2020b) studied the reaction of the stock market and observed a negative relation between the number of cases and stock market returns. A study on the US and European stock markets by Heyden and Heyden (2021) also revealed a negative response of the stock markets to news of COVID-19-related deaths. Bakry et al. (2022), Bannigidadmath et al. (2022), Rahman et

al. (2021), Ashraf (2020a), and Harjoto et al. (2021) looked into the impact that stimulus packages declared by governments had had on the stock market and noticed that the stock market of the respective countries had showed positive reactions to it. There has also been substantial work examining the impact that the COVID-19 pandemic has had across economies, and the results reveal how the pandemic has influenced the stock markets negatively (Ganie et al., 2022; Harjoto et al., 2021; Xu, 2021; Fernandez-Perez et al., 2021; Hasan et al., 2021). In their work, Pandey and Kumari (2021) examined the impact of COVID-19 on the global stock markets, and the results show that the impact on the developed markets is more significant in the long run as compared to that of the emerging nations. Moreover, the study also shows that the impact on the Asian countries is significantly more as compared to that of the American countries. There are also quite a few studies examining the impact of COVID-19 on the stock markets' volatility both at the aggregate and industry levels. Izzeldin et al. (2023) considered the G7 economies and observed heightened volatility and negative impact on consumer services and the healthcare sector. Zehri (2021) considering the Asian and U.S. stock markets and Bora and Basistha (2021) considering the Indian stock market concluded that the pandemic had led to heightened volatility, whereas Li et al. (2021) considering G-20 countries found that the developed economies were the primary spillover transmitters, whereas the developing economies were only the receivers. Studies by Mazur et al. (2021) and Baek et al. (2020) examined the sectoral performance of the markets and noticed that the real estate, hospitality, transportation, and entertainment sectors exhibited a drastic fall, whereas the food and healthcare sectors were resilient during the pandemic.

Thus, it is evident from the above that in recent years the attention of researchers in examining the financial effects of crises has increased as a result of COVID-19, and there has also been significant effort in covering the many aspects of the crisis. However, studies focusing on the impact that conflicts have on global financial markets are comparatively scarce. The work of Frey and Kucher (2000) records the negative impact that wars have on the government bond prices of warring nations. Leigh et al. (2003) examined the impact of the U.S.-led war in Iraq on the stock markets around the world and noticed a substantial fall in the stock prices with an increase in the probability of war, while Schneider and Troeger (2006) considered three events of conflict, namely the war between Israel and the Palestinians, the U.S.-led conflict with Iraq, and the civil wars in former Yugoslavia, and found that all three events influenced the stock market negatively. Regarding the Ukraine–Russia conflict started in 2022, Alam et al. (2022) examine its impact on the connectedness of stock markets and commodity markets of G7 and BRIC nations. The results suggest that gold and silver commodities and the US, China, and Brazil are receivers of shocks,

whereas the other countries are major transmitters of shock. The impact of the Russia–Ukraine crisis on the Australian stock market was analysed by Kamal et al. (2023), which revealed a negative impact on the market. Das et al. (2023) investigated the impact of the conflict on the European stock markets and found a negative effect of the same. Additionally, they also found that the manufacturing, mining, and construction sectors were more affected as compared to other sectors. Sun et al. (2022), Izzeldin et al. (2023), and Sun and Zhang (2023) analysed the varying impacts of the war on global financial markets and noticed that the EU markets experienced more negative effects as compared to other nations. The influence of the Russia–Ukraine geopolitical risk on the major currencies of the world was also studied by Bossman et al. (2023), and it has been observed that the effects were asymmetric across the currencies with CHF and EUR, showing significant insensitivity towards GPR. Federle et al. (2022) further studied if proximity to warring nations has any impact on the economy of a country, and results show that the countries near the warring nations generate more negative returns compared to other countries. Yousaf et al. (2022) analysed the impact that the Ukraine–Russia conflict has on the G-20 nations, and the study revealed that the markets of Poland, Russia, and Hungary exhibit negative reactions in the pre-event window, whereas the other countries react negatively in the post-event window. Moreover, the impact of the Ukraine–Russia-induced geopolitical risk on the E7 and G7 nations was studied by Bossman and Gubareva (2023b), who, again, revealed asymmetric effects across the nations where the markets of Russia and China exhibited significant downfall.

Though there have been published plenty of works on the two major crises of recent times, it is noticeable from the existing literature that there has not been any study comparing the reactions of the global financial markets to two of the most catastrophic events of the recent times. Thus, with this study, we specifically aim to fill this gap in the literature by analysing the impacts of “black swan” events on stock markets, and the researchers also intend to illustrate how the stock markets’ responses vary with the nature of the event.

3. Data and Methodology

The Sample

Taking into account the objective, the present study considered the indices of the G-20 countries. The sample consists of 20 countries; however, excluding the European Union, the final sample comprises 19 countries. The final sample countries are further classified into developed/developing countries and region-wise, and the same are presented in *Table 1*.

Table 1. *Classification of the G-20 nations*

G-20 Countries	Developed / Developing	G-20 Countries	Developed / Developing
All Africa		All Europe	
South Africa	Developing Economy	France	Developed Economy
All Americas		Germany	Developed Economy
Argentina	Developing Economy	Italy	Developed Economy
Brazil	Developing Economy	Russia	Developed Economy
Canada	Developed Economy	Türkiye	Developing Economy
Mexico	Developing Economy	United Kingdom	Developed Economy
United States	Developed Economy	All Middle East	
All Asia/Pacific		Saudi Arabia	Developing Economy
Australia	Developed Economy		
China	Developing Economy		
India	Developing Economy		
Indonesia	Developing Economy		
Japan	Developed Economy		
South Korea	Developing Economy		

Source: author's compilation

The Data

The present study is based on secondary data, i.e. closing prices, collected from an open-source website, investing.com, around the outbreak of COVID-19 and the conflict between Russia and Ukraine.

Events under Study

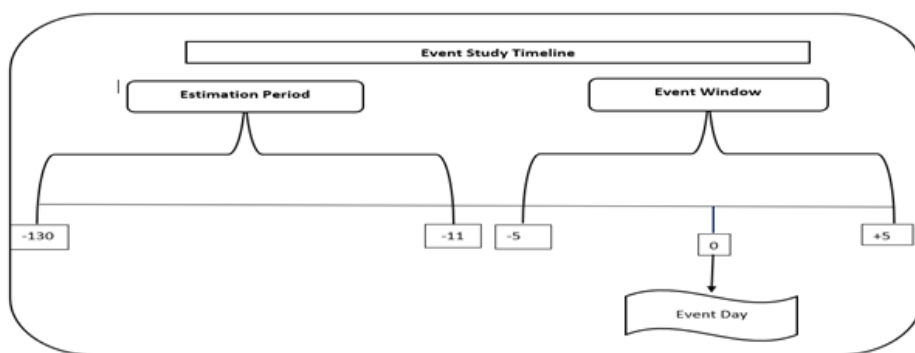
In recent times, the world has witnessed two large-scale devastating events in the form of the COVID-19 pandemic and the conflict between Russia and Ukraine. Both events have impacted almost every nation of the world directly and indirectly as well. Considering the same, the present study has looked into both events to see their impact on the stock market of G-20 nations. In the present study, 11 March 2020 is considered as the announcement date for COVID-19 and 24 February 2022 as the announcement date for the Russia–Ukraine conflict.

Tools and Techniques

The present study employed the event study methodology to empirically capture the market behaviour around the occurrence of an event. This method is considered

one of the effective and popular methods that evaluate the influence of an event on the securities return around the event days. It facilitates the forecasting of securities returns around the announcement of an event (Anwar et al., 2017). Several authors, namely Fama et al. (1969), Brown and Warner (1980), and MacKinlay (1997), played a critical role in enhancing, developing, and popularizing the methodology among finance scholars.

The analysis performed with the help of the event study methodology begins with finalizing the estimation period, and then the impact of the event under study is examined during the event period. Based on Peterson (1989), according to whom a longer time horizon gives better estimation, the estimation period of 120 days is considered and an event window of 11 days (-5 days to +5 days), and the same is graphically presented in *Figure 1*.



Source: authors' calculation

Figure 1. Event study timeline

At the outset, the daily returns of the security ($R_{j,t}$) are determined by dividing the price of the security, “j” for the day, “t” with the price of the same security on day, “t-1”. In this study, the Excel function “ln”, which represents the natural logarithm, is employed for computing the returns of the securities. This approach yields returns that exhibit minimal to no skewness and serial correlation. In essence, utilizing the natural logarithm serves to enhance and improve the normality of the return series.

Proceeding further, the mean return calculated during the estimation period is taken as expected returns $E(R)$ for each index. The study has employed the Stata function as suggested by Pacicco et al. (2018) for conducting the event study.

Further, the abnormal returns (AR) are calculated by subtracting the expected returns $E(R)$ from the actual returns ($R_{j,t}$).

Thereafter, the abnormal returns are calculated for a pool of firms through a cross-sectional aggregation of the abnormal returns.

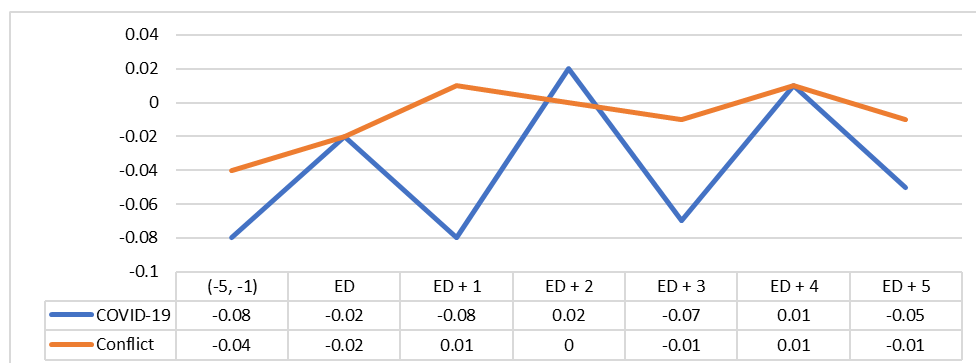
To gain further insight about behaviour, the AAR is aggregated over a period of time, and the impact of the event is observed within those shorter windows, known as cumulative average abnormal returns (CAAR), and is calculated as follows:

After completing the calculation of AAR and CAAR, the final step in the methodology is to examine the economic relevance of the AAR and CAAR by their statistical significance, which is tested using a parametric t-test. Further, to compare the impact of the events, a paired sample t-test is employed on the AAR during COVID-19 and the conflict.

4. Data Analysis and Interpretation

Impact of COVID-19 and the Conflict on the Stock of the G-20 Nations

Figure 2 displays the average changes in the stock of G-20 economies around the event period of the outbreak of COVID-19 and the conflict. From the figure, it can be seen that the stock of G-20 economies is in a positive trend during the conflict as compared to COVID-19. During the pre-event window of both events, the stock was in a negative trend, and on the event day, the stock displayed a similar reaction, but as the days passed, the stock reaction differed depending on the event. Further, the significance of the abnormal returns is tested, and the same is presented in Table 2.



Source: authors' calculation

Figure 2. Reaction of G-20 nations during COVID-19 and the conflict

From Table 2, it can be seen that during both events the stock reactions were similar, i.e. -2.00 per cent on the event day. During the pre-event stage, the stock presented a negative impact of 8.00 per cent for COVID-19 and 4.00 per cent for the conflict. Immediately after the outbreak, i.e. on ED + 1, the stock return during COVID-19 is significantly negative; however, in the case of the conflict, a significant positive

trend is witnessed in the stock return. During COVID-19, the market continued to be in a negative trend except for ED + 2 and ED + 4, while during the conflict the market continued to exhibit a positive trend except for ED + 1, ED + 2, and ED + 4.

Table 2. *Reaction of G-20 economies during COVID-19 and the conflict*

Windows	COVID-19	p-v	Conflict	p-v
(-5, -1)	-0.08	0.00***	-0.04	0.00***
ED	-0.02	0.00***	-0.02	0.00***
ED + 1	-0.08	0.00***	0.01	0.00***
ED + 2	0.02	0.00***	0.00	0.11
ED + 3	-0.07	0.00***	-0.01	0.00***
ED + 4	0.01	0.01**	0.01	0.01**
ED + 5	-0.05	0.00***	-0.01	0.05*

Source: authors' calculation

Note: significance levels: * $p < 0.10$, ** $p < 0.05$, and *** $p < 0.01$.

Further, a paired sample t-test was conducted (*Table 3*), which indicated significant differences in the reaction of the G-20 nations around COVID-19 and the conflict. Of the two events, COVID-19 seems to have an adverse effect on the stock of G-20 nations.

Table 3. *Paired sample test of means of G-20 nations during COVID-19 and the conflict*

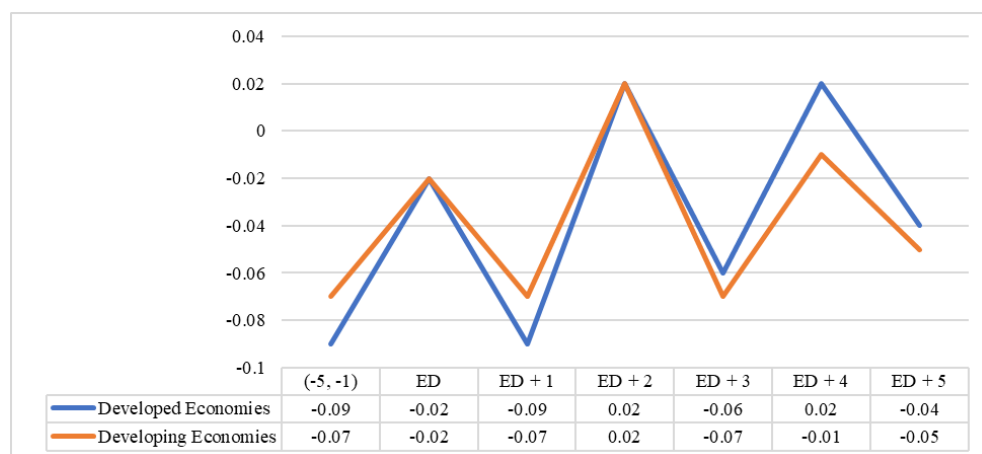
	COVID-19	Conflict
Mean	-0.039	-0.009
Observations	7	7
P(T <= t) two-tail	0.08*	
t Critical two-tail	2.44	

Source: authors' calculation

Note: significance levels: * $p < 0.10$, ** $p < 0.05$, and *** $p < 0.01$.

The Impact of COVID-19 on the Stock of Developed and Developing Nations

Figure 3 displays the average changes in the stocks of developed and developing nations around the event period of the outbreak of COVID-19. From the figure, it can be seen that the stocks of both developed and developing nations moved symmetrically with only minor variations. Further, the significance of the abnormal returns is tested, and the same is presented in *Table 4*.



Source: authors' calculation

Figure 3. Reaction of developed and developing nations during COVID-19

From Table 4, it can be seen that during both events the stock reaction was similar, i.e. -2.00 per cent on the event day. During the pre-event period, the stock represented a negative impact of 9.00 per cent for developed nations and 7.00 per cent for developing nations. Immediately after the outbreak, i.e. on ED + 1, the stocks of both developed and developing nations displayed a negative reaction. However, on ED + 2, a positive response of 2.00 per cent was witnessed for each category. Then again, on ED + 3 and ED + 5, both types of nations displayed negative reactions, while on ED + 4, developed nations showed a positive trend and developing nations exhibited insignificant negative returns.

Table 4. Reactions of developed and developing economies during COVID-19

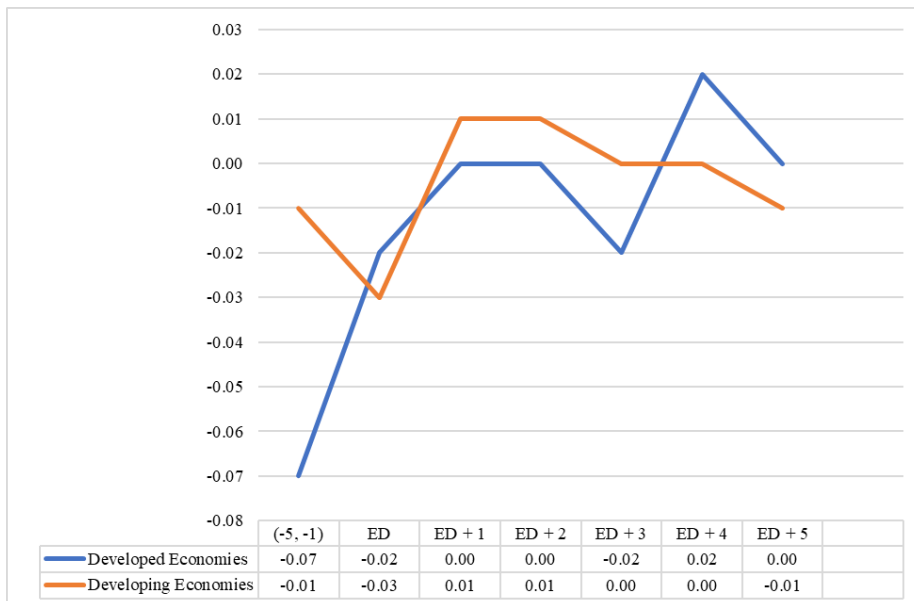
Windows / G-20 Economies	(-5, -1)		ED		ED + 1		ED + 2		ED + 3		ED + 4		ED + 5	
	CAR	p-v	CAR	p-v	CAR	p-v	CAR	p-v	CAR	p-v	CAR	p-v	CAR	p-v
Developed Economies	-0.09	***	-0.02	***	-0.09	***	0.02	***	-0.06	***	0.02	***	-0.04	***
Developing Economies	-0.07	***	-0.02	***	-0.07	***	0.02	***	-0.07	***	-0.01	***	-0.05	***

Source: authors' calculation

Note: significance levels: * $p < 0.10$, ** $p < 0.05$, and *** $p < 0.01$.

Impact of the Conflict on the Stock of Developed and Developing Nations

Figure 4 demonstrates the behaviour of developed and developing nations during the conflict, and it becomes clear from the response that, when compared to developing nations, stocks of developed nations were far more sensitive towards the event of the conflict between Russia and Ukraine. On the event day, the stocks of developed nations experienced a greater negative impact compared to developing nations. Followed by a short recovery on ED + 1 and ED + 2, the downward trend continued in the stock markets of developing economies from ED + 3 in the post-event period, whereas for developed nations the results were mixed. Further, the significance of the abnormal returns is tested, and the same is presented in Table 5.



Source: authors' calculation

Figure 4. Developed and developing nations during the conflict

It is evident from Table 5 that during the pre-announcement period, the stock markets of both developed and developing nations exhibited a negative trend with statistically significant negative returns in the case of developed nations. On the event day, both developed and 22 developing nations' stock markets experienced significant negative returns. On the contrary, immediately after the ED, i.e. on ED + 1 and ED + 2, stock markets of both developed and developing nations exhibited positive returns, which were statistically significant in the case of developing nations only. On the following days, i.e. on ED + 3, developed nations experienced negative returns followed by positive returns on ED + 4, all of which were statistically significant.

Table 5. *Reactions of developed and developing countries during the conflict*

Windows / G-20 Economies	(-5, -1)		ED		ED + 1		ED + 2		ED + 3		ED + 4		ED + 5	
	CAR	p-v	AR	p-v	AR	p-v	AR	p-v	AR	p-v	AR	p-v	AR	p-v
Developed Economies	-0.07	0.00***	-0.02	0.00***	0.00	0.45	0.00	0.38	-0.02	0.00***	0.02	0.00***	0.00	0.18
Developing Economies	-0.01	0.20	-0.03	0.00***	0.01	0.00***	0.01	0.01**	0.00	0.53	0.00	0.93	-0.01	0.15

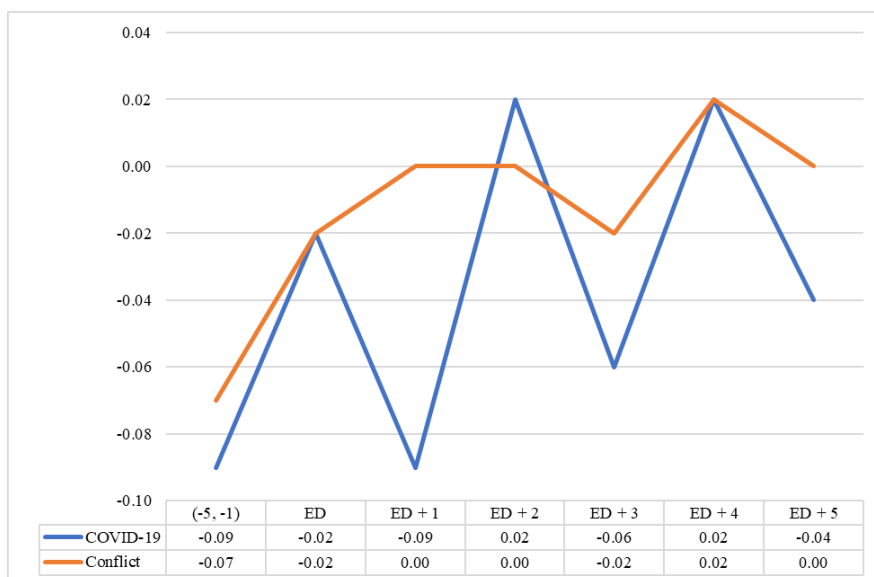
Source: authors' calculation

Note: significance levels: * $p < 0.10$, ** $p < 0.05$, and *** $p < 0.01$.

Impact of COVID-19 and the Conflict on the Stock of Developed Nations

Figure 5 presents the behaviour of developed nations during COVID-19 and the conflict. The stocks of developed nations are comparatively more sensitive towards COVID-19 than towards the conflict. Moreover, on the event day, both events are seen to have caused a similar reaction in the stock markets of developed nations, i.e. a negative one. However, in the subsequent days, the markets exhibited higher fluctuation in times of COVID-19, while they appeared to be more stable during the conflict.

Further, the significance of the abnormal returns is tested, and the same is presented in Table 6.



Source: authors' calculation

Figure 5. *Developed nations during COVID-19 and the conflict*

Table 6 further confirms that in the pre-announcement period of both events, the stock markets of developed nations exhibited a negative trend that continued up until the event day. In the case of COVID-19, the market demonstrated high volatility with statistically significant negative returns on ED + 1, ED + 3, and ED + 5 followed by a positive reaction on ED + 2 and ED + 4. However, in the case of the conflict, statistically significant negative returns are observed only on ED + 3 followed by significant positive returns on ED + 4.

Table 6. *Reactions of developed economies during COVID-19 and the conflict*

Windows	COVID-19	p-v	Conflict	p-v
(-5, -1)	-0.09	0.00***	-0.07	0.00***
ED	-0.02	0.00***	-0.02	0.00***
ED + 1	-0.09	0.00***	0.00	0.45
ED + 2	0.02	0.00***	0.00	0.38
ED + 3	-0.06	0.00***	-0.02	0.00***
ED + 4	0.02	0.00***	0.02	0.00***
ED + 5	-0.04	0.00***	0.00	0.18

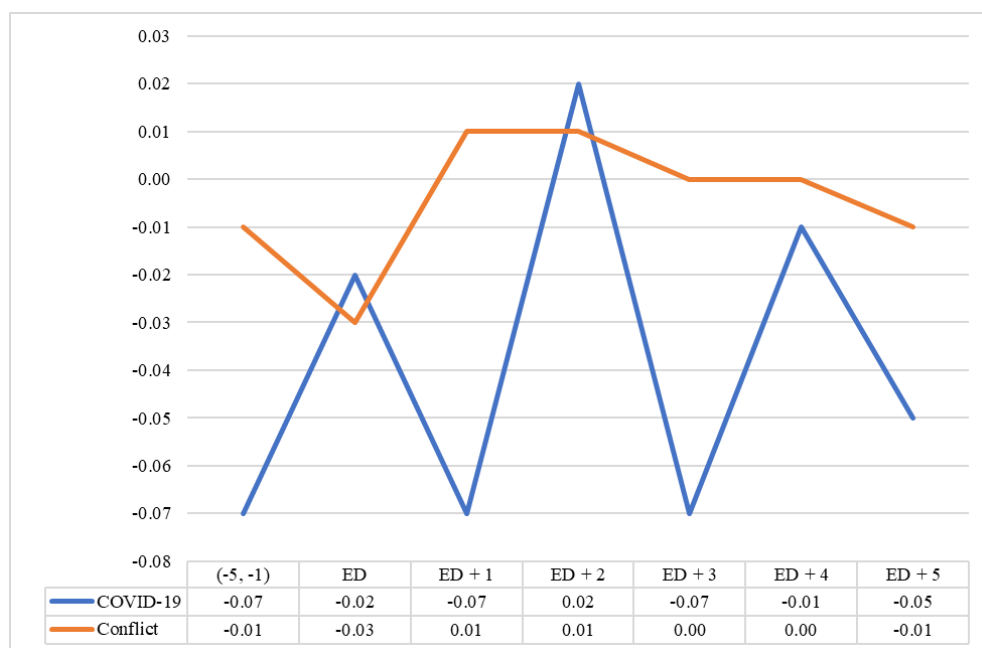
Source: authors' calculation

Note: significance levels: * $p < 0.10$, ** $p < 0.05$, and *** $p < 0.01$.

Impact of COVID-19 and the Conflict on the Stock of Developing Nations

Figure 6 presents the behaviour of developing nations during COVID-19 and the conflict. The stock markets of developing nations are found to be comparatively more sensitive to the COVID-19 outbreak than to the conflict. However, on the event day, the announcement of the conflict caused a rather adverse reaction in the markets of developing economies, but on the subsequent days, the markets appeared to be a lot more stable. On the other hand, in the case of COVID-19, stocks exhibited a greater degree of volatility in the post-announcement period. Further, the significance of the abnormal returns is tested, and the same is presented in Table 7.

From Table 7, it can be observed that during the pre-announcement period of both events, the stock market exhibited a negative trend, and the same continued up until the event day. However, on ED + 1 for the conflict, the returns were positive and significant, while in the case of COVID-19, the markets continued to be in a negative trend. In the case of the conflict, the stocks continued to be in a positive trend except ED + 5, but none were significant, while in the case of COVID-19, the returns continued to be in a negative trend, and all were significant except for ED + 4.



Source: authors' calculation

Figure 6. Developing nations during COVID-19 and the conflict

Table 7. Reactions of developing economies during COVID-19 and the conflict

Windows	COVID-19	p-v	Conflict	p-v
(-5, -1)	-0.07	0.00***	-0.01	0.2
ED	-0.02	0.00***	-0.03	0.00***
ED + 1	-0.07	0.00***	0.01	0.00***
ED + 2	0.02	0.00***	0.01	0.01**
ED + 3	-0.07	0.00***	0.00	0.53
ED + 4	-0.01	0.2	0.00	0.93
ED + 5	-0.05	0.00***	-0.01	0.15

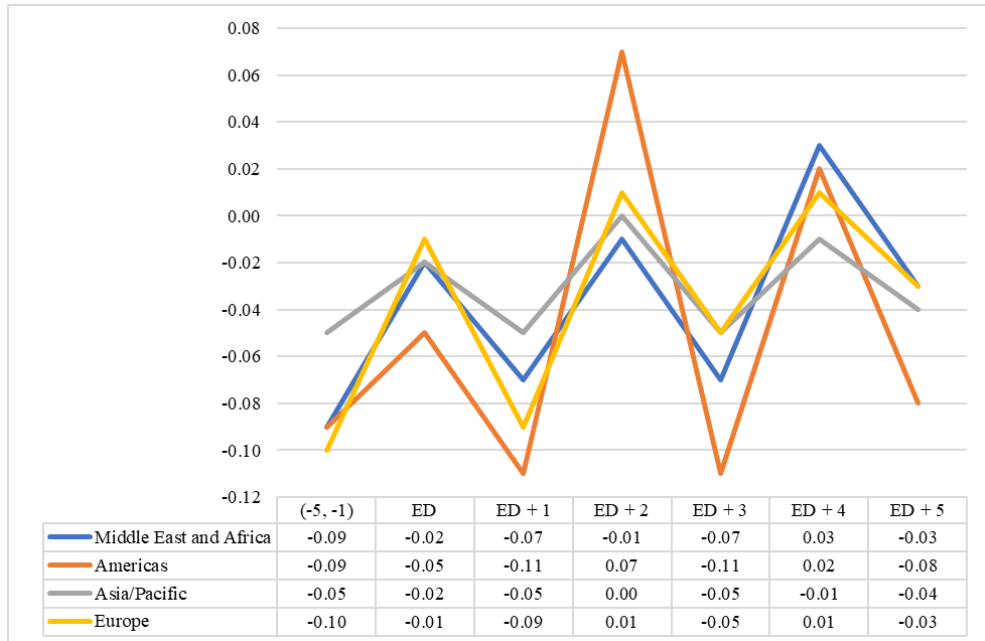
Source: authors' calculation

Note: significance levels: * $p < 0.10$, ** $p < 0.05$, and *** $p < 0.01$.

Region-Wise Impact of COVID-19

Figure 7 presents the stock market behaviour of all regions under G-20 nations during the COVID-19 pandemic and finds that all the stock markets are sensitive towards the outbreak of COVID-19. On event day, all the stock markets report

negative returns, and the markets continue their downward trend on ED + 2. From this, it can be said that the market is slow in responding to the information released during the outbreak of COVID-19. In the subsequent days, a significant fluctuation can be observed, which indicates investors' confused state of mind regarding the COVID-19 pandemic. Further, the significance of the abnormal returns is tested, and the same is presented in *Table 8*.



Source: authors' calculation

Figure 7. Region-wise impact of COVID-19

From *Table 8*, it becomes clear that during the pre-announcement period of COVID-19, stock markets of all the major regions exhibit a negative trend that continues up until ED + 1. However, from ED + 2 onwards, the markets experience high volatility, as the market returns on ED + 2 and ED + 4 are positive and significant for the majority of the regions followed by negative returns on ED + 3 and ED + 5. These fluctuations reflect investors' confused state of mind due to anxiety and fear concerning COVID-19.

Further, a paired sample t-test is conducted (*Table 9*), which found that there was no significant difference in the reactions of the different regions around the COVID-19 pandemic.

Table 8. *Region-wise impact of COVID-19*

Windows / Region	(-5, -1)		ED		ED + 1		ED + 2		ED + 3		ED + 4		ED + 5	
	CAAR	p-v	CAAR	p-v	CAAR	p-v	CAAR	p-v	CAAR	p-v	CAAR	p-v	CAAR	p-v
Middle East and Africa	-0.09	0.00***	-0.02	0.00***	-0.07	0.00***	-0.01	0.30	-0.07	0.00***	0.03	0.00***	-0.03	0.00***
Americas	-0.09	0.00***	-0.05	0.00***	-0.11	0.00***	0.07	0.00***	-0.11	0.00***	0.02	0.01**	-0.08	0.00***
Asia/Pacific	-0.05	0.00***	-0.02	0.00***	-0.05	0.00***	0.00	0.26	-0.05	0.00***	-0.01	0.04**	-0.04	0.00***
Europe	-0.10	0.00***	-0.01	0.39	-0.09	0.00***	0.01	0.07***	-0.05	0.00***	0.01	0.18	-0.03	0.00***

Source: authors' calculation

Note: significance levels: * $p < 0.10$, ** $p < 0.05$, and *** $p < 0.01$.**Table 9.** *Region-wise analysis*

Impact of COVID-19				
SI No.	Region(s)	Mean	t-stat	p-v
1	<i>Middle East and Africa</i>	-0.037	0.762	0.237
	<i>Americas</i>	-0.050		
2	<i>Middle East and Africa</i>	-0.037	-0.588	0.289
	<i>Asia/Pacific</i>	-0.031		
3	<i>Middle East and Africa</i>	-0.037	0.000	0.500
	<i>Europe</i>	-0.037		
4	<i>Americas</i>	-0.050	-0.993	0.179
	<i>Asia/Pacific</i>	-0.031		
5	<i>Americas</i>	-0.050	-0.804	0.226
	<i>Europe</i>	-0.037		
6	<i>Asia/Pacific</i>	-0.031	0.548	0.302
	<i>Europe</i>	-0.037		

Source: authors' calculation

Note: significance levels: * $p < 0.10$, ** $p < 0.05$, and *** $p < 0.01$.

Region-Wise Impact of the Conflict

Figure 8 depicts the reactions of stock markets of different regions around the announcement of the conflict. It is clear from the figure that except for Europe the stock markets of all the other regions exhibit a stable and upward trend around the outbreak of the conflict. The stocks of Europe exhibited a higher degree of fluctuation as compared to other regions. Further, the statistical significance of the fluctuations is tested using a t-test, and the same is displayed in Table 10.



Source: authors' calculation

Note: significance levels: * $p < 0.10$, ** $p < 0.05$, and *** $p < 0.01$.

Figure 8. Region-wise impact of conflict

Table 10 shows that during the pre-announcement period, stock markets in all the regions except Asia/Pacific generated negative returns. On the event day, all the markets except for the Americas continued to react negatively. However, on ED + 1, the stock markets of the Americas, Asia/Pacific, and Europe exhibited positive reactions, which were also reflected in the markets of the Middle East/Africa and Americas on the subsequent days. However, a significant negative response is observed in the markets of Europe on ED + 2, ED + 3, and Asia/Pacific on ED + 5. This indicates the post-conflict negative effect on the stock of the Asia/Pacific region and Europe.

Table 10. *Region-wise impact of the conflict*

Windows / G-20 Economies	Middle East and Africa	p-v	Americas	p-v	Asia/Pacific	p-v	Europe	p-v
(-5, -1)	-0.01	0.60	-0.03	0.01**	0.00	0.61	-0.07	0.00***
ED	-0.02	0.00***	-0.01	0.31	-0.03	0.00***	-0.03	0.00***
ED + 1	0.01	0.27	0.01	0.03**	0.01	0.00***	0.03	0.00***
ED + 2	0.02	0.01**	0.01	0.07*	0.01	0.17	-0.01	0.04**
ED + 3	0.01	0.17	0.00	0.59	0.00	0.97	-0.02	0.00***
ED + 4	0.00	0.88	0.00	0.96	0.01	0.17	0.02	0.01**
ED + 5	0.00	0.75	-0.01	0.13	-0.01	0.04**	0.00	0.96

Source: authors' calculation

Note: significance levels: * $p < 0.10$, ** $p < 0.05$, and *** $p < 0.01$.

A paired sample t-test is conducted to present the difference in reactions, and the same is displayed in *Table 11*. From the table, it is evident that the mean returns of only the Middle East and Africa and the Americas are significantly different from each other, while in the case of the other regions, there is no significant difference in the reactions around the outbreak of the conflict.

Table 11. *Region-wise analysis*

Impact of the Conflict				
SI No.	Region(s)	Mean	t-stat	p-v
1	Middle East and Africa	0.001	1.549	0.086*
	Americas	-0.004		
2	Middle East and Africa	0.001	0.795	0.229
	Asia/Pacific	-0.001		
3	Middle East and Africa	0.001	1.162	0.145
	Europe	-0.011		
4	Americas	-0.004	-0.505	0.316
	Asia/Pacific	-0.001		
5	Americas	-0.004	0.801	0.227
	Europe	-0.011		
6	Asia/Pacific	-0.001	0.866	0.210
	Europe	-0.011		

Source: authors' calculation

Note: significance levels: * $p < 0.10$, ** $p < 0.05$, and *** $p < 0.01$.

A Comparative Chart on the Reactions of Different Regions during COVID-19 and the Conflict

Here the reaction of each region during COVID-19 and the conflict is compared using a paired sample t-test. From *Table 12*, it is evident that there exists a significant difference in the reactions of the Middle East and Africa during COVID-19 and the conflict. A similar result is witnessed for the Americas and Asia/Pacific; however, in the case of Europe, no significant difference is witnessed in the reactions during COVID-19 and the conflict.

Table 12. *Comparison of the impact of COVID-19 and the conflict on different regions*

Regions	Event	Mean	t-stat	p-v
Middle East and Africa	COVID-19	-0.04	-2.33	0.03**
	Conflict	0.00		
Americas	COVID-19	-0.05	-1.84	0.06*
	Conflict	0.00		
Asia/Pacific	COVID-19	-0.03	-3.15	0.01**
	Conflict	0.00		
Europe	COVID-19	-0.04	-1.44	0.10
	Conflict	-0.01		

Source: authors' calculation

Note: significance levels: * $p < 0.10$, ** $p < 0.05$, and *** $p < 0.01$.

5. Conclusions

The COVID-19 pandemic has wreaked havoc all over the world, and the financial consequences were felt all over the financial markets. On the other hand, Russia's invasion of Ukraine led to an intense geopolitical conflict, whose financial implications were felt in the markets globally. Given the varying nature of these events, the present study is an attempt to examine the impact of the COVID-19 outbreak and the Russia–Ukraine conflict on the stock market using an extensive sample of G-20 nations. The sample has been classified into developing and developed nations, and another classification has been carried out based on their region to facilitate the analysis and comparison of the different market reactions. To achieve its objective, the present study employed event study methodology and paired sample t-test on the index return of the G-20 nations.

Results revealed that stock markets all over the world experienced negative returns on the event day for both events. Our findings demonstrate that the stock markets all over the world experienced higher volatility and negative returns during the COVID-19 pandemic, and the same results are confirmed by previous studies (see Anh and Gan, 2021; Ashraf, 2020b; Al-Awadhi et al., 2020; Ganie et al., 2022; Mishra and Mishra, 2021; Mishra et al., 2020), where the stock market indices of different nations exhibited strong negative reactions and an increased degree of volatility. During COVID-19, developing nations experienced a higher volatility caused by the heightened uncertainty related to the pandemic, leading to panic selling in stock markets. The difference in the reactions of the emerging markets as compared to that of the developed markets can also be corroborated by other studies (Harjoto et al., 2021; Pandey and Kumari, 2021).

In the region-wise analysis during COVID-19, the present study finds that there exists no significant differences among the reactions of the various regions, as all the markets experienced significant negative returns and heightened volatility. However, Pandey and Kumari (2021) find that the Asian stock markets have been significantly affected, whereas the American markets have not experienced any significant impact. The present findings regarding the impact of the conflict is comparable to that of Yousaf et al. (2022), who found the adverse impact of the event on the stock markets of G-20 nations. Higher volatility and negative returns in the European and Asian market can be observed from the region-wise analysis conducted during the present study. The difference in reaction can be further backed by the studies of Federle et al. (2022) and Bossman and Gubareva (2023b), which conclude that financial markets closer to and more connected with the warring nations experience higher negative returns. The present study finds an overall negative reaction of the markets to the Russia–Ukraine conflict, which is consistent with previous literature (Kamal et al., 2023; Das et al., 2023).

The findings of the present study provide a clear depiction of the differences and similarities in the market reactions. The findings are extremely valuable and have practical implications for decision makers such as market regulators, investors, and governments across the globe in understanding how such global events resonate within a specific region, as it can be particularly useful to formulate country-specific measures to strengthen stock market resilience globally.

The present study has at least two known drawbacks, the first of which being the consideration of limited events and the second being the limited sample size of only 20 nations. Apart from that, a longer window can also be considered in future research to analyse and compare the long-term behaviour of the markets.

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Private Investment and Economic Growth in South Africa: A Multivariate Causality Approach

Glenda MALULEKE

¹ Department of Economics, University of South Africa, South Africa
e-mail: malulg@unisa.ac.za

Abstract. This study examines the causal relationship between private investment and economic growth in South Africa using the autoregressive distributed lag (ARDL) bound test for cointegration and data from 1980 to 2022. The study incorporated other macroeconomic determinants of private investment in the model, such as public investment and financial development, to create a multivariate Granger causality model. The results indicate that in the long and short run there is bidirectional causality between private investment and economic growth. It is also found that there is unidirectional causality from public investment to private investment in the long run. However, there is bidirectional causality between public investment to private investment, while there is unidirectional causality from private investment to financial development in the short run. Based on these results, the study concludes that economic growth and public investment promote private investment in South Africa.

Keywords: public investment, financial development, multivariate Granger causality, South Africa

JEL Classification: E22, O16, O47

1. Introduction

The findings from the studies that have been conducted to determine the relationship between private investment and its determinants (Mlambo and Oshikoya, 2001; Erden and Holcombe, 2006; Ambaye et al., 2013; Maluleke, 2024) have been inconclusive. These determinants from these studies include public investment, economic growth, interest rates, credit to private sector, and inflation, among others. These studies have found that the impact of the determinants on private investment can be positive, negative, or inconclusive; however, most

of the studies found that the determinants have a positive effect. Although the debate on the determinants of private investment has not been fully settled. It has been well researched unlike the causality dimension whose debate is still nascent, as economies engage in the pro-investment mode, designing policies that attract private investment. In recent times, the debate has widened, extending from merely establishing the drivers of private investment to the addition of the causality element, further examining the direction of causality between private investment and its determinants (see Tan and Tang, 2012; Molapo and Damane, 2015). Furthermore, in terms of the causality between private investment and its various determinants such as economic growth, the literature is both scant and inconclusive, leaving policy gaps, especially in African countries and South Africa in particular, where economies are desperate to increase investment and improve their economic growth prospects. Prior studies tended to focus on determining the factors of private investment. However, little attention has been given to the assessment of the causal linkages between private investment and economic growth.

In literature, there are four views that exist on this causal relationship between private investment and its numerous macroeconomic determinants. These are: unidirectional causality from determinants to private investment, unidirectional causality from private investment to the determinants, bidirectional causality between private investment and the determinants, and no causal relationship between private investment and the determinants (see Erenburg and Wohar, 1995).

Even though several studies have been done on the dynamic causal linkage between private investment and some of its macroeconomic determinants in developing and developed countries, the finds are largely inconclusive. Therefore, the study aims to fill this gap by investigating the causal relationship between private investment and economic growth in South Africa using multivariate Granger causality. The motivation for the study focusing on South Africa is that the country has developed policies and strategies over the years to increase the level of investment. As the country wants to promote and increase the level of investment, especially from the private sector, the current study aims to establish whether economic growth causes private investment. The findings of the study will also add to the literature on the causal relationship between private investment and its determinants in Southern African countries.

The rest of the study is organized as follows: Section 2 reviews literature on the causality between private investment and its determinants, Section 3 discusses the methodology selected to examine the causal relationship, Section 4 presents the empirical findings and discussion of the results, and, lastly, Section 5 concludes the study.

2. Literature Review

The findings on the causal relationship between private investment and its determinants, although limited, show that all four possible outcomes of the analysis have found support in empirical literature. Thus, there is empirical evidence of unidirectional causality from private investment to its determinants and from determinants to private investment, bidirectional causality between private investment and its determinants, and no causality between private investment and its determinants.

In Malawi, Mataya and Veeman (1996) analysed the investment behaviour in the private and public goods sectors between 1967 and 1988 and used the Granger causality test. The study found that there was a bidirectional causality between private and public investment. Nazlioglu et al. (2009) investigated the causality between investment and financial development in Turkey in both the short and the long run using quarterly data from 1987-1 to 2007-1. Using the Dolado and Lutkepohl test of Granger causality, the study found that there was a bidirectional causality between private investment and financial development.

Using the Granger causality test, Keho and Echui (2011) found that public investment in transport infrastructure had not caused private investment both in the short and the long run in Côte d'Ivoire over the period from 1970 to 2002. Also using the Granger causality test, Aurangzeb and Haq (2012) examined the causal relationship between investments and economic growth in Pakistan for the period from 1981 to 2010. They also examined the causal relationship using the Granger causality test and found a unidirectional causality running from economic growth to private investment.

Muyambiri et al. (2012) examined the relationship between private and public investment in Zimbabwe for the period from 1967 to 2004, and the findings from the Granger causality test reveal that there is unidirectional causality from private to public investment. Also using the Granger causality test, Tan and Tang (2012) examined the dynamic relationship between private domestic investment, the user cost of capital, and economic growth in Malaysia for the period from 1970 to 2009 and found that there was a unidirectional causality running from private domestic investment to economic growth and to the user cost of capital in the long run. In the short run, there is a bi-directional causality between private domestic investment and user cost of capital and between private domestic investment and economic growth.

Xu and Yan (2014) investigated the causal relationship between private investment and disaggregated government investment in China for the period

from 1980 to 2011. Using the Granger causality test, the results reveal that there is unidirectional causality from government investment in public goods to private investment and bidirectional causality between government investment in private goods and private investment in China.

In Lesotho, Molapo and Damane (2015) examined the direction of causality between private investment and its determinants using the Granger causality test for the period from 1982 to 2013. The study found that there was a unidirectional causality running from private investment to GDP per capita, a bidirectional causality between private investment and government investment and did not find a causal relationship between private investment and general price level.

Using the Granger causality test for Tanzania, Mabula and Mutasa (2019) found that there was no causal relationship between private investment and domestic debt, external debt, debt service, and private consumption expenditure. Olaifa and Benjamin (2019) used the Toda-Yamamoto (T-Y) causality test and found that there was a bidirectional causality between private sector investment and government capital expenditure in Nigeria. Also using the Toda-Yamamoto (TY) Granger causality test, Ari et al. (2019) examined the causal relationship between public investment and private investment in GCC countries (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates (UAE)) for the period from 1960 to 2015. They found that in two of the counties, Bahrain and Kuwait, there was unidirectional causality running from private to public investment and bidirectional causality between public and private investment. The study further established that there was nonlinear bidirectional causality between public and private investment in Saudi Arabia and the UAE.

Ari and Koc (2020) investigates the nonlinear causal relationships between public/private investment and economic growth in the U.S. and China using data from 1960 to 2015. The linear causality results reveal that private investment has bidirectional causality between economic growth and public investment in China and in the U.S. and that in the U.S. there is a unidirectional nonlinear causality running from private to public investment and from economic growth to private investment. The nonlinear Granger causality test results show that private investment has bidirectional causality with economic growth and public investment in China, while in the U.S. there is a unidirectional nonlinear causality running from private to public investment and from economic growth to private investment. Awad et al. (2021) used the Granger causality test and found that there was no causality between domestic private investment and lending interest rates in Palestine. A summary of empirical studies on the causal relationship between private investment and its determinants is presented in the table below.

Table 1. *A summary of empirical studies on the causal relationship between private investment and its determinants*

Author(s)	Country and sample period	Methodology	Direction of Causality
Unidirectional Causality from Private Investment to Determinants			
Muyambiri et al. (2012)	Zimbabwe 1967–2004	Granger causality test	private investment → public investment
Tan and Tang (2012)	Malaysia 1970–2009	Granger causality test	private domestic investment → economic growth private domestic investment → user cost of capital
Molapo and Damane (2015)	Lesotho 1982–2013	Granger causality test	private investment → GDP per capita
Ari et al. (2019)	GCC countries 1960–2015	TY Granger causality test	private investment → public investment (Bahrain and Kuwait)
Ari and Koc (2020)	U.S. and China 1960–2015	TY and Nonlinear Granger causality test	Linear and nonlinear causality for the U.S. private investment → public investment
Unidirectional Causality from Determinants to Private Investment			
Hyder (2001)	Pakistan 1964–2001	Granger causality test	economic growth → private investment public investment → private investment
Aurangzeb and Haq (2012)	Pakistan 1981–2010	Granger causality test	economic growth → private investment
Xu and Yan (2014)	China 1980–2011	Granger causality test	government investment in public goods → private investment
Ari et al. (2019)	GCC countries 1960–2015	TY Granger causality test	nonlinear causality: public investment → private investment (Bahrain, Oman, and Qatar)
Ari and Koc (2020)	U.S. and China 1960–2015	TY and nonlinear Granger causality test	linear and nonlinear causality for U.S. economic growth → private investment
Bidirectional Causality between Private Investment and Determinants			
Erenburg and Wohar (1995)	1954–1989	Multivariate Granger causality	private investment ↔ public investment
Mataya and Veeman (1996)	Malawi 1967–1988	Granger causality test	private investment ↔ public investment

Author(s)	Country and sample period	Methodology	Direction of Causality
Tan and Tang (2012)	Malaysia 1970–2009	Granger causality test	In the short run: private domestic investment ↔ user cost of capital private domestic investment ↔ economic growth
Nazlioglu et al. (2009)	Turkey 1987-1–2007-1	Dolado and Lutkepohl test of Granger causality	private investment ↔ financial development
Xu and Yan (2014)	China 1980–2011	Granger causality test	government investment in private goods ↔ private investment
Molapo and Damane (2015)	Lesotho 1982–2013	Granger causality test	private investment ↔ government investment
Ari et al. (2019)	GCC countries 1960–2015	T-Y and nonlinear Granger causality test	Public investment ↔ private investment (Oman, Qatar, United Arab Emirates) Nonlinear causality: public investment ↔ private investment (Saudi Arabia and United Arab Emirates)
Olaifa and Benjamin (2019)	Nigeria 1981–2016	T-Y causality test	private sector investment ↔ government capital expenditure
Ari and Koc (2020)	U.S. and China 1960–2015	TY and nonlinear Granger causality test	linear and nonlinear causality for China public investment ↔ private investment private investment ↔ economic growth
Studies That Found No Causality between Private Investment and Determinants			
Keho and Echui (2011)	Côte d'Ivoire 1970–2002	Granger causality test	private investment ≠ public investment in transport
Molapo and Damane (2015)	Lesotho 1982–2013	Granger causality test	private investment ≠ general price level
Mabula and Mutasa (2019)	Tanzania 1970–2016	Granger causality test	private investment ≠ domestic debt, external debt, debt service and private consumption expenditure
Awad et al. (2021)	Palestine Q1/2008–Q4/2017	Granger causality test	private investment ≠ lending interest rate

Source: author's compilation

Notes: ↔ is bidirectional causality, → is unidirectional causality, and ≠ is no causality.

3. Methodology

To examine the causal relationship between private investment and economic growth, the study employs the autoregressive distributed lag (ARDL) methodology and the error correction model (ECM) Granger causality framework. The ARDL approach was selected, as it has advantages such as its efficiency for small samples and that the variables do not need to be integrated in the same order, wherefore variables that are $I(0)$ and $I(1)$ can be included in the model. As there are limitations with the bivariate causality framework, this study used the multivariate Granger causality. This is because the bivariate causality model suffers from the omission of an important variable in the model, and this could lead to erroneous causal inferences (Luintel and Khan, 1999). Therefore, public investment and financial development are included as intermittent variables to make a multivariate Granger causality framework. The variables are chosen because in the literature they have been found to be the determinants of private investment (see Ngoma et al., 2019; Mose et al., 2020; Maluleke et al., 2023). The multivariate Granger causality model function is expressed as follows:

$$PrvI = f(Y, PubI, FD)$$

Private investment (PrvI), which is the dependent variable, is measured by private investment as a percentage of GDP. The explanatory variables include economic growth (Y) proxied by GDP per capita, public investment (PubI) measured by public investment as a percentage of GDP, and financial development (FD) proxied by domestic credit to private sector as a percentage of GDP. The study utilized annual time series data from 1980 to 2022 obtained from the World Bank Development Indicators. The selection of the study period was based on the availability of reliable data on the variables included in the study. The measurement of the variables is presented in *Table 2*.

Table 2. *Definitions of the variables*

Variables	Measurements
PrvI – Private investment	Private investment as a percentage of GDP
Y – Economic growth	GDP per capita (constant 2015 US \$)
PubI – Public investment	Public investment as a percentage of GDP
FD – Financial development	Domestic credit to private sector as a percentage of GDP

Source: author's compilation

The ARDL model for cointegration is conducted by taking in turn each variable included in the model as a dependent variable. Following Pesaran et al. (2001),

the ARDL model used in this study for all the equations is expressed as follows (see Nyasha and Odhiambo, 2020):

$$\begin{aligned}
 \Delta PrvI_t &= a_0 + \sum_{i=1}^n a_{1i} \Delta PrvI_{t-i} + \sum_{i=0}^n a_{2i} \Delta Y_{t-i} + \sum_{i=0}^n a_{3i} \Delta PubI_{t-i} + \sum_{i=0}^n a_{4i} FD_{t-i} \\
 &\quad + a_1 PrvI_{t-1} + a_2 Y_{t-1} + a_3 PubInv_{t-1} + a_4 FD_{t-1} + \mu_{1t} \\
 \Delta Y_t &= \gamma_0 + \sum_{i=1}^n \gamma_{1i} \Delta Y_{t-i} + \sum_{i=0}^n \gamma_{2i} \Delta PrvI_{t-i} + \sum_{i=0}^n \gamma_{3i} \Delta PubI_{t-i} + \sum_{i=0}^n \gamma_{4i} \Delta FD_{t-i} + \Delta TO_{t-i} \\
 &\quad + \gamma_1 Y_{t-1} + \gamma_2 PrvI_{t-1} + \gamma_3 PubI_{t-1} + \gamma_4 FD_{t-1} + \mu_{2t} \\
 \Delta PubI_t &= \sigma_0 + \sum_{i=1}^n \sigma_{1i} \Delta PubI_{t-i} + \sum_{i=0}^n \sigma_{2i} Y_{t-i} + \sum_{i=0}^n \sigma_{3i} PrvI_{t-i} + \sum_{i=0}^n \sigma_{4i} \Delta FD_{t-i} \\
 &\quad + \sigma_1 InPubI_{t-1} + \sigma_2 Y_{t-1} + \sigma_3 PrvI_{t-1} + \sigma_4 FD_{t-1} + \mu_{3t} \\
 \Delta FD_t &= \delta_0 + \sum_{i=1}^n \delta_{1i} \Delta FD_{t-i} + \sum_{i=0}^n \delta_{2i} \Delta Y_{t-i} + \sum_{i=0}^n \delta_{3i} \Delta PubI_{t-i} + \sum_{i=0}^n \delta_{4i} \Delta PrvI_{t-i} \\
 &\quad + \delta_1 FD_{t-1} + \delta_2 Y_{t-1} + \delta_3 PubI_{t-1} + \delta_4 PrvI_{t-1} + \mu_{4t}
 \end{aligned}$$

The study tests for cointegration among the variables in the causality models before Granger causality could be estimated. The computed F-statistic is used to determine the cointegration. If the computed F-statistic is above the value of the upper critical bounds, then the null hypothesis is to be rejected. If the F-statistic is below the values of the lower bounds, then the null hypothesis of no cointegration is accepted (Pesaran et al. 2001). After the confirmation of cointegration between private investment and the explanatory variables, the causal relationship is investigated using the multivariate Granger causality model based on an ECM framework. The ECM-based Granger multivariate causality model specifications are provided as follows:

$$\begin{aligned}
 \Delta PrvI_t &= a_0 + \sum_{i=1}^n a_{1i} \Delta PrvI_{t-i} + \sum_{i=0}^n a_{2i} \Delta Y_{t-i} + \sum_{i=0}^n a_{3i} \Delta PubI_{t-i} + \sum_{i=0}^n a_{4i} FD_{t-i} \\
 &\quad + a_5 ECM_{t-1} + \mu_{1t} \\
 \Delta Y_t &= \gamma_0 + \sum_{i=1}^n \gamma_{1i} \Delta Y_{t-i} + \sum_{i=0}^n \gamma_{2i} \Delta PrvI_{t-i} + \sum_{i=0}^n \gamma_{3i} \Delta PubI_{t-i} + \sum_{i=0}^n \gamma_{4i} \Delta FD_{t-i} \\
 &\quad + \gamma_5 ECM_{t-1} + \mu_{2t}
 \end{aligned}$$

$$\begin{aligned}\Delta PubI_t &= \sigma_0 + \sum_{i=1}^n \sigma_{1i} \Delta PubI_{t-i} + \sum_{i=0}^n \sigma_{2i} Y_{t-i} + \sum_{i=0}^n \sigma_{3i} PrvI_{t-i} + \sum_{i=0}^n \sigma_{4i} \Delta FD_{t-i} \\ &\quad + \sigma_5 ECM_{t-1} + \mu_{3t} \\ \Delta FD_t &= \delta_0 + \sum_{i=1}^n \delta_{1i} \Delta FD_{t-i} + \sum_{i=0}^n \delta_{2i} \Delta Y_{t-i} + \sum_{i=0}^n \delta_{3i} \Delta PubI_{t-i} + \sum_{i=0}^n \delta_{4i} \Delta PrvI_{t-i} + \\ &\quad \delta_5 ECM_{t-1} + \mu_{4t},\end{aligned}$$

where: *PrvI* – the private investment; *Y* – the economic growth; *PubInv* – the public investment; *FD* – financial development; $\mu_{1t} \dots \mu_{4t}$ – the error term; $a_0, \gamma_0, \sigma_0, \delta_0$ – the constants; $a_1 \dots a_4, \gamma_1 \dots \gamma_4, \sigma_1 \dots \sigma_4, \delta_1 \dots \delta_4$ – the coefficients; $a_5, \gamma_5, \psi_5, \delta_5$ – the error correction term.

After confirmation of the cointegration relationship, the next step is to examine the direction of causality between the variables by including the ECM as an additional variable in the analysis where cointegration was confirmed. The Granger causality test is performed without an ECM for the equations where no cointegration is confirmed. The short-run causality is determined by the joint Wald *F* test, while the significance of the lagged error correction term using the t-statistics determines the long-run causality (see Chirwa and Odhiambo, 2019; Hossin, 2023).

4. Discussion of the Results

Table 3 shows the descriptive statistics of the variables, which are private investment, economic growth, public investment, and financial development. The reported results include the mean, maximum, minimum values, and standard deviation. The descriptive statistics results indicate that economic growth (*Y*) is more spread out with a standard deviation of 679.293 and that public investment has the lowest standard deviation of 1.875. The results further show that the variables of interest, which are economic growth and private investment, are normally distributed. This is revealed by the probability values of the Jarque–Bera statistics that are higher than the 0.05 level of significance.

Table 3. *Descriptive statistics*

	PrvI	Y	PubI	FD
Mean	13.989	5354.244	4.061	100.956
Median	13.594	5329.489	3.211	105.276
Maximum	18.908	6263.104	8.447	142.422
Minimum	10.768	4269.700	2.416	50.085
Std. Dev.	2.157	679.293	1.875	26.416
Skewness	0.753	-0.043	1.231	-0.527

	PrvI	Y	PubI	FD
Kurtosis	2.749	1.537	3.053	1.996
Jarque–Bera	4.080	3.757	10.607	3.709
Probability	0.130	0.152	0.005	0.157
Observations	42	42	42	42

Source: author's calculations

The study starts by testing the variables for stationarity. Although the ARDL-bounds approach does not require all the variables included in the model to be integrated of the same order, it requires that all the variables are not integrated of order higher than 2. Therefore, it is important to conduct the stationarity test, and the Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) tests are utilized for this purpose in the present study. The results show that all the variables are integrated of order I(1) when using both tests. The results of the stationarity test are reported in *Table 4*.

Table 4. Stationarity test of all variables

Variable	GLS-DF Test		PP Test	
	Trend and intercept		Trend and intercept	
	Level	Δ	Level	Δ
PrvI	-2.559	-4.186***	-2.081	-3.956**
Y	-1.639	-4.634***	-1.913	-4.922***
PubI	-1.179	-5.687***	-1.467	-6.282***
FD	0.680	-4.629**	0.858	-5.788***

Source: author's calculations

Notes: ** and *** indicate stationarity at 5% and 1% significance levels respectively; Δ is first difference.

As all the variables are integrated of I(1), the ARDL bounds test for cointegration can be used. Therefore, the next step is to perform the bounds F-statistic test for cointegration to confirm if there is a long-run relationship or not among the variables. The results of the cointegration test are reported in *Table 5*.

Table 5. Cointegration test results

Dependent Variable	Lag selection	F-Statistic				Conclusion	
<i>PrvI</i>	[2,2,0,0]	5.304***				Cointegrated	
<i>Y</i>	[2,2,0,0]	4.252*				Cointegrated	
<i>PubI</i>	[1,2,0,2]	2.789				Not cointegrated	
<i>CRED</i>	[2,0,0,0]	3.017				Not cointegrated	
Asymptotic critical values	1%		5%		10%		
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	
	4.29	5.61	3.23	4.35	2.72	3.77	

Source: author's calculations

Notes: * and *** indicate statistical significance at 10% and 1% levels respectively.

The Akaike Information Criteria (AIC) is used to determine the ARDL optimal lag length, and the results indicate that the null hypothesis of no cointegration for private investment and economic growth equations is rejected at 1% and 10% levels of significance. For public investment and financial development equations, it is found that there are no cointegrating relationships. The results of the cointegration tests in *Table 5* suggest that the cointegration relationship between private investment and the explanatory variables differs depending on the dependent variable used. The empirical findings of cointegration for private investment and economic growth indicate that there is at least a one-way Granger causality present between private investment, economic growth, public investment, and financial development (see Narayan and Smyth, 2008). However, this does not show the direction of the causal flow among the variables. Therefore, the next step is to test for causality between the variables in the model, for which the results are presented in *Table 6*.

Table 6. *Results of the multivariate causality test*

Dependent Variable	Short-Run Causality				Long-Run Causality <i>ECT</i> _{<i>t</i>-1} [t-statistics]
	F-statistics [Probability]				
	ΔPrvI	ΔY	ΔPubI	ΔFD	
ΔPrvI	—	8.400*** [0.000]	7.981*** [0.008]	0.638 [0.430]	-0.419*** [-4.817]
ΔY	5.751*** [0.003]	—	1.398 [0.246]	0.650 [0.426]	-0.071*** [-4.313]
ΔPubI	5.729** [0.023]	2.036 [0.131]	—	3.271** [0.035]	—
ΔFD	6.748** [0.014]	0.208 [0.651]	8.887*** [0.006]	—	—

Source: author's calculations

Notes: *** and ** indicate statistical significance at 1% and 5% levels respectively.

The results in *Table 6* show that there is bidirectional causality between private investment and economic growth in the long and short run in South Africa. The results concur with findings of previous studies such as Hyder (2001), Aurangzeb and Haq (2012), and Ari and Koc (2020), who have found economic growth to cause private investment. The results seem to suggest that the level of private investment in South Africa is determined by the economic growth of the country. However, in the short run, the study also found a bidirectional causality between private and public investment. Studies such as Erenburg and Wohar (1995), Mataya and Veeman (1996), among others, have also found a bidirectional causality between private and public investment.

The short-run unidirectional causal relationship is supported by the F-statistic, which is statistically significant, while the long-run causal relationship is supported by the coefficient of the ECM, which is negative and statistically significant as expected. In the long run, the causality was found to be from public investment to private investment only. The findings of the study further show that private investment causes financial development in the short run, while there is no causality in the long run. The ECM for the public investment and financial development equations are not reported, as the null hypothesis of no cointegration could not be rejected. *Table 7* presents the summary of the causality test results between private investment and economic growth.

Table 7. *Summary of the causality test results*

Short run	Long run
$Y \leftrightarrow \text{PrvI}$	$Y \leftrightarrow \text{PrvI}$
$\text{PubI} \leftrightarrow \text{PrvI}$	$\text{PubI} \rightarrow \text{PrvI}$
$\text{PrvI} \rightarrow \text{FD}$	$\text{PrvI} \neq \text{FD}$

Source: author's compilation

Note: $\leftrightarrow$ is bidirectional causality, $\rightarrow$ is unidirectional causality, and $\neq$ is no causality.

5. Conclusions

The study examined the causal relationship between private investment and economic growth in South Africa for the period from 1980 to 2022 using the multivariate Granger causality model. The study finds that in the long and short run there is bidirectional causality between private investment and economic growth. Regarding public investment, there is bidirectional causality only in the short run and unidirectional causality from public investment to private investment in the long run. The study also found that there was unidirectional causality from private investment to financial development in the short run in South Africa and no causality between the two variables in the long run.

The study concludes that economic growth is the driver for private investment in South Africa. In the long run, investment is found to drive private investment. Therefore, for the economy to increase the level of private investment, the government should invest in infrastructure and not in sectors or goods that will compete with the private sector. The study further recommends that the government should formulate policies that will create a conducive environment that will develop the economy and stimulate private investment in the country such as openness of the economy, low and stable inflation rate. Therefore, the government should also continue with the incentives that encourage the private sector to participate in the economy.

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Safety Citizenship Behaviour in Malaysia Public Transportation: The Role of Safety- Specific Transformational Leadership and Safety Consciousness

Chandrakantan SUBRAMANIAM,¹ Johanim JOHARI,¹
Munir Shehu MASHI,² Choo Ling SUAN,³ Siti Hawa
HARITH,¹ Ruzilawati ISNIN⁴

¹ School of Business Management, Universiti Utara Malaysia, 06010 Sintok Kedah, Malaysia

² Department of Business Management, Federal University Dutsin-Ma, Dutsin-Ma, Nigeria

³ School of Economics and Management, Xiamen University Malaysia, 43900 Sepang, Selangor, Malaysia

⁴ Prasarana Malaysia Berhad, 59000 Jalan Bangsar, Kuala Lumpur, Malaysia
e-mails: ¹ chandra@uum.edu.my, johanim@uum.edu.my, sitihawaharith@gmail.com;

^{2*} munirshehu@gmail.com; ³ lingsuan.choo@xmu.edu.my; ⁴ ruzilawati.isnin@gmail.com

Abstract. Safety-specific transformational leadership (SSTL) is crucial in public railway transport due to the higher occupational hazards. This paper tests the direct relationship between SSTL and safety citizenship behaviour (SCB) dimensions, such as civic virtue, helping, stewardship, voice, initiating safety-related changes, and whistleblowing. The study was conducted with employees of a Light Rapid Transit (LRT) Railway Service Company, and the data were analysed using SPSS and SmartPLS 4.0.8.3. Results show significant positive relationships between SSTL and the civic virtue, stewardship, voice, and whistleblowing dimensions of SCBs. Safety consciousness significantly moderated the relationship between SSTL and both initiating safety-related changes and stewardship. The study discusses various theoretical and practical implications for public transportation.

Keywords: safety-specific transformational leadership, safety citizenship behaviour, railway, safety consciousness, SmartPLS, Malaysia

JEL Classification: I10, I12, I18

1. Introduction

The railway is one of the main modes of transportation in Malaysia, especially for those living in the city area of Kuala Lumpur. Data from the Ministry of Transport Malaysia reveals that for the first quarter (from January to April) of 2021 the number of passengers using the six main services of Light Rail Transit (LRT) Ampang Line, LRT Kelana Jaya Line, KL Monorail, Metro Rail Transit (MRT) SBK Line, KLIA Express, and KLIA Transit is nearly 20 million (Statistic of Rail Transport, 2021). The public transport usage in 2022 has increased to 24% daily in the city centre as compared to 18% in 2018 (Ravindran, 2022). The railway transport sector plays a significant role in Malaysia's national income. With more upcoming MRT projects lined up, the government is estimating a total of 531 billion Malaysian Ringgit (RM) in economic value for ten years (Yusoff et al., 2021).

Malaysian railway services operate under the Land Public Transport Agency, which has now been absorbed into the Ministry of Transport. According to the Malaysia Land and Public Transport Act (Act 715) (Land et al. Act 2010 (Act 715), 2011), a railway accident is defined as an event that results in the death of a person, serious injury to a member of the public, a train passenger, or a person operating or driving a train, in significant damage to property or goods transported on the railway, or in an incident of the kind that typically results in such loss, injury, or damage.

Accidents involving public LRT or MRT have been reported in Malaysia. In October 2006, an empty LRT coach jumped a concrete barrier while stopping at the Sentul Timur station, leaving a portion of the coach dangling about 25 meters above the ground (Lourdes and Singh, 2006). Subsequently, in March 2015, a monorail service experienced an issue that resulted in a four-car train's rubber tyre catching fire at Titiwangsa Station (Shahrudin, 2015). Furthermore, a malfunction in the signalling and communication system between Ampang Park and Dang Wangi Station left the LRT Kelana Jaya Line stranded in September 2016. The most recent public LRT accident happened on 24 May 2021, when two LRTs collided due to miscommunication, causing 213 injuries, including 166 minor and 47 serious injuries (Chin, 2021).

A study by Kyriakidis et al. (2015) reported that many public railway accidents had happened due to degraded human performance and human error. A sizable fraction of all train accidents, including those that take place in switching yards, are caused by human factors. These LRT, MRT, and monorail incidents caused line service disruptions, property (coaches) and equipment damage, financial loss for the corporation, and reputational harm (Mashi et al., 2020).

Apart from that, a review of the literature also reported that one of the significant factors that highly contribute to occupational accidents is safety citizenship behaviour (SCB). SCB applies the principle of reciprocity, which highlights the

high-quality relationship between the employees and their supervisor (Hofmann et al., 2003; Zhang et al., 2020). Having a good relationship between the supervisor and employees can further encourage safety participation and subsequently avoid any unwanted occurrences or accidents at the workplace (Zhang et al., 2020).

SSTL is crucial in the railway transport industry because of the higher occupational hazards. With strong SSTL, trust, and support from the supervisor, the SCBs can be further cultivated in the organization (Irshad et al., 2021). Another important aspect is safety consciousness, which could help enhance the link between SSTL and SCBs. Safety consciousness is the employees' positive attitude and awareness that could encourage them towards SCBs (Meng and Chan, 2020). Conscientious workforces are committed and strive for their personal goals compared to less conscientious employees. As a result, safety consciousness can encourage better SSTL and SCBs. This paper intends to investigate the influence of SSTL on SCBs while examining the moderating role of safety consciousness in the relationship above. Therefore, the objectives of this study are twofold: (1) to test the direct relationship between SSTL and SCB dimensions (i.e. civic virtue, helping, stewardship, voice, initiating safety-related changes, and whistleblowing); (2) to examine the moderating role of safety consciousness in the relationship between SSTL and SCB.

This study addresses three important contributions to the safety and leadership literature. Firstly, conventionally studied leadership philosophies, such as transformational and transactional leadership, need to be revised to understand leadership in complex and changing settings such as railways (Hughes et al., 1983). The behaviours that leaders should adopt in this complicated and dynamic environment should be specific (Zheng et al., 2022). Secondly, the study provides an understanding of various boundary situations where SSTL may promote SCB. This study verifies the positive effects of SSTL on SCB by including safety consciousness as a moderator (Meng and Chan, 2020). Finally, research shows that there are few studies on public management, including managing safety, in developing countries such as Malaysia (Zheng et al., 2022). However, with the rising demand for public railway services in Malaysia, occupational accidents and injuries among workers have had such negative effects that it has prompted calls for such studies. Therefore, this study fills in these gaps. *Figure 1* shows the research framework investigated in this study.

The remainder of the paper is organized as follows: Section 2 focuses on a review of the literature, Section 3 provides the methodology of the study, including sampling technique, measurement of variables, and data collection, Section 4 reports on the findings of the study, and, finally, Section 5 focuses on discussion, theoretical and practical implications, and conclusions.

2. Literature Review

2.1. Safety-Specific Transformational Leadership (SSTL)

Safety-specific transformational leadership (SSTL) incorporates tactics and strategies of transformational leadership, but the emphasis is on safety at work (Barling et al., 2002). The concept of transformational leadership was initially introduced by Burns (1978), while Bass (1985) elaborated further on the idea. The elements of transformational leadership do not rely on wages or rewards for performance; instead, they pinpoint motivation as the key (Bass, 1985). Rainey (2003) further stressed that transformational leaders do not exert direct control over their followers; on the other hand, they shape a positive change in their subordinates' climate perception. Having clear and engaging visions, communicating how these visions can be attained, being empowered as a sign of trusting the followers to achieve their dreams, leading by example, and motivating them to achieve higher-order needs are key in shaping an individual's climate perception (Rainey, 2003).

Since Andriessen (1978) demonstrated that the leadership and safety standards of the leader play a significant role in determining SCB, SSTL may be one of these elements that could affect SCB and efficient and appropriate PPE utilization among public railway employees. Railway leaders may help safety departments promote safety and improve rail safety behaviour outcomes by implementing SSTL concepts and tactics. As demonstrated in other occupations, these tactics may help promote good safety climate perceptions on the railway and may initiate, sustain, and improve SCB (Barling et al., 2003; Clarke, 2013; Mullen et al., 2011).

Even though SSTL emphasizes workplace safety, it also integrates elements of transformative leadership (Barling et al., 2002). The four main aspects of transformational leadership – idealized influence, inspiring motivation, intellectual stimulation, and individualized consideration – plus contingent compensation were included in the development of SSTL, which has implications for safety-specific leadership (Barling et al., 2002). SSTL is typically considered to be a justifiable unidimensional indicator that was initially validated by Barling and colleagues (Barling et al., 2002).

SSTL is linked to improved occupational safety outcomes, such as a safe work environment, safety awareness, and SCB (Barling et al., 2002; Mullen et al., 2011). Within the public railway service, there have also been positive, substantial connections shown between SSTL, safety climate, and SCB (Li et al., 2020). Given the impact on general SCB, it is anticipated that SSTL will also affect specific compliance-oriented behaviours, such as the usage of personal protective equipment (PPE). Safety motivation has received just a cursory examination as part of the theoretical framework connecting SSTL to safety behaviours, particularly

to PPE use, and more attention needs to be paid to how SSTL affects SCB outside of the context of safety climate. An individual's willingness to put forth an effort to practice safe actions is referred to as their SCB in the context of social exchange theory and reciprocity (Blau, 1964). This paradigm contends that due to the inherent reciprocity principles in social exchange interactions, the concern of the management and of the organization leaders for employees' safety stimulates the workers to engage in desired SCB (Clarke, 2013 Barling *et al.*, 2002; Mullen *et al.*, 2011).

Good leaders deliver safety messages to their employees to encourage them to abide by the occupational safety standards, rules, and regulations at the workplace. A study by Lu *et al.* (2019) further reveals that leaders or supervisors with SSTL can boost the employees' motivation and persuade them to participate actively and comply with the organization's safety standards (Lu *et al.*, 2019; Irshad *et al.*, 2021). A study conducted by Arief *et al.* (2020) reported that there was a significant direct relationship between SSTL and safety behaviour based on a survey undertaken among 40 factory employees in Indonesia. This suggests that leaders who are highly concerned with their subordinates' safety and welfare substantially increase productive safety manners and behaviour among the employees (Arief *et al.*, 2020). As a result, the organization reported fewer injuries and occupational accidents. A similar finding has also been reported in a study by Mirza and Isha (2020), which was undertaken on 270 production workers in the oil and gas industry across Malaysia. SSTL was reported to have significantly reduced occupational accidents in the oil and gas industry (Mirza and Isha, 2020).

2.2. Safety Citizenship Behaviour (SCB)

A study by Li *et al.* (2020) defined SCBs as behaviour that emphasizes supporting or helping a group of employees to improve safety at work. The employees' safety performance can further be enhanced through the mutual support of other employees (Mashi *et al.*, 2022), as well as through the effective relationship between the supervisors (Abdelmotaleb and Saha, 2018; Cesário and Magalhães, 2017; Zhang *et al.*, 2020). There is also a direct connection between SCBs and safety participation. Studies show that SCBs act as accident prevention catalysts when there is a significant reduction in the number of safety violations committed by employees in the workplace (Li *et al.*, 2020). It has also been reported that a high level of safety participation among the employees is due to the SCBs (Li *et al.*, 2020).

The main role of SCBs is to reduce occupational accidents and minimize risks, workplace hazards, and property damages. SCBs apply the concept of supervisor and employee engagement, which is based on affiliation and trust (Hofmann *et al.*, 2003; Wijewardena, 2014; Zhang *et al.*, 2020). Besides that, SCBs also apply the concepts of altruism and courtesy. Altruism emphasizes the discretionary

behaviour of helping other employees at the workplace to solve a problem or any task. Meanwhile, courtesy highlights the discretionary behaviour of avoiding any conflict between co-workers at the workplace.

Apart from that, another SCB concept that plays a significant role is the voluntary behaviour approach, which emphasizes the construction of personnel safety behaviour through the mutual support of the employees at the workplace to achieve the organizational safety goals further (Li et al., 2020). All the SCBSCB concepts are crucial to further improving the quality of work performance. Through these approaches, SCBs can achieve a higher safety standard at the organizational level and subsequently minimize future occupational accident risks and hazards (Li et al., 2020).

A study by Hofmann et al. (1995) further measures the role of safety citizenship through six sub-dimensions: civic virtue, helping, stewardship, voice, initiating safety-related changes, and whistleblowing. Firstly, civic virtue is defined as the employees' positive involvement in organizational activities, such as attending safety meetings. Secondly, helping is associated with the assistance provided by the employee to his other colleague. Next, stewardship and voice are focused on taking care of the other employees' well-being and on whether there is improvement in their colleagues' work activities. Subsequently, initiating safety-related changes targets the improvement of the organization. Finally, whistleblowing is the action taken towards those who violate safety at the workplace and which recognizes those who protect their colleagues from any unsafe work situation or any consequences that could be associated with an occupational accident (Hofmann et al., 1995). Thus, in this study, the SCBs are further investigated based on the following six sub-dimensions:

2.3. Safety-Specific Transformational Leadership and Civic Virtue

Civic virtue is a behaviour that expresses how concerned the employees are about the organization's well-being (Clark et al., 2014). Employees who are highly worried about the organization will actively participate in occupational safety and health activities (Clark et al., 2014). Apart from that, civic virtue also portrays the employee's loyalty towards the organization. The employees usually do not display any problems with the safety and health policy, procedures, or any activities implemented by the organization. They indeed show high safety commitment and involvement (Clark et al., 2014; Srithongrungrung, 2011).

Although Nurjanah et al. (2020) did not study the dimensions of OCB separately, it has already been mentioned that the variable of OCBs has been integrated with the other five OCB components, and civic virtue is one of the included components (Nurjanah et al., 2020). The study, which involved civil servants at the Inspectorate General of the Ministry of Education and Culture in Jakarta,

Indonesia, confirmed that the proactive leadership style shown by their leaders had significantly improved their OCBs (Khan et al., 2020; Nurjanah et al., 2020).

Moreover, a study by Khan et al. (2020) further confirmed that transformational leadership has significantly fostered civic virtue behaviour among the supervisors and employees of the hospitality industry in Anhui province, China. Transformational leadership roles played by the leaders further promote the employees' happiness, well-being, and physical health (Khan et al., 2020). As a result, the dimension of civic virtue under the OCB construct has become an important condition for the strong development of the service industry. Based on the empirical pieces of evidence discussed above, SSTL can significantly influence the SCBs of civic virtue. Thus, the following hypothesis is formulated:

H1: SSTL has a positive and significant influence on civic virtue.

2.4. Safety-Specific Transformational Leadership and Helping

The dimension of helping under the OCBs is also known as altruism, which consists of the discretionary helping behaviour practised by employees. The study by Dash and Pradhan (2014) reveals that altruism includes all helping and volunteering behaviours. Both employees and leaders who can foster altruism and helping behaviour can cultivate a positive and healthy interpersonal relationship, which subsequently results in a better work climate (Ahmad et al., 2014; Dash and Pradhan, 2014). Punj and Krishnan (2006) reported that transformational leadership significantly influenced altruism. Altruism, which is one of the dimensions under the OCBs, has proven to enhance organizational performance (Punj and Krishnan, 2006). Meanwhile, Majeed et al. (2017) reported that transformational leadership has significantly influenced OCBs based on a study conducted among teachers in public-sector higher education institutions in Pakistan. Based on the empirical pieces of evidence discussed above, SSTL can significantly influence the SCB's efforts to help. Thus, the following hypothesis is formulated:

H2: SSTL has a positive and significant influence on helping.

2.5. Safety-Specific Transformational Leadership and Stewardship

Organizational stewardship is measured by the organization's ability to use leadership influence to contribute back to society. Stewardship behaviour is a situation where the employee trusts the vertical relationship of leader-subordinate with the organization (Rashid et al., 2019). The leader's supervisory role, which requires them to take care of their employees, will enhance the trust between them and ensure the employee's well-being.

A cross-sectional study conducted among mental health service providers in San Diego reported that transformational leadership has significantly increased employee well-being through better personal accomplishment (Green et al., 2014). Based on the core value of transformational leadership, leaders are expected to play a vital role in supervising and monitoring their employee's daily work. The leader needs to understand whether the employees are in a distressed situation or feeling lost while performing their work. A proactive leader will be able to detect such a situation and help take care of the employees so that the issue will not affect their well-being (Green et al., 2014).

A similar finding has also been reported in a longitudinal study undertaken on Danish eldercare workers (Munir et al., 2010). A positive and significant association between transformational leadership and a reduction in employees' depression was recorded. Working in the eldercare centre indeed puts greater pressure on the employees; however, the transformational leadership that the eldercare centre's leaders have practised has had a positive impact on the employees. As a result, leaders can ensure employee well-being. Based on the empirical pieces of evidence discussed above, SSTL can significantly influence the SCBs of stewardship. Thus, the following hypothesis is formulated:

H3: SSTL has a positive and significant influence on Stewardship.

2.6. Safety-Specific Transformational Leadership and Voice

Wang et al. (2019) defined voice behaviour as a form of communication used by employees to improve the current situation or apply a change-oriented approach for a healthier situation at the workplace. Normally, employee voice has also been used to aim for a better status quo among the employees (Parker and Collins, 2010). This subsequently helps to cultivate a better work environment and prevent any organizational harm.

Voice behaviour is one of the dimensions under the OCBs that allows employees to communicate and voice their thoughts at work (Wang et al., 2019). The employees have been encouraged to speak up to their leaders on any issue that becomes a concern for them. Nevertheless, voicing a problem or issue, especially one related to the leaders themselves, is a challenging task. Thus, the element of transformational leadership, which highlights traits like building trust and good rapport in the vertical relationship of leader–subordinate, is important to motivate the employees to speak the truth (Liu et al., 2010).

Similarly, the study by Rasheed et al. (2021) also confirmed that transformational leadership has significantly influenced the voice behaviour of employees at small and medium-sized enterprises (SME). The employees are more confident in speaking up about their concerns or issues with their leader. The boundaries that

exist between leader and subordinate can be removed, and a healthier relationship between both parties can be further fostered (Rasheed et al., 2021). Based on the empirical evidence discussed above, SSTL can significantly influence the SCBs of voice. Thus, the following hypothesis is formulated:

H4: SSTL has a positive and significant influence on voice.

2.7. Safety-Specific Transformational Leadership and Initiating Safety-Related Changes

Safety-related changes are being measured through the safety improvements that can be achieved by the employees to improve organizational performance (Hofmann et al., 1995). An improvement in the employees' safety behaviour can help the organization reduce any unwanted incidents and minimize the accident risk at the workplace.

A study by Shi (2021) further links safety behaviour with safety compliance and safety participation. Safety compliance concerns the employee's ability to comply with the organization's safety rules and procedures such as wearing personal protective equipment provided by the organization (Shen et al., 2017). Meanwhile, safety participation refers to an employee's voluntary participation in safety activities, including attending safety meetings and helping co-workers on issues relating to safety (Shen et al., 2017; Arief et al., 2020).

Moreover, an extensive literature review also reported that SSTL could reduce any near-miss incident through the mediating role of the safety climate (Isha et al., 2019). The researchers further reported that employees who work under leaders with SSTL values are well equipped with safety awareness. The leaders believe that any near-miss incidents should not be routine and that such incidents should not happen again in the future (Isha et al., 2019). Based on the empirical pieces of evidence discussed above, SSTL can significantly influence SCBs in initiating safety-related changes. Thus, the following hypothesis is formulated:

H5: SSTL has a positive and significant influence on initiating safety-related changes.

2.8. Safety-Specific Transformational Leadership and Whistleblowing

Whistleblowing is defined as an action taken by the employees to disclose or expose any unlawful or immoral practices or activities committed by the leaders to the organization's management (Caillier, 2015). In an organization, the whistleblowing process involves two parties: the employees and their supervisors. The supervisors are usually the first to receive the employees' complaints, and they indeed play a critical role in the whistleblowing process (Caillier, 2013, 2015).

The whistleblowing process is one of the most important occasions in the organization because of the effect of the complaints made by the employees to the supervisor or the organization's management. It is the responsibility of the supervisor or of the organization's management to set a friendly tone and eliminate the hostile environment after receiving the complaint (Bhal and Dadhich, 2011). Or else the employees will no longer want to report or disclose any unlawful behaviour or activities committed by the wrongful party due to the hostile treatment they receive (Bhal and Dadhich, 2011).

The literature on the relationship between transformational leadership and whistleblowing needs to be more extensive. A comprehensive review of the literature found only a few studies. A survey by Caillier (2013) reported that transformational leadership is positively associated with whistleblowing. This indicates that the significant practices of transformational leadership applied in the organization have put the employees in a comfortable position to report any wrongful behaviour (Caillier, 2013, 2015). Rabie and Abdul Malek (2020) further reported that ethical leadership positively impacts the intention of the telecom sector's employees to act as whistle-blowers in the workplace, and Mohamed-Isa et al. (2020) proposed that ethical leadership positively influences whistleblowing intention in their conceptual paper. Based on the empirical pieces of evidence discussed above, SSTL can significantly affect the SCBs of whistleblowing. Thus, the following hypothesis is formulated:

H6: SSTL has a positive and significant influence on whistleblowing.

2.9. The Moderating Role of Safety Consciousness

Safety consciousness is defined as an individual's insight and understanding of the working conditions and circumstances, which can further help to improve the safety state of the organization (Meng and Chan, 2020). Awareness of safety and health is crucial for employees, especially when they are working in a highly hazardous industry. Safety consciousness and alertness help to avoid accidents at the workplace.

Safety consciousness applies the concept of positive self-efficacy, which helps the individual execute behaviour based on his capacity without jeopardizing his safety and health (Meng et al., 2020). This will help reduce any unwanted risk at work, even in the absence of supervision from the supervisor. Safety consciousness also helps in promoting safety performance. Hence, employees show greater responsibility for abiding by the organization's safety standards and policies (Meng and Chan, 2020).

Besides that, safety awareness proved to significantly influence safety behaviour in a study conducted among healthcare professionals in Ankara, Turkey (Uzuntarla

et al., 2020). Employees with high safety awareness show better judgment and the ability to terminate any work hazard or risk. Healthcare personnel working in hazardous conditions and environments are prone to occupational accidents and diseases. As a result, the management highly emphasized cultivating safety awareness and consciousness among the employees (Uzuntarla et al., 2020).

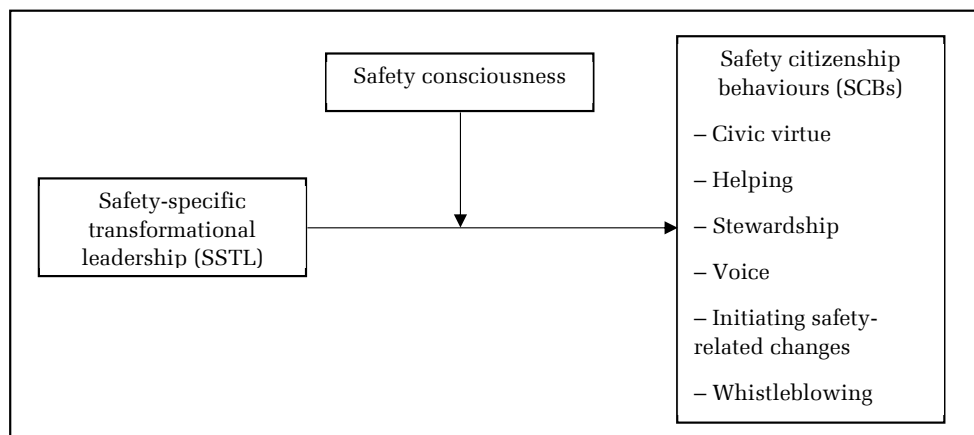


Figure 1. *A research framework*

Based on the literature discussed above, it can be summarized that safety consciousness can help influence the outcome of the SCBs. As proposed by MacKinnon (2011), a variable is considered a moderator when it can affect the strength of the relationship between one variable (i.e. an independent variable) and another variable (i.e. a dependent variable). Therefore, it clearly shows that safety consciousness plays a moderator role in this study. Safety consciousness may likely play a moderator role in this study because it will facilitate the positive effect SSTL has on the SCB of railway workers. As a result, public railway workers with a high degree of safety consciousness are more inclined to participate in SCB activities than employees who have a low level of safety consciousness; therefore, the following hypotheses are formulated:

H7: Safety consciousness moderates the relationship between SSTL and SCB, in which the relationship is stronger when safety consciousness is higher.

H7a: Safety consciousness moderates the relationship between SSTL and civic virtue, and the relationship is stronger when safety consciousness is higher.

H7b: Safety consciousness moderates the relationship between SSTL and helping, and the relationship is stronger when safety consciousness is higher.

H7c: Safety consciousness moderates the relationship between SSTL and stewardship, in which the relationship is stronger when safety consciousness is higher.

H7d: Safety consciousness moderates the relationship between SSTL and voice, in which the relationship is stronger when safety consciousness is higher.

H7e: Safety consciousness moderates the relationship between SSTL and initiating safety-related changes, and the relationship is stronger when safety consciousness is higher.

H7f: Safety consciousness moderates the relationship between SSTL and whistleblowing, and the relationship is stronger when safety consciousness is higher.

2.10. Transformational Leadership Theory

Transformational leadership theory is a leadership style in which a leader works with a subordinate to inspire, guide, and execute the required changes towards achieving the desired behaviour or outcome (Khan et al., 2020). This theory emphasizes the importance of an effective leader in fostering and cultivating the desired result. A good leader is expected to act accordingly to set an example for the employees. Another crucial aspect of this theory is the engagement between the leader and the subordinate.

Having good communication and rapport in this vertical relationship can further develop trust, belief, and motivation, which finally results in the anticipated finding (Lai et al., 2020). The transformational leadership theory is fit to underpin this research, which applies a similar concept of cultivating the leader–subordinate relationship. Such a relationship is vital to encourage SCBs, which can further help to avoid any unwanted incidents and accidents at the workplace. Apart from that, the transformational leadership theory also comprises four dimensions: idealized influence, inspirational motivation, intellectual stimulation, and, finally, individualized consideration (Lai et al., 2020).

The application of the Transformational Leadership Theory and the research model can be seen through the vertical relationship between leader and subordinate, which helps to ensure the smooth transition between the SSTL and SCBs, specifically on the six dimensions of civic virtue, helping, stewardship, voice, influence in initiating safety-related changes, and whistleblowing. As mentioned in the literature, SSTL, which applies the concept of transformational leadership theory, has significantly influenced Indonesian factory workers' safety behaviour (Arief et al., 2020). The idea of transformational leadership theory, which emphasizes the leader's role to guide and inspire the employees' motivation towards anticipated safety behaviour, has successfully led to better safety performance among the factory workers (Arief et al., 2020).

3. Methodology

This study is being undertaken by 327 employees of the public Light Rapid Transit (LRT) Railway Service Company. The respondents are the technical employees who perform rail-related duties such as hostlers (train drivers), rail maintenance and repairing railway equipment, and rail operation (supervising, monitoring, and controlling train services). They are highly exposed to hazards and risks at the workplace. At the end of the data collection process, only 98 completed questionnaires were returned, representing 30% of the response rate. The low response rate justifies how stressful their work is to serve the general public.

Structured survey questions consist of twelve demographic items, eight items of SSTL, and seven items of safety consciousness, which were adopted from Barling *et al.* (2002). The SSTL items consist of four sub-dimensions (i.e. idealized influence, inspirational motivation, intellectual stimulation, and individualized consideration). Some of the included items are: "My manager shows determination to maintain a safe work environment." (idealized influence of SSTL); "My manager talks about his or her values and beliefs about the importance of safety." (inspirational motivation of SSTL); "My manager suggests new ways of doing our jobs more safely." (intellectual stimulation of SSTL); "My manager spends time showing me the safest way to do things at work." (individualized consideration of SSTL); "I know what protective equipment and clothing is required for my job." (safety consciousness).

Items for SCBs were adopted from Hofmann *et al.* (2003), which measure the six sub-dimensions of SCBs (i.e. helping, voice, stewardship, whistleblowing, civic virtue (keeping informed), and initiating safety-related changes). Some of the items are: "I volunteer for safety committees." (helping); "I make safety-related recommendations about work activities." (voice); "I will be a champion to protect fellow working colleagues from safety hazards" (stewardship); "I prefer to explain to other working colleagues that I will report safety violations." (whistleblowing); "I will be a champion to attend safety meetings." (civic virtue, keeping informed); "I try to improve safety procedures." (initiating safety-related changes).

The questionnaire is measured using a five-point Likert-type scale ranging from "strongly disagree" (1) to "strongly agree" (5) and is prepared in both English and Malay. The original instruments (English) were translated into Malay by academic experts to ensure the consistency of the translation process. The data were analysed using SPSS and SmartPLS 4.0.8.3.

4. Results and Analysis

4.1. Demographic and Descriptive Results

The survey reveals that the majority of rail transport operators are male, with 69.4% having a diploma and 17.3% having a related certificate. The average age range is between 26 and 35 years, with a minimum of five years of experience. Most of them have never experienced any occupational injuries.

Table 1 presents the descriptive statistics, including the means and standard deviations of the variables under study. As shown in Table 1, the mean value of all the constructs ranged between 3.293 and 3.967, and the standard deviation ranged between 0.673 and 1.011.

Table 1. Results of the descriptive statistics of all the latent constructs ($N = 98$)

Latent Constructs	Items	Mean	Std. Dev.
SSTL	8	3.654	0.905
Safety Consciousness	7	3.967	0.673
Civic Virtue	3	3.293	1.011
Helping	6	3.728	0.732
Stewardship	5	3.559	0.836
Voice	4	3.648	0.732
Initiating Safety-Related Changes	4	3.747	0.739
Whistleblowing	5	3.549	0.769

4.2. Common Method Variance

This study addressed common method bias (CMV) by using data from all respondents simultaneously. To minimize single-source bias, procedural and statistical remedies were applied. Procedural remedies included obtaining expert opinions, checking content validity, employing reverse-worded questions, and emphasizing anonymity. Statistical remedies included Harman's single-factor method, which explained only 34.59% of the total variance, indicating no common method bias. This approach ensured confidentiality and honesty in respondents' responses (Podsakoff et al., 2003). The study conducted a full collinearity test to address single-source bias. Five out of eight variables had a VIF of less than 5, while three variables had a VIF of more than 5, indicating that single-source bias is not a significant issue (refer to Table 2) (Kock, 2015).

Table 2. *Full collinearity testing*

Virtue	Help	ISRC	Stew	Voi	Whistle	SSTL	Scons
5.002	5.231	2.310	3.755	3.680	5.605	2.541	3.804

Notes: ISSTL – safety-specific transformational leadership, Scons – safety consciousness, Help – helping, ISRC – initiating safety-related changes, Stew – stewardship, Virtue – civic virtue, Voi – voice, Whistle – whistleblowing.

4.3. Measurement Model Evaluation

The measurement model underwent convergent and discriminant validity tests, with all constructs reporting loading values above 0.7. The composite reliability (CR) and average variance extracted (AVE) were also above 0.7 and 0.5 respectively (Hair et al., 2014) (refer to *Table 3*).

Table 3. *Results of the measurement model*

Construct	Item	Loading	CR	AVE^a
Virtue	Virtue1	0.943	0.968	0.911
	Virtue2	0.972		
	Virtue3	0.949		
Help	Help1	0.821	0.941	0.727
	Help2	0.864		
	Help3	0.879		
	Help4	0.907		
	Help5	0.877		
	Help6	0.757		
ISRC	ISRC1	0.837	0.904	0.701
	ISRC2	0.876		
	ISRC3	0.857		
	ISRC4	0.776		
Stew	Stew1	0.908	0.941	0.799
	Stew2	0.920		
	Stew3	0.922		
	Stew4	0.821		
Voi	Voi1	0.891	0.924	0.752
	Voi2	0.808		
	Voi3	0.876		
	Voi4	0.892		
Whistle	Whistle1	0.736	0.930	0.727
	Whistle2	0.904		
	Whistle3	0.835		
	Whistle4	0.895		
	Whistle5	0.884		

Construct	Item	Loading	CR	AVE ^a
SSTL	SSTL1	0.851	0.971	0.810
	SSTL2	0.898		
	SSTL3	0.910		
	SSTL4	0.912		
	SSTL5	0.925		
	SSTL6	0.925		
	SSTL7	0.905		
	SSTL8	0.872		
SCons	SCons4	0.870	0.923	0.751
	SCons5	0.855		
	SCons6	0.891		
	SCons7	0.848		

Notes: Stew5, SCons1, SCons2, and SCons 3 were deleted due to low loading; ISSTL – safety-specific transformational leadership, Scons – safety consciousness, Help – helping, ISRC – initiating safety-related changes, Stew – stewardship, Virtue – civic virtue, Voi – voice, Whistle – whistleblowing.

Upon completing convergent validity, discriminant validity, which refers to the extent to which items measure distinct concepts, was assessed. This was evaluated using the HTMT ratio criterion, which is known to be more reliable in determining discriminant validity (Henseler et al., 2016). The HTMT criterion results in this study indicated that discriminant validity is achieved with an exception. The highest correlation found between whistleblowing and civic virtue is 0.92, which is beyond the conventional yardstick of 0.85 (Henseler et al., 2016). Similarly, as shown in *Table 4*, the correlation between whistleblowing and stewardship is 0.898, the correlation between stewardship and civic virtue is 0.864, and the relationship between voice and helping behaviour is 0.875, which is also beyond the value suggested by Hessler et al. (2015).

Table 4. *Heterotrait-monotrait (HTMT) criterion for discriminant validity*

	Virtue	Help	ISRC	SSTL	SConcs	Stew	Voice	Whistle
Virtue								
Help	0.769							
ISRC	0.602	0.815						
SSTL	0.536	0.585	0.566					
SCons	0.432	0.798	0.717	0.750				
Stew	0.864	0.768	0.606	0.627	0.553			
Voi	0.691	0.875	0.759	0.638	0.767	0.748		
Whistle	0.920	0.792	0.673	0.619	0.515	0.898	0.823	

Note: Discriminant validity is established at $HTMT_{0.85}/HTMT_{0.90}$.

Thus, the HTMT inference assessment was deployed using the confidence interval of HTMT through the bootstrapping method (Henseler et al., 2016). In establishing discriminant validity, the confidence interval of the 28 relationships should not be greater than the value of 1. The HTMT inference results based on the confidence interval value, as shown in *Table 5*, indicate that the confidence interval does not show a value of 1 on any of the constructs (Henseler et al., 2016), which confirms discriminant validity. Therefore, this study achieves both types of validity.

Table 5. *Heterotrait-monotrait (HTMT) inference criterion for discriminant validity*

	95.00%
Help -> Virtue	0.853
ISRC -> Virtue	0.780
ISRC -> Help	0.908
SSTL -> Virtue	0.726
SSTL -> Help	0.760
SSTL -> ISRC	0.781
SCons -> Virtue	0.629
SCons -> Help	0.889
SCons -> ISRC	0.825
SCons -> SSTL	0.878
Stew -> Virtue	0.924
Stew -> Help	0.893
Stew -> ISRC	0.801
Stew -> SSTL	0.771
Stew -> SCons	0.737
Voi -> Virtue	0.797
Voi -> Help	0.956
Voi -> ISRC	0.866
Voi -> SSTL	0.746
Voi -> SCons	0.874
Voi -> Stew	0.866
Whistle -> Virtue	0.961
Whistle -> Help	0.884
Whistle -> ISRC	0.834
Whistle -> SSTL	0.756
Whistle -> SConcs	0.689
Whistle -> Stew	0.956
Whistle -> Voi	0.918

Notes: ISSTL – safety-specific transformational leadership, Scons – safety consciousness, Help – helping, ISRC – initiating safety-related changes, Stew – stewardship, Virtue – civic virtue, Voi – voice, Whistle – whistleblowing.

4.4. Structural Model

SmartPLS 4.0.8.3 was used to examine the hypothesized paths, and the hypothesized relationships are depicted in *Table 6*. Results indicate that a positive relationship exists between SSTL and civic virtue ($\beta = 0.457$, $t = 2.598$, $p < 0.01$), thus supporting H1. Additionally, a significant positive relationship between SSTL and stewardship ($\beta = 0.454$, $t = 2.566$, $p < 0.01$) reveals that H4 is also supported. It also shows a significant positive relationship between SSTL and voice ($\beta = 0.228$, $t = 2.466$, $p < 0.01$). Hence, H5 is supported. Similarly, a significant positive relationship between SSTL and whistleblowing ($\beta = 0.520$, $t = 4.169$, $p < 0.01$) is indicated, which supports H6. However, there is no relationship between SSTL and helping ($\beta = 0.095$, $t = 0.685$, $p > 0.05$) and likewise between SSTL and initiating safety-related changes ($\beta = 0.143$, $t = 0.654$, $p > 0.05$); therefore, H2 and H3 are not supported (refer to *Table 6*).

Significantly, the findings from *Table 6* demonstrated the highest significant standardized beta coefficient ($\beta = 0.520$), which indicates that whistleblowing is the most considerable construct that SSTL predicts among rail transport operators in Malaysia. Stewardship, civic virtue, and voice follow this.

As presented in *Table 6*, hypotheses 7a–7f state that safety consciousness moderates the relationship between SSTL and dimensions of SCB, such that the relationship is stronger when the level of safety consciousness is high. Specifically, this relationship was stronger (i.e. more positive) for individuals with high safety consciousness than for individuals with low safety consciousness. The finding showed that the interaction terms representing SSTL * safety consciousness on initiating safety-related changes ($\beta = 0.121$, $t = 1.684$, $p < 0.05$) and SSTL * safety consciousness on stewardship changes ($\beta = 0.130$, $t = 1.687$, $p < 0.05$) were statistically significant. Therefore, hypotheses H7c and H7d are supported. However, the moderation result also shows that safety consciousness consequences did not moderate the relationship between SSTL and other dimensions of SCB; hence, H7a, H7b, H7e, and H7f are not supported.

Table 6. *Structural model*

	Std. Beta	Std. Dev	t-value	p values	BCI LL	BCI UL	f2	
SSTL -> Virtue	0.457	0.176	2.598	0.005*	0.128	0.709	0.149	Small
SSTL -> Help	0.095	0.138	0.685	0.247	-0.118	0.329	0.010	
SSTL -> ISRC	0.143	0.218	0.654	0.256	-0.132	0.597	0.018	
SSTL -> Stew	0.454	0.177	2.566	0.005**	0.124	0.714	0.171	Medium
SSTL -> Voi	0.228	0.093	2.466	0.007**	0.100	0.400	0.055	Small
SSTL -> Whistle	0.520	0.125	4.169	0.001**	0.284	0.701	0.222	Medium

	Std. Beta	Std. Dev	t-value	p values	BCI LL	BCI UL	f2	
SCons x SSTL -> Virtue	0.106	0.077	1.374	0.085	-0.026	0.227	0.022	
SCons x SSTL -> Help	0.009	0.059	0.161	0.436	-0.090	0.102	0.000	
SCons X SSTL -> ISRC	0.121	0.072	1.684	0.046*	0.005	0.237	0.036	Small
SCons x SSTL -> Stew	0.130	0.078	1.678	0.047*	0.017	0.273	0.039	Small
SCons x SSTL -> Voi	0.104	0.063	1.660	0.049	-0.005	0.202	0.031	
SCons x SSTL -> Whistle	0.126	0.092	1.374	0.085	-0.022	0.277	0.036	

Notes: ISSTL – safety-specific transformational leadership, SCons – safety consciousness, Help – helping, ISRC – initiating safety-related changes, Stew – stewardship, Virtue – civic virtue, Voi – voice, Whistle – whistleblowing.

As recommended by Dawson (2014), using two-way interaction with a continuous moderator, the result of the path coefficients (β) was used to plot this relationship. *Figures 2–3* indicate the relationship between SSTL and initiating safety-related changes and the relationship between SSTL and stewardship. The relationship is stronger (i.e. more positive) for individuals with high safety consciousness than for individuals with low safety consciousness. This indicates that initiating safety-related changes and stewardship increase for rail transport operators when both specific transformational leadership and safety consciousness are high (see *figs. 2–3*).

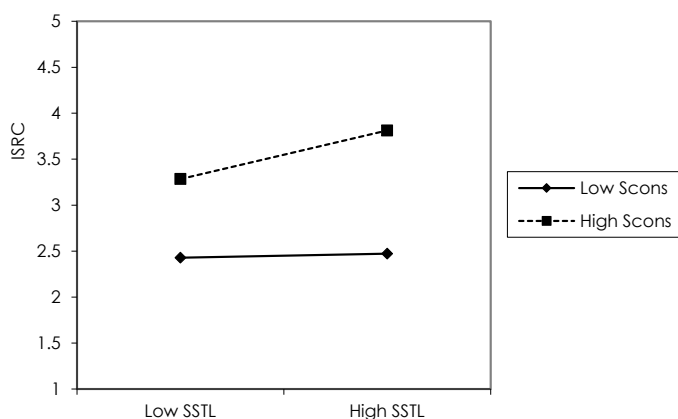


Figure 2. Interaction effect of SSTL and safety consciousness on initiating safety-related changes

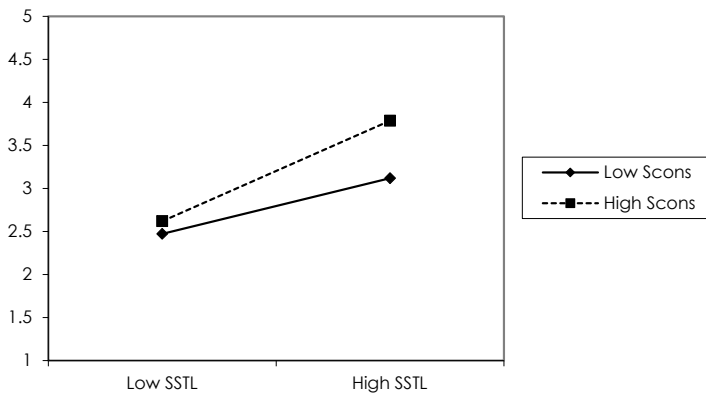


Figure 3. Interaction effect of safety-specific transformational leadership and safety consciousness on stewardship

PLS predict is a sample-based procedure for generating case-level predictions on items or constructs. It uses a 5-fold procedure to assess predictive relevance. If all item differences are lower than strong predictive power, predictive power is assumed. If all differences are higher, low predictive power is confirmed. The PLS model has moderate predictive power, with most errors lower than the LM model (Shmueli et al., 2019). *Table 7* indicates that the majority of the item's errors in the PLS model were lower than in the LM model, suggesting that the present model has moderate predictive power.

Table 7. PLS predict

	PLS	LM	PLS-LM	
	RMSE	RMSE	RMSE	Q ² predict
Virtue1	1.019	1.003	0.016	0.142
Virtue2	0.985	0.989	-0.004	0.138
Virtue3	0.950	0.982	-0.032	0.192
Help1	0.833	0.850	-0.017	0.311
Help2	0.847	0.764	0.083	0.331
Help3	0.633	0.731	-0.098	0.374
Help4	0.698	0.775	-0.077	0.294
Help5	0.613	0.723	-0.110	0.417
Help6	0.613	0.682	-0.069	0.285
ISRC1	0.831	0.879	-0.048	0.224
ISRC2	0.740	0.812	-0.072	0.287
ISRC3	0.745	0.874	-0.129	0.257
ISRC4	0.791	0.814	-0.023	0.165
Stew1	0.835	0.925	-0.090	0.201
Stew2	0.862	0.941	-0.079	0.170

	PLS	LM	PLS-LM	
Stew3	0.887	0.956	-0.069	0.222
Stew4	0.767	0.946	-0.179	0.276
Voi1	0.621	0.662	-0.041	0.390
Voi2	0.786	0.889	-0.103	0.201
Voi3	0.718	0.813	-0.095	0.327
Voi4	0.682	0.691	-0.009	0.376
Whistle1	0.966	0.987	-0.021	0.033
Whistle2	0.782	0.764	0.018	0.169
Whistle3	0.750	0.873	-0.123	0.184
Whistle4	0.937	0.977	-0.040	0.156
Whistle5	0.743	0.748	-0.005	0.277

Notes: ISSTL – safety-specific transformational leadership, Scons – safety consciousness, Help – helping, ISRC – initiating safety-related changes, Stew – stewardship, Virtue – civic virtue, Voi – voice, Whistle – whistleblowing.

5. Discussions

Based on the results, it is evident that there is a significant and positive relationship between SSTL and civic virtue. This is consistent with previous studies by Khan et al. (2020) and Nurjanah et al. (2020). A plausible reason is that leaders in the present study demonstrated SSTL effectively. This inspires and motivates the employees to go beyond their job responsibilities and contribute to the greater good of the organization. This inspiration has ultimately led to a sense of civic duty and civic virtue among employees.

The current research also substantiates a significant and positive relationship between SSTL and stewardship. This result is consistent with the findings reported by Rashid et al. (2019) and Green et al. (2014). It is important to note that safety-specific transformational leaders often create a shared vision that emphasizes the importance of safety and health in an organization. This shared vision can foster a sense of stewardship among employees, encouraging them to be continuously responsible for all safety and health matters in the organization.

The findings also revealed that there is a significant and positive relationship between SSTL and voice. This is in line with findings documented in studies by Rasheed et al. (2021) and Liu et al. (2010). Safety-specific transformational leaders often actively advocate good safety and health practices, including the safety and well-being of organizational members. Therefore, when employees feel that their leaders care about their safety and well-being, they are more likely to feel psychologically safe. They are also more comfortable expressing their opinions and concerns as they think that their input is valued.

The study also reported a significant and positive relationship between SSTL and whistleblowing. This is consistent with findings in previous studies by Caillier

(2013). SSTL creates an environment where employees feel comfortable voicing their concerns regarding safety and health practices in the organization. Most importantly, they will not be punished for speaking their mind. The culture of openness and trust nurtured by safety-specific transformational leaders encourages employees to engage in whistleblowing behaviour specifically related to safety and health matters.

The findings reported that there was no significant relationship between SSTL and helping behaviour. This result is inconsistent with earlier studies reported by Punj and Krishnan (2006) and Majeed et al. (2017). It is worth noting that the vast majority of the employees in the present study are in the age group of 26–35 years old. Generally, employees in this age group are in the early stages of their careers. They are considered part of the millennial generation, which is known for valuing work–life balance, career advancement, and a sense of purpose in their work. Hence, they may have different priorities in their job and may not consider helping behaviour a priority. They may prioritize completing their tasks over helping others, especially if they perceive helping behaviour as a distraction from their work. Since they are still in the early stages of their careers, they may be dealing with a certain level of complexity when performing tasks assigned to them. If the tasks are too challenging or require too much time, employees may not have the capacity to engage in helping behaviour.

The findings reported that there was no significant relationship between SSTL and initiating safety-related changes. This is inconsistent with prior findings by Shen et al. (2017) and Arief et al. (2020). Initiating changes is undeniably a daunting task, especially for employees who are in the early stages of their careers, because it requires strenuous efforts and a great deal of passion and commitment. They may need more time to be ready to be empowered by leaders to take ownership of workplace safety and initiate changes for a safer workplace. Additionally, the effectiveness of leaders in initiating changes boils down to how the leaders' actions are perceived by employees (Walk, 2023). If employees do not perceive the leaders' actions as transformative enough in advocating good safety practices, they are less likely to partake in safety change initiatives.

Some of the reasons for the lack of significance in some hypotheses, such as the relationships between SSTL and helping behaviours and initiating safety-related changes, could be as follows: either employees view helping and initiating changes as more discretionary or individualistic actions, less influenced by leadership and more by personal motivation or situational factors, or leadership styles may not as directly influence these particular behaviours as other behaviours like whistleblowing or stewardship, which are more closely tied to ethical considerations and organizational culture. The impact of SSTL may be more subtle and context-dependent than previously thought, as these findings contradict the body of research that claims transformational leadership always improves positive behaviours (Barling et al.,

2003; Clarke, 2013; Mullen et al., 2011). Additionally, the moderating effect of safety consciousness was only significant for a subset of behaviours, indicating that individual differences and perceptions of safety are important factors in how leadership influences behaviour and emphasizing the significance of personalized and context-aware leadership strategies.

Based on the moderation analysis, it was found that safety consciousness significantly moderated the SSTL and initiated safety-related changes. Safety consciousness also significantly moderated the SSTL–stewardship link. In other words, both of the empirical links are stronger for individuals with high safety consciousness and vice versa. This indicates that safety-related change initiatives and stewardship behaviour can be elevated substantially when employees experience higher SSTL and have a higher level of safety consciousness. The findings are consistent with the preceding study by Meng and Chan (2020). One plausible reason is that employees who have higher safety consciousness may be more receptive to SSTL and more likely to exhibit behaviours that support stewardship and initiate changes (Podsakoff et al., 2003). Conversely, employees with low safety consciousness may be more resistant to SSTL and less likely to engage in stewardship behaviour and change initiatives. This justifies the significant moderating role of safety consciousness in the present study.

5.1. Theoretical Implications

There are various theoretical contributions to this study. First, this study builds on previously established research frameworks about the variables that affect employee safety behaviour, specifically SCBs. Prior studies have concentrated on safety leadership, transactional leadership, and transformative leadership (Barling et al., 2002). However, more obvious and more specialized SSTL should have been given more attention. Our research closes this gap by looking at SSTL and safety consciousness in one model. Although this topic is understudied, the current study emphasizes the crucial role safety consciousness plays in determining employee SCBs. Consequently, by highlighting its positive impacts in encouraging SCBs in the railway sector in Malaysia, which expanded leadership and SCBs, the study provides an understanding of various boundary situations where SSTL may promote SCB. This study verifies the positive effects of SSTL on SCB by including safety consciousness as a moderator (Meng and Chan, 2020).

5.2. Practical Implications

Railway organizations are recommended to prioritize the implementation of safety-specific transformational leadership (SSTL) practices by prioritizing the

most effective areas, such as fostering civic virtue, stewardship, whistleblowing, and voice. It is the responsibility of leaders to promote open communication and create a safe workplace environment where workers may report safety issues without worrying about facing consequences. These principles can be reinforced via regular training and workshops on the value of safety, ethical behaviour, and each employee's role in upholding safety standards. Further ingraining these practices into the company culture can be achieved by creating explicit policies and processes for reporting safety concerns as well as by honouring and rewarding staff members who go above and beyond in their safety practices.

Railway organizations must incorporate safety measures into their everyday operations and decision-making procedures in order to cultivate a safety-conscious workforce. This can be accomplished by forming safety committees with members from all organizational levels to guarantee that safety is taken into account in every conversation. This kind of thinking can be strengthened by offering continuing education and training that highlights the value of safety consciousness and, in particular, by emphasizing the advantages of adhering to strict safety regulations. In addition, conducting frequent safety audits and feedback loops – where staff members may offer feedback on safety procedures and witness concrete modifications based on their recommendations – will foster a sense of accountability and ownership for upholding a secure workplace.

However, the study's limitations suggest the need for further research to validate findings across different cultural contexts and explore additional leadership characteristics beyond SSTL. Future studies should employ longitudinal or experimental methods to establish causality more reliably and incorporate a broader range of leadership variables. By addressing these limitations and continuing to explore the interaction between safety consciousness and leadership, railway organizations can further enhance safety initiatives and contribute to the well-being of employees and the general public in Malaysia's public transport sector.

6. Conclusions

The study explores the relationship between safety and citizenship behaviour (SSTL) and safety and citizenship behaviour in the railway transport sector. It has found a significant association between SSTL and civic virtue, stewardship, voice, initiating safety-related changes, and whistleblowing. The research recommends that leaders set an example by adhering to safety regulations and motivating others. The study also suggests updating safety protocols to raise workers' safety consciousness.

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Asymmetry in Okun's Law Revisited: New Evidence on the Cyclical Unemployment– Cyclical Output Nexus in the Free State Province (South Africa) Using a Nonlinear ARDL Model

Oyeyinka Sunday OMOSHORO-JONES

Department of Free State Provincial Treasury, South Africa

e-mail: omsyka@yahoo.com

Abstract: This paper examines the asymmetric unemployment–output nexus employing the nonlinear autoregressive distributed lag (NARDL) model. Cyclical components of unemployment and real output are estimated from annual data covering 1994–2019, using the Hodrick–Prescott and the Corbae–Ouliaris detrending techniques. Controlling for structural change effects, we find a statistically significant asymmetric cyclical unemployment–cyclical output relationship in the long run and the short run in the Free State province (South Africa), regardless of the detrending method used. Specifically, empirical results show that a one-percent increase in cyclical output can reduce cyclical unemployment between 0.70 and 0.87 percentage points, albeit conditioned on sustained economic growth. Also, the significant long-run coefficients of cyclical output reveal that an economic upturn between 1.88 and 2.03 percent would reduce unemployment by one percent. Based on our findings, proactive implementation of macro-fiscal policies consisting of demand-and-supply-side interventions is required to spur economic growth and lower the prevailing high unemployment rate in the province.

Keywords: Okun's law, NARDL, Hodrick–Prescott filter, Corbae–Ouliaris filter, South Africa

JEL Classification: C51, E24, E32, J64

1. Introduction

The seminal work by Okun (1962) formalized the widely accepted notion of the inverse relationship between output and unemployment, connecting activity in the goods market to activity in the labour market. This relationship, universally known as Okun's law, laid an enduring theoretical foundation and extensively researched

theory in macroeconomics (see e.g. Ball et al., 2017; Weber, 1995; Prachowny, 1993; Gordon, 1984). Broadly, Okun (1962) found that a three-percentage-point increase in cyclical output leads to a one-percentage-point decrease in cyclical unemployment in the United States (US), producing an empirical regularity of 3:1 ratio encapsulating the output–unemployment trade-off generally regarded as a useful “rule of thumb”, providing policymakers with a benchmark to measure the cost of higher unemployment (see Palley, 1993: 144; Moosa, 1997: 664; Lee, 2000: 331).¹

However, as the empirical literature assessing Okun’s law develops, three shortcomings are evident. Firstly, a large number of studies confirming Okun’s law are devoted to developed economies, most notably the US and European countries (see e.g. Ball et al. 2017; Huang and Yeh, 2013; Holmes and Silverstone, 2006; Altissimo and Violante, 2001), but developing economies are less studied, particularly African countries where high unemployment and anaemic economic growth are rampant.²

Secondly, numerous extant studies limit their analysis validating Okun’s law to the country (or aggregate) level solely utilizing national data, ignoring the importance of similar investigation using regional (i.e. provincial or state) data (see Freeman, 2000: 558; Christopolous, 2004: 612; Villaverde and Maza, 2009: 290; Binet and Facchini, 2013: 2). Thirdly, several studies modelled the output–unemployment relationship solely based on the linear assumption initially posited by Okun’s law. This model specification is not only biased since it ignores the possibility of an asymmetric link between these macro-variables (Palley, 1993: 145; Shin et al., 2014: 299) but also produces forecasting errors and spurious or inconclusive inferences, resulting in flawed prescriptions that render formulated policy ineffective (see Harris and Silverstone, 2001; Virén, 2001; Silvapulle et al., 2004).

The attempt to remedy the deficiencies in the extant studies has led to the emergence of two nascent strands of empirical literature. On the one hand, studies in the first strand of the emergent literature provide irrefutable evidence of asymmetry in Okun’s law (see Palley, 1993; Lee, 2000; Harris and Silverstone, 2001; Virén, 2001; Silvapulle et al., 2004; Cuaresma, 2003, Shin et al., 2014 among others), invalidating the original linear assumption typically used in modelling output–unemployment relationship in many studies. Particularly the initial assumption that output and unemployment are linearly related as postulated in Okun’s law implies that both positive output (economic upturns) and negative output (downturns) have similar absolute effects on unemployment (Shin et al., 2014: 229); however, due to structural

1 For example, see Moosa (1997) for empirical proof affirming Okun’s coefficient as the most suitable benchmark for measuring unemployment cost.

2 See e.g. Ibourk and Elaynaoui (2024) for a recent survey of studies validating Okun’s law in African countries.

change effects and/or the cyclical nature of the business cycle, a relative change in cyclical unemployment would depend on whether the cyclical output is negative (economic upswing) or positive (downswing), ascertaining the presence of an asymmetric relationship between unemployment and changes in output growth (see Neftçi, 1984; Palley, 1993: 145; Cuaresma, 2003: 440).

On the other hand, studies in the second strand of the emergent literature extend the analysis of the output–unemployment relationship to the regional (i.e. sub-country, provincial, or state) level, asserting that the analysis of the output–unemployment relationship within the context of Okun's law using only national data suffers from aggregation bias, masking the existing interregional disparity (i.e. differences or heterogeneity), which can be significant, as well as the variation in estimates of Okun's coefficient at the regional level due to region-specific factors such as structural change effects, dissimilar economic structures, different levels of population, unemployment, output growth, and industrialization (see e.g. Adanu, 2005; Binet and Facchini, 2013; Durech et al., 2014).

Surprisingly, studies using regional (i.e. provincial- or state-level) data have documented strong evidence confirming that Okun's law holds in some regions but is invalid in other regions within the same country, and they estimated that Okun's coefficients at a country (i.e. aggregate or national) level differ from estimates of Okun coefficients at the regional level (or across the regions) where Okun's law holds (see e.g. Guisinger et al. (2018) for the US, Villaverde and Maza (2009) for Spain, and Freeman (2000) for the US).³

Indisputably, assessing the output–unemployment relationship at the regional level is important for empirical and policy-related reasons. Empirically, such analysis provides useful information on the magnitude (or size) of Okun's coefficients across regions and the influence of regional differences in the responsiveness of output to reductions in unemployment (Freeman, 2000: 558). In policymaking, evidence from regional analysis of Okun's law could aid policymakers in adopting effective stabilization policies to deal with unemployment at both the regional and the national levels. As such, efficient demand management policies could be implemented by policymakers to lower unemployment in regions where Okun's law holds, while alternative strategies (for example, raising infrastructure spending or providing tax incentives to attract foreign investment or monetary incentives to firms to train unskilled job seekers) can be used in regions where Okun's law is found invalid (Christopoulos, 2004: 612).

Hitherto, only a few studies have tested asymmetric Okun's law in South Africa that rely mostly on national data, thus restricting their analysis to the country level, except Kavase and Phiri (2020), who examined asymmetric Okun's relationship at the provincial level, in South Africa. To this end, very little is known about the nature (i.e. symmetric or asymmetric) of the existing linkages between changes in

3 Refer to the literature review section for reported findings from related regional studies.

unemployment and changes in output at the provincial level in South Africa. This deficiency makes effective policymaking elusive at the national and provincial levels, rendering nationally adopted policies based on the recommendations from studies using national data ineffective.

This present paper fills the gap in the extant literature by examining the existence of asymmetric Okun's law in the Free State province in South Africa utilizing provincial data. Our analysis is relevant for two main reasons: firstly, analysed available data from Statistics South Africa (Stats SA, 2019a, 2020) reveal that the Free State province is among the top three regions experiencing a persistently high rate of unemployment, which is above 25% (but grew to 38% in 2018), and anaemic economic growth, averaging about 2% between 2000 and 2019 (see *Figure A1* in the *Appendix*). Even during periods of relative economic expansion, the provincial unemployment rate remains elevated. For example, between 1997 and 2007, the regional real gross domestic product (GDPR) for the Free State province rose to 3.7% from around 1%; in contrast, the unemployment rate surged to 28% from 25% during the same period. Subsequently, the real GDPR growth dramatically declined to around 1.4% in 2017 before turning negative (-0.2%) in the following year, while the provincial unemployment rate surged to 33.7% in 2017 and rose further to nearly about 38% in 2018. Observably, periods of relative expansion (i.e. 2001–2005 and 2010–2012) in the Free State provincial economy do not reduce unemployment, contradicting Okun's law, but align with the debatable “jobless growth” phenomenon in South Africa (see e.g. Phiri, 2014; Leshoro, 2013; Hodge, 2009; Marinkov and Geldenhuys, 2007; Casale et al., 2004). Hence, evidence validating the existence of asymmetric Okun's law in the focused region using provincial data might explain why unemployment is typically irresponsive to output growth shock, especially during expansion.

Secondly, the South African government has ratified at least six macro-policies since 1994, which have failed in achieving the common goal of raising annual economic growth above 5% and reducing the unemployment rate below 14% (see Stats SA, 2019b; NDP, 2012; NGP, 2010; The Presidency, 2006, 2007),⁴ as the country grapples with a stubbornly high unemployment rate (on average, above 24%) and weak economic growth, which only peaked at around 5% in the 2000s (i.e. from 2005 to 2007, and steadily fell below 1% in 2018) (see *Figure A2* in the *Appendix*). In this regard, evidence of an asymmetric unemployment–output relationship in the Free State province could also explain why the nationally adopted policies are ineffective in reducing unemployment and spurring output

4 The nationally adopted policies include the *Reconstruction and Development Programme* (RDP) in 1994, the *Growth, Employment, and Redistribution Strategy* (GEAR) in 1998, the *Accelerated and Shared Growth Initiative for South Africa* (ASGISA) in 2004, the *Joint Initiative for Priority Skills Acquisition* (JIPSA) in 2007, the *New Growth Path* (NGP) in 2010, and recently the *National Development Plan* (NDP) in 2012. Out of these, only the ASGISA produced an average annual growth of about 5% between 2005 and 2007.

growth (Virén, 2000: 253). All in all, evidence from our analysis supporting the existence of asymmetric Okun's relationship in the Free State province could be useful in determining the desirable or optimal output growth required to reduce unemployment, which in turn enhances the effectiveness of policymaking (Harrison and Silverstone, 2001; Silvapulle et al., 2004; Moosa, 2008).

To this end, this paper tests asymmetry in Okun's law in the Free State province by examining the relationship between cyclical unemployment and cyclical output over the period from 1996 to 2019, employing the popular nonlinear autoregressive distributive lag (NARDL) model developed by Shin et al. (2014). This model is the most apt for our analysis because it is superior to many advanced econometric tools given its ability to decompose cyclical output variables into partial sum processes of positive and negative changes capturing the responsiveness to cyclical unemployment, to positive and negative cyclical outputs, flexibly captures both long- and short-run asymmetries existing between variables, proficiently deals with misspecification bias, and produces robust inferences when sample size is small.⁵

To the best of our knowledge, only the study by Kavase and Phiri (2020) has examined asymmetric Okun's law across South African provinces and has found that Okun's law does not hold in the Free State province, but a positive long-run relationship between cyclical unemployment and cyclical output exists, which contradicts Okun's law. Even so, this previous study suffers from two shortcomings: firstly, the authors ignore the impact of structural change on the asymmetric relationship between cyclical unemployment and cyclical output, which in turn could affect the stability of estimated Okun's coefficients (see e.g. Lee, 2000: 348; Sögner and Stiassny, 2002), particularly at the provincial level (Apergis and Rezitis, 2003:114). Secondly, in this previous study, only one detrending method is used to generate cyclical variables; nonetheless, this procedure is inadequate to confirm the robustness of variation in estimated Okun's coefficients across the provinces, which may differ when two or more detrending methods are utilized (see Freeman, 2000; Adanu, 2005; Villaverde and Maza, 2009; Phiri, 2014; Marinkov and Geldenhuys, 2007, among others).

We remedied limitations in the previous study closest to ours, in three ways. Firstly, unlike Kavase and Phiri (2020), we applied the Hodrick–Prescott (HP, 1997) and the Corbae–Oularis (CO, 2006) detrending methods to estimate cyclical variables used in constructing two separate asymmetric models, allowing us to control the sensitivity of Okun's coefficients in the presence of long- and short-run asymmetries (Lee, 2000: 346) and also to affirm the robustness of estimated Okun's coefficients, which can be obscured when only one detrending method is used. Secondly, the structural change effect on estimates of Okun's coefficients is accounted for, by adding dummy variables into our asymmetric models. Thirdly,

5 The NARDL model is an extension of the ARDL model introduced by Pesaran et al. (2001), and hence it has similar advantages.

the reliability of the obtained results is assessed by performing a sensitivity analysis, which entails re-estimating the baseline models with cyclical variables of real GDP per capita (instead of the real cyclical output initially used) to capture the influence of population growth on the validity of Okun's law (Adanu, 2005) and on the asymmetric links between the cyclical output and unemployment variables in the FS province. On this basis, our results can be considered reliable, robust, and useful for policy formulation, hence our significant contribution to the literature.

The rest of this paper is structured as follows. Section 2 discusses relevant theory and surveys empirical studies in two emergent strands of the literature assessing the validity of Okun's law. Section 3 presents the data and detrending methods used to generate cyclical variables. Modelling the gap specification of Okun's law employing the NARDL modelling framework is provided in Section 4, and empirical results are discussed in Section 5. Section 6 concludes with some policy recommendations.

2. Literature Review

This sub-section surveys relevant studies in two nascent strands of the vast literature that have made significant contributions which have refined the empirical analysis of Okun's law, with studies in the first strand of the literature assessing asymmetry in Okun's law and those in the second strand of literature extending the analysis of Okun's law to the regional (i.e. provincial or state) level.

2.1. Theoretical Discussion

The importance of Okun's law has long been established from both theoretical and empirical perspectives. Theoretically, the combination of Okun's law with the Phillips curve produces an aggregate supply curve for an economy (Prachowny, 1993: 331), creating a link between the inflation rate, unemployment rate, and economic growth (Marinkov and Geldenhuys, 2007: 374). This linkage is important for macroeconomic policy, particularly in determining the desirable or optimal growth rate, and as a prescription for reducing unemployment (Silvapulle et al. 2004: 354; Moosa, 2008: 8). Empirically, the Okun coefficient, which measures the responsiveness of unemployment to changes in output growth, is a useful "rule of thumb" in forecasting and policymaking (Harris and Silverstone, 2001: 1; Moosa, 2008: 8).

Nevertheless, Neftçi (1984) observed unemployment exhibiting a differentiated response during periods of economic expansion and contraction in the US, which reinforces the notion that an asymmetric link could exist between changes in unemployment and changes in output, during different phases of the business cycle. As such, the response of unemployment to a positive cyclical output shock

(i.e. economic expansion) may differ (in magnitude) from a negative cyclical output shock (i.e. economic contraction).

In theory, unemployment could respond asymmetrically to changes in output during the business cycle, at least in three ways. Firstly, if the cost of reducing the quantity of labour (e.g. retrenchment packages) is perceived to be high during the economic downturn, firms may adopt a “labour hoarding” strategy to retain existing workers but reduce their working hours or the number of shifts to maximize profit or lower total costs, and they can adopt a “labour spreading” strategy when the economy recovers or expands by extending employees’ working hours through overtime or increasing the number of shifts, without hiring additional workers (Palley 1993: 149). Secondly, based on the notion of labour market hysteresis, cyclical output shocks could exert a permanent effect on structural unemployment, to the extent that unemployment does not revert to its pre-crisis level after economic recovery (Blanchard and Summers, 1986). Thirdly, firms may not hire the same quantity of labour shed to optimize revenue or cope with high operational costs during economic downturns when the economy recovers, given equal magnitude of negative and positive shocks (Shin et al. 2014: 299).

Indeed, both Harrison and Silverstone (2001: 1) and Silvapulle et al. (2004: 356) have stressed the importance of testing for asymmetry in Okun’s law on the following grounds: theoretically, it is useful for discriminating between competing theories of joint labour and goods market behaviour. In policymaking, the knowledge about the extent of asymmetry in the output–unemployment relationship is useful in formulating structural (e.g. labour market reforms) and stabilization policies (e.g. suitable monetary policy stance). Empirically, ignoring asymmetry in Okun’s law, when it exists, generally leads to model misspecification, poor forecasting and spurious inferences in hypothesis testing by rejecting the null hypothesis that both output and unemployment are asymmetrically cointegrated, that is, a long-run relationship exists between the two macro-variables. Consequently, our analytical strategy in this study is guided by the aforementioned theoretical reasoning.

2.2. Empirical Evidence

Among the studies investigating asymmetric Okun’s relationship in the US, the earliest contribution by Neftçi (1984) shows that the unemployment rate has gone through much sharper increases when the US economy contracts than when it declines during expansions, while Rothman (1991) found an asymmetric response in unemployment to positive and negative output growth shocks, and Palley (1993) reported similar findings – however, he finds a stronger response in unemployment to negative output growth using a dynamic model.

Subsequently, Altissimo and Violante (2001) also find evidence for an asymmetric unemployment–output relationship owing to the larger impact of propagated shocks

on unemployment than output during recessions in the US, in a nonlinear VAR model. Meanwhile, Cuaresma (2003) employed a regime-dependent specification of Okun's law and found a more significant asymmetric contemporaneous effect of cyclical output on cyclical unemployment during economic recessions than during expansions. Using a dynamic structural time-series model, Silvapulle et al. (2004) discovered that an inverse asymmetric cyclical output–cyclical unemployment relationship exists in the US but that the contemporaneous effect of positive cyclical output on cyclical unemployment quantitatively differs from negative ones. Alike, Holmes and Silverstone (2006) used a Markov regime-switching model to capture asymmetries within and across regimes and found a significant asymmetric inverse relationship between cyclical output and unemployment in the U.S., especially during economic expansion.

Considering studies investigating the validity of asymmetric Okun's law in European countries belonging to the Organisation for Economic Co-operation and Development (OECD), for example, Lee (2000) examined asymmetric Okun's relationship in 16 OECD countries using a static model which allows changes (i.e. negative and positive) in unemployment to determine output growth and found a significantly higher Okun coefficient for decreases (as compared to increases) in the unemployment rates for Finland, Japan, and the US, but the opposite holds for Canada, France, and the Netherlands.

Virén (2001) conducted a similar analysis in 20 OECD countries relying on an asymmetric error correction-based model (in which changes in unemployment are determined by positive and negative changes in output) and obtained results confirming asymmetric Okun's relationship with output growth having a strong effect on unemployment during periods of low unemployment and higher output (and vice versa). Likewise, Harris and Silverstone (2001) also estimated an asymmetric error correction model (where Okun's coefficient is either above or below long-run equilibrium) consisting of 7 OECD countries, and they found unemployment reacting asymmetrically to contemporaneous changes in output contingent on upswings or downswings in the business cycle, validating asymmetric Okun's law for Australia, Japan, New Zealand, United Kingdom, United States, and Germany.

In the same vein, Huang and Yeh (2013) found highly significant asymmetric unemployment–output trade-offs for 53 OECD countries both in the short and long run at the state and country level, in a panel ARDL model, while Shin et al. (2014) confirmed the existence of a negative asymmetric relationship between cyclical output and unemployment in the US, Canada, and Japan utilizing a NARDL model, and Tang and Bethencourt (2017) found evidence for long-run and short-run asymmetries between cyclical unemployment and cyclical output in most of the 17 Eurozone countries studied, with the help of a NARDL model.

So far, few studies have examined the existence of asymmetric Okun's law in South Africa. Among these, in an asymmetric error-correction model accounting for

structural breaks, Marinkov and Geldenhuys (2007) found an asymmetric cyclical output–cyclical unemployment relationship existing in South Africa and highly significant asymmetric contemporaneous effects of cyclical output on cyclical unemployment, with estimates of Okun coefficients ranging from -0.77 to -0.18 across the different detrending methods used. Also, Phiri (2014) reported similar findings on asymmetric Okun's law in a dataset covering the period of 2000–2013; however, further results reveal that unemployment granger causes economic growth in the long run, supporting the notion of “jobless growth phenomenon” prevailing in South Africa.

More recently, computing a NARDL model with quarterly data spanning the period from 1994Q1 to 2017Q4, Mazorodze and Siddiq (2018) found a significant asymmetric cyclical unemployment–cyclical output relationship in the long run but a symmetric relationship in the short run, partly due to dominant unionized labour market in South Africa. The authors conclude that a 10% increase in positive (negative) cyclical output reduces (raises) unemployment by 8% in the long run. In contrast, Sere et al. (2020) found an insignificant positive asymmetric relationship between changes in output on unemployment in the long run and a statistically significant inverse relationship between these variables in the short run, in an estimated NARDL model over the period from 1994Q1 to 2019Q4.

Considering studies in the second strand of literature assessing the validity of Okun's law at the sub-country level using regional (i.e. provincial or state level) data, findings from the earliest study by Freeman (2000) validate output–unemployment relationship consistent with Okun's law in 8 regional economies in the US over the period of 1958–1998 and evidence of trivial interregional differences at the regional level, with varying Okun's coefficients ranging between 1.87 and 3.57, in contrast to the coefficient of about 2 found for the US economy, at the national level.

Elsewhere, Apergis and Rezitis (2003) found that Okun's law holds in 8 regional economies studied in Greece over the period from 1960 to 1997, with Okun's coefficients ranging from 1.15 to 3.56 across the regions, and insignificant interregional disparity irrespective of the detrending methods used, except in the cases of Epirus (2.97 to 3.19) and North Aegean (3.56 to 3.69) Islands that exhibit higher Okun's coefficients attributed to structural change. In a subsequent study, Christopoulos (2004) found that Okun's law only held in 6 out of 13 regional Greek economies investigated over the period of 1971–1993 and that regional Okun's coefficients varied between 0.37 and 1.70.

Similarly, Adanu (2005) considered the existence of Okun's law in 10 Canadian provinces using regional data covering the period of 1981–2001 and discovered a significant regional difference with weighted-provincial Okun's coefficients ranging between 1.32 and 1.58 across the two detrending methods employed. Also, Villaverde and Maza (2009) found that Okun's law applies to 15 out of 17

Spanish regional economies studied during the period of 1980–2004 and variation in Okun's coefficients with values ranging from 0.32 to 1.55 across the regions, compared to the coefficient of 0.91 for the entire Spain. Alike, Binet and Facchini (2013) confirmed Okun's law in 14 out of 22 regional economies in France, and varying Okun's coefficients across the regions, with values between 0.91 and 1.81.

More recently, Durech et al. (2014) assessed regional disparity in the responsiveness of output to changes in unemployment across 14 regions in the Czech Republic and 7 regions in Slovakia. Their results validate Okun's law in 11 (out of 14) regions in Czechia and 5 (out of 8 regions) in Slovakia, with strong evidence of significant regional disparity, and regional Okun's coefficients ranging from 2.58 (for Bratislava) to 3 (for Prague) in Czechia and from 0.92 (for Olomouc) to 1.11 (for Nitra) in Slovakia. Also, the empirical results of Guisinger et al. (2018) show that Okun's law holds in 47 out of 51 states examined in the US over the period from 1977 to 2012 and found significant regional disparity (i.e. estimated Okun's coefficients of about 21.6% of state pairs are statistically different) with variations in Okun's coefficients across the states, ranging from 1.25 (for Colorado) to 4.38 (for North Dakota), compared to the coefficient of about 2.03 obtained for the US at the national (aggregate) level.

Focusing on South Africa, Kavase and Phiri (2020) discovered that Okun's law applied to only 2 out of 9 provinces using provincial data over the period of 1996–2016 and weakly significant Okun coefficients with values varying from 0.51 (for Western Cape) to 1.91 (for KwaZulu-Natal), while there is also evidence of a significant asymmetric relationship between cyclical output and cyclical unemployment in both the long and the short run existing in these provinces, but other provinces mostly exhibit significant short-run asymmetries, except the Free State province, where a positive long-run asymmetry is detected, which contradicts Okun's law.

Aside from Kavase and Phiri (2020), empirical investigation on asymmetric Okun's law at the provincial (regional) level in South Africa is inexistent. Since our work remedies the shortcomings in this earlier study, as previously mentioned, our result can be considered more reliable, robust, and useful in policy formulation. Based on this, our contribution to the extant literature is significant and timely.

3. Data and Treatment

Our estimated dynamic models contain annual time series on the gross domestic product (GDP at constant prices, 2010 = 100), GDP per capita (constant prices, 2010 = 100), and the total unemployment for the Free State province, from 1999 to 2019. Nominal series (i.e. GDP and GDP per capita) are converted to real series using the Consumer Price Index (CPI, 2010 = 100). Annual data are primarily

sourced from the Statistics South Africa (<https://www.statssa.gov.za/>), and S&P Global South Africa Regional eXplorer (<https://www.ihsmarkit.co.za/>) databases. Data are seasonally adjusted utilizing the Seasonal and Trend decomposition (STL) method (see Cleveland et al., 1990).⁶

Generally, the gap specification of Okun's law requires unobserved information about unemployment and output trends. Since there is no definite guideline in the empirical literature on which detrending method (i.e. filters) should be used to generate these trend series, we estimated cyclical (or gap) and trend components of the real GDP and unemployment growth rates from their respective observed series, y_t and u_t applying the Hodrick–Prescott (1997) and Corbae–Ouliaris (2006) filtering methods.

Characteristically, the HP filter is a two-sided linear that computes the smoothed series y^* of y by minimizing the variance of y around y^* subject to a penalty function that contains the change in the trend growth of y^* , written in the form as follows:

$$\Theta = \sum_{t=1}^T (y_t - y_t^*)^2 + \lambda \sum_{t=2}^{T-1} [(y_{t+1}^* - y_t^*) - (y_t^* - y_{t-1}^*)]^2 \quad (1)$$

In Eq. (1), the penalty parameter λ , controls the smoothness of the series y^* with the residual $y_t - y^*$ indicating the deviation from the trend and is commonly referred to as the business cycle component.

In addition to the HP filter, as previously stated, cyclical components (or gap variables) of the selected time series are also generated utilizing the CO filter (a frequency-domain filter), which is superior in extracting cyclical components without losing observations at the endpoints of the series. As such, the CO filter generates detrended series with super-consistent finite sample properties that are statistically reliable and asymptotically converge to their true growth cycle (Corbae and Ouliaris, 2006). In contrast to time-domain filters (for example, HP-, Band-pass-, and Baxter King-filters) that suffer from end-point problems, the CO filter is unsusceptible to end-point problems.

More specifically, by using Monte Carlo simulations, Corbae and Ouliaris (2006) show that the CO filter has superior finite sample properties by producing a detrended series that is statistically reliable (with much lower mean-squared error) and asymptotically converges to their true growth cycle. For a brief exposition, consider a non-stationary time series x_t with a deterministic component z_t and an unobserved stochastic component $\tilde{x}_t$ denoted as:

6 The STL decomposes annual, quarterly, and monthly data into seasonal and trend components, making it a versatile and superior decomposition method compared to the commonly used ARIMA-based decomposition methods (e.g. TRAMO-SEATs and X-11). This decomposition method generates robust seasonal series using Loess estimation, producing robust estimates of the trend-cycle and seasonal components from time-series data with irregular patterns and/or missing values.

$$x_t = \Pi_2' z_t + \tilde{x}_t, \quad (2)$$

with z_t being a $p + 1$ dimensional deterministic sequence and $\tilde{x}_t$ a zero-mean time series. Given that $\tilde{x}_t$ is a first-differenced $[I(1)]$ stationary series defined as $\Delta x_t = v_t$ with a Wold representation:

$$v_t = \sum_{j=0}^{\infty} c_j \xi_{t-j}, \quad (3)$$

where spectral density $f_v(\lambda) > 0$ for all λ , coefficients $c_j = \sum_{j=0}^{\infty} j^{\frac{1}{2}} |c_j| < \infty$, and $\xi = iid(0, \sigma^2)$, which has finite fourth moments. Here, the discrete Fourier transform of $\tilde{x}_t$ for $\lambda_s \neq 0$ is given by:

$$w_{\tilde{x}}(\lambda_s) = \frac{1}{1 - e^{i\lambda_s}} w_v(\lambda_s) - \frac{e^{i\lambda_s}}{1 - e^{i\lambda_s}} \frac{[\tilde{x}_n - \tilde{x}_0]}{n^{1/2}}, \quad (4)$$

where $\lambda_s = \frac{2\pi s}{n}$ ($s = 0, 1, \dots, n-1$) are the fundamental frequencies of a sample n .

But the second term in Eq. (4) shows that the Fourier transform that follows $I(1)$ process is not asymptotically independent across fundamental frequencies because it is a deterministic trend in the frequency domain with a random coefficient

$\frac{[\tilde{x}_n - \tilde{x}_0]}{n^{1/2}}$, rather they are frequency-wise dependent by virtue of the component $n^{1/2} \tilde{x}_n$, which produces a common leakage to all frequencies, $\lambda_s \neq 0$, and in the limit as $n \rightarrow \infty$. This leakage problem and bias estimates of cyclical components are fixed by de-trending the second term in Eq. (4) using a frequency-domain regression to generate an unbiased estimate of $w_{\tilde{x}}(\lambda_s)$ represented as:

$$w_{(1/n)}(\lambda_s) = \frac{-1}{\sqrt{n}} \left(\frac{e^{i\lambda_s}}{1 - e^{i\lambda_s}} \right) \quad (5)$$

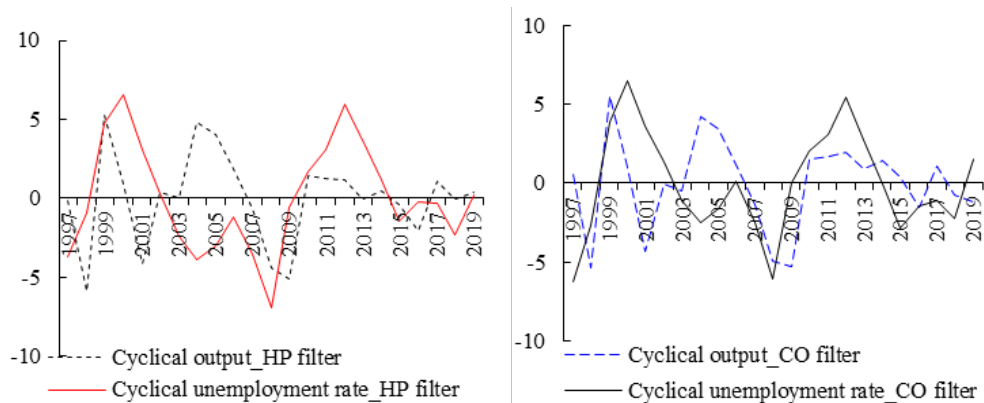
The leakage from the low frequency expressed in Eq. (5) can be removed by de-trending in the frequency domain, leaving an asymptotically unbiased

$\frac{1}{1 - e^{i\lambda_s}} w_v(\lambda_s)$ estimate over the non-zero frequencies. This estimate is $\sqrt{n}$ -consistent and has a good finite samples series.

More importantly, the smoothing parameter of the HP filter is set to 100 equivalent to the value of 6.25, as suggested by Ravn and Uhlig (2002), to generate robust filtered data from annual series, whereas the maximum (s) and minimum (e) values of the CO filter are set to 2 and 8 (frequencies 0.25 and 1 respectively) to retain the oscillation periods in our annual data, congruent to the business cycle.⁷

Figure 1 plots the evolution of the cyclical components of the unemployment and output (i.e. real GDP) series based on the HP and CO filters. In both cases, the three notable sharp troughs (peaks) in the cyclical output (cyclical unemployment) coincide with major global events such as (i) the 1997 Asian currency crisis, (ii) the unwinding of the speculative tech bubble (i.e. the dot.com bubble) in 2000/2001, and (iii) the synchronized fall in global economic growth during the 2007/08 recession.

Observably, cyclical unemployment exhibits a much higher magnitude compared to cyclical output, corroborating the persistently high unemployment rate in the Free State province, particularly during an economic expansion. Also, the inverse relationship between the cyclical output and cyclical unemployment is less clear-cut during the 25 years being studied, as the cyclical variables often cross at values different from zero, implying that a positive output gap is uncorrelated to a negative unemployment gap (or vice versa).



Source: author's estimation using EViews 11

Figure 1. Estimated cyclical components of real output and unemployment using the HP and CO filters (baseline models)

Moreover, to a large extent, there is evidence of a dominant positive correlation between unemployment and output growth in the Free State province, especially during the periods of 1998–2000 and 2009–2013, suggesting that the inverse unemployment–output nexus regularity theorized by Okun's law does not hold,

7 Refer to the recommended procedure for applying the Corbae–Ouliaris frequency-domain filter to time series, available at: <http://fmwww.bc.edu/repec/bocode/c/couliari.html>.

implying that an increase in economic activity level during these periods of economic expansion does not create the much-needed job opportunities in the provincial labour market. This inference concretely supports the evidence of the jobless growth phenomenon found in South Africa in the past decade, as stated earlier (see e.g. Phiri, 2014; Marinkov and Geldenhuys, 2007).

4. The Model: Non-Linear Autoregressive Distributed Lag (NARDL) Framework

To examine and validate the existence of an asymmetric relationship between cyclical output and cyclical unemployment, we rely on the gap specification of Okun's law, which links the activities in the goods market to the labour market, as well as captures movements in unemployment around the natural rate of unemployment owing to fluctuations in actual output around its trend growth over the business cycle, as stated earlier. Moreover, the NARDL modelling framework introduced by Shin et al. (2014) is most suitable for our empirical analysis because it effectively uncovers the "hidden cointegration" existing between positive and negative components of the cyclical variables (Granger and Yoon, 2002) and efficiently deals with the misspecification bias due to endogeneity or serial correlation by allowing the inclusion of an optimal number of lagged variables into the system.

For our application, consider an inverse relationship between the cyclical components of unemployment and output simply defined as:

$$\begin{aligned} u_t - u_t^* &= \alpha_0 + \beta(y_t - y_t^*) + \varepsilon_t & \beta < 0 \\ &\equiv u_t^g = \alpha_0 + \beta y_t^g + \varepsilon_t \end{aligned} \quad (6)$$

where: y_t and u_t are observed real output (i.e. actual output) and unemployment rate respectively; y_t^* is the potential output, and u_t^* is the natural rate of unemployment; y_t^g captures the cyclical output ($y_t - y_t^*$); u_t^g accounts for cyclical unemployment ($u_t - u_t^*$);⁸ β denotes the Okun's coefficient; ε_t is the stochastic error term.

Next, a dynamic NARDL model is constructed using the specified model in Eq. (1) based on the unrestricted ARDL (p, q) model in the form:

$$\Delta u_t^g = \alpha_0 + \beta_1 u_{t-1}^g + \beta_2 y_{t-1}^g + \lambda_1 \sum_{k=1}^p \Delta u_{t-k}^g + \lambda_2 \sum_{k=1}^q \Delta y_{t-k}^g + \delta ECT_{t-1} + \xi_t \quad (7)$$

8 In this paper, the macro-variables cyclical output, cyclical unemployment, and cyclical components are interchangeably referred to as output gap, unemployment gap, and gap variables respectively.

where Δ is the first-difference operator, λ_1 and λ_2 are the short-run coefficients with β_2 being the long-run coefficient (normalized on β_1), ξ_t is the normally distributed residual term such that $\xi_t \sim IID(0, \sigma^2)$, and δ is the coefficient of the one-period lagged error correction term ECT_{t-1} , which measures the adjustment speed of the system to its long-run equilibrium following a shock. Notably, the coefficient of the ECT_{t-1} term is expected to be negative and statistically significant to confirm the existence of a long-run relationship among variables.

However, the symmetric ARDL model specified in Eq. (2) is unsuitable to achieve our empirical objective, as it assumes that changes in cyclical unemployment are linearly related to fluctuations in cyclical output. Following Shin et al. (2014), short-run and long-run asymmetries are introduced into Eq. (2) by defining the potential output y_t^g as a $k \times 1$ vector consisting of multiple regressors such that $y_t^g = y_t^{g+} + y_t^{g+} + y_t^{g-}$, yielding an asymmetric long-run regression expressed as:

$$u_t^g = \beta^+ y_t^{g+} + \beta^- y_t^{g-} + \xi_t \quad \xi_t \sim N(0, \sigma^2), \quad (8)$$

where β^+ and β^- are nonlinear error correction terms associated with asymmetric long-run parameters, y_t^{g+} and y_t^{g-} are the partial sum processes of positive and negative changes in cyclical output, and y_t^g is defined as:

$$\begin{aligned} y_t^{g+} &= \sum_{k=1}^t \Delta y_k^{g+} = \sum_{k=1}^t \max(\Delta y_k^g, 0) \\ y_t^{g-} &= \sum_{k=1}^t \Delta y_k^{g-} = \sum_{k=1}^t \max(\Delta y_k^g, 0) \end{aligned} \quad (9)$$

The decomposition of cyclical output into associated positive and negative changes in Eq. (9) captures the effects of differentiated output shocks on the unemployment rate during economic upswings (expansion) and downswings (recession) over the business cycle.

Substituting Eq. (9) into Eq. (7) yields a dynamic nonlinear ARDL (p, q) model consisting of an error correction mechanism represented as:

$$\begin{aligned} \Delta u_t^g &= \alpha_0 + \sum_{k=1}^p \rho_k u_{t-k}^g + \theta_k^+ y_{t-k}^{g+} + \theta_k^- y_{t-k}^{g-} + \sum_{k=1}^{p-1} \varphi_k \Delta u_{t-k}^g + \sum_{k=0}^{q-1} (\pi_k^+ y_{t-k}^{g+} + \pi_k^- y_{t-k}^{g-}), \quad (10) \\ &+ \mu ECT_{t-1} + \omega_t \quad \text{for } k = 1, \dots, q \end{aligned}$$

where θ_k^+ and θ_k^- are the asymmetrically distributed lagged parameters, φ is the autoregressive parameter, and ω_t is an IID process with zero mean and constant variance, σ^2 . Parameters ρ , θ_k^+ , and θ_k^- are long-run coefficients, while π_k^+ and π_k^-

are short-run coefficients. In this case, $\beta^{g+} = -\theta^+ / \rho$ and $\beta^{g-} = -\theta^- / \rho$ are the asymmetric long-run coefficients. The reliable estimates of θ_k^+ , θ_k^- , π_k^+ , and π_k^- are estimated using the standard ordinary least square method.

To account for the impacts of structural changes that can influence the asymmetric cyclical unemployment–cyclical output relationship, we add dummy variables into the specified dynamic NARDL model in Eq. (10), which is re-estimated as:

$$\Delta u_t^g = \sum_{k=1}^p \rho_i u_{t-k}^g + \theta_k^+ y_{t-k}^{g+} + \theta_k^- y_{t-k}^{g-} + \gamma_1 D_{t-k} + \sum_{k=1}^{p-1} \varphi_i \Delta u_{t-k}^g + \sum_{k=0}^{q-1} (\pi_k^+ y_{t-k}^{g+} + \pi_k^- y_{t-k}^{g-}) + \gamma_2 \Delta D_{t-k} + \mu ECT_{t-1} + \omega_t \quad \omega_t \sim N(0, \sigma^2) \quad (11)$$

where γ_1 and γ_2 are the coefficients of the dummy variables identified based on the breakpoint unit root test and constructed for the periods of 2001–2009 and 2007–2012, while D_t denotes break dates such that $D_t = 1$ for $t \geq BD$ and 0 otherwise.

Table 1. Results of the performed unit root tests on the cyclical variables y_t^g , yc_t^g , and u_t^g

Unit root test	HP filter		CO filter	
	Intercept	Intercept & trend	Intercept	Intercept & trend
DF-GLS				
y_t^g	-4.21*	-4.24*	-4.12*	-4.10*
u_t^g	-2.16**	-2.25	-2.36**	-2.65
Δu_t^g		-3.43**	-3.07*	-3.30**
yc_t^g	4.04*	4.05*	-3.94*	-3.89*
PP				
y_t^g	-4.07*	-3.95**	-4.05*	-2.99***
u_t^g	-2.48	-2.44	-3.94**	-2.87
Δu_t^g	-3.28**	-6.98*	--	-7.19*
yc_t^g	-3.89*	-3.78**	-3.88*	-3.77**
Breakpoint				
<i>Innovative outlier (DF min-t, F-stat.)</i>				
y_t^g	-4.34*** [2004]	-6.50* [2007]	-4.22*** [2004]	4.63 [2007]
Δy_t^g	-8.39* [2001]		8.25* [2001]	7.61* [2002]
u_t^g	-5.82* [2008]	-4.99*** [2008]	-5.39* [2008]	-5.32** [2008]
Δu_t^g		-5.80* [2008]		
yc_t^g	-4.24*** [2004]	-6.46* [2007]	-4.12 [2004]	-4.04 [2001]
Δyc_t^g	-8.151* [2001]		-7.99* [2001]	-7.21* [2002]

Unit root test	HP filter		CO filter	
	Intercept	Intercept & trend	Intercept	Intercept & trend
<i>Additive outlier</i> (DF min- <i>t</i> , F-stat.)				
y_t^g	-4.62** [2003]	5.09*** [2006]	-4.86* [2009]	-4.85 [2010]
Δy_t^g	[2003]	-7.68* [2001]		-7.67* [2010]
u_t^g	-5.26* [2006]	-4.50 [2005]	-5.62* [2005]	-5.50** [2005]
Δu_t^g		-7.72* [2008]		
yc_t^g	-4.61** [2003]	-5.03* [2006]	-4.66** [2009]	-4.63 [2009]
Δyc_t^g		-7.38* [2001]	-7.38* [2001]	-7.34* [2002]

Notes: *, **, and *** denote the significance of associated p-values at 1%, 5%, and 10% levels respectively. Breaks are chosen based on Dickey–Fuller min-*t* with optimal lag length (up to 4) being selected using F-statistics. Parameters y_t^g and u_t^g denote cyclical output and cyclical unemployment.

Finally, the bound-testing procedure proposed by Pesaran et al. (2001) to establish whether variables are cointegrated (i.e. long-run relationship) is performed using the dynamic NARDL model specified in Eq. (11). Here, the bound-testing procedure is based on a modified *F*-test of the joint null, $\hat{\rho} = \theta_k^+ = \theta_k^- = 0$. The standard Wald test is used to determine the presence of an asymmetric relationship between the two cyclical variables in both the long run ($H_0 : \hat{\theta} = \theta_k^+ = \theta_k^-$) and the short run (either as $H_0 : \pi_k^+ = \pi_k^-$ for all $i = 0, \dots, q-1$ or as $H_0 : \sum_{i=0}^{q-1} \pi_k^+ = \sum_{i=0}^{q-1} \pi_k^-$).⁹

5. Empirical Results and Discussion

5.1. Unit Root Test

Typically, the specified NARDL model in Eq. (11) would be considered invalid if any of the interested variables are *I*(2) stationary. Thus, the stationarity properties (i.e. order of integration) of the chosen cyclical variables were established using the augmented Dickey–Fuller GLS (Elliot et al. 1996), the Phillips–Perron (1989; hereafter PP), and the breakpoint (with DF min-*t* for capturing breaks in data owing to innovation and additive outliers) unit root tests.¹⁰

The results of the implemented unit root tests reported in *Table 1* generally show that the generated cyclical components of total unemployment, real output, and real GDP per capita are mostly stationary in level, *I*(0), or require first differencing,

9 Carrying out the Wald test on the joint null of $\pi_k^+ = \pi_k^-$ and additive symmetry, $\sum_{i=0}^{q-1} \pi_k^+ = \sum_{i=0}^{q-1} \pi_k^-$, it produces a strong form and a weak form of short-run symmetry respectively.

10 The BP unit root test allows for a structural break in the deterministic trend to be endogenously determined at unknown dates. This test was developed based on the theoretical contributions of Perron (1989), Vogelsang and Perron (1998), Zivot and Andrews (1992), and Banerjee et al. (1992).

$I(1)$. In addition, the breakpoint (BP) unit root test result indicates structural breaks in these cyclical variables that coincide with notable global events or shocks, justifying the inclusion of dummy variables in the computed nonlinear models.

5.2. Cointegration Analysis

Having found that the cyclical components of unemployment and output are either $I(0)$ or $I(1)$ stationary, the next step is to apply the bound-testing procedure to determine whether these gap variables are asymmetrically (or symmetrically) cointegrated, that is, whether they exhibit nonlinear or linear relationships in the long run, as stressed in the previously discussed empirical literature.

Table 2. Results of bounds test for cointegration in the baseline NARDL models with HP- and CO-filtered cyclical variables

Dependent variable: ΔU_t^g		Function: $\hat{u}_t^g = f(\hat{y}_t^{g+}, \hat{y}_t^{g-})$			
Detrending method	Dynamic specification	F -statistic F_{pss}		Conclusion	
HP filter	NARDL (2,2,1,1)	20.712		Asymmetric cointegration exists	
CO filter	NARDL (2,2,1,1)	7.6087		Asymmetric cointegration exists	
Asymptotic critical values (CVs) for $k = 3$.					
1%		5%		10%	
$I(0)$	$I(1)$	$I(0)$	$I(1)$	$I(0)$	$I(1)$
5.333	7.063	3.71	5.018	3.008	4.15

Notes: $I(0)$ and $I(1)$ denote the upper bound and lower bound levels respectively. Asymptotic critical values (CVs) for nonlinear models are evaluated based on Case III (unrestricted constant and restricted), as in Pesaran et al. (2001).

To test for cointegration, two dynamic NARDL models as specified in Eq. (11) were computed, with one consisting of cyclical unemployment and cyclical output (based on real GDP) variables produced by the HP filter and the second one comprising cyclical components of unemployment and real output generated using CO filter.¹¹ Also, each estimated model consists of optimal lags of 2 selected based on the Akaike information criterion (AIC).

In what follows, the bound testing procedure is applied to test the joint F -test for the null of $\hat{\rho} = \hat{\theta}_k^+ = \hat{\theta}_k^- = 0$ (see Pesaran et al., 2001), and the cointegration analysis results reported in Table 2 show that the values of the joint F -statistics (F_{pss}) exceed the upper bound critical values at a 1% significance level, indicating the existence of an asymmetric relationship between the cyclical unemployment and

11 The computed NARDL models here are taken as the baseline models.

cyclical output (generated using the HP and CO filtering methods) in the estimated dynamic nonlinear models.¹²

5.3. Evidence of Asymmetric Cyclical Unemployment–Cyclical Output Nexus

Given the evidence of an asymmetric long-run relationship between cyclical unemployment and cyclical output in the estimated baseline nonlinear models, we assess the fitness of the asymmetric dynamic model by testing for the null hypothesis of long-run symmetry ($W_{LR} : \theta_k^+ = \theta_k^-$) and short-run symmetry ($W_{SR} : \sum_{i=0}^{q-1} \hat{\pi}_k^+ = \sum_{i=0}^{q-1} \hat{\pi}_k^-$) using the Wald statistic following an asymptotic chi-square (χ^2) distribution.

The result of the performed Wald tests for the baseline nonlinear models is reported in *Table 3* (lower panel), and it firmly rejects the null hypothesis of a symmetric relationship between cyclical unemployment and output in the long run and the short run. In particular, the *F*-statistics for long-run (W_{LR}) and short-run (W_{SR}) asymmetries are 32.5 and 5.29, respectively, in the baseline nonlinear model with HP-filtered cyclical variables, while the respective values of W_{LR} and W_{SR} are 11.6 and 8.80 in the model with CO-filtered cyclical variables. Overall, the results of the Wald statistics for W_{LR} and W_{SR} in the computed baseline models are statistically significant at a 1% significance level, validating the existence of the asymmetric cyclical unemployment–cyclical output nexus in the Free State province.

As regards the asymmetric inverse relationship between cyclical unemployment and cyclical output in the long run, the results in *Table 3* (upper panel) show negative and statistically significant coefficients for the one-period lagged cyclical unemployment and the “positive” changes in cyclical output in the baseline models, indicating the presence of a “partial” long-run asymmetric cyclical unemployment–cyclical output nexus in the Free State province. Interpretively, the coefficients of the long-run cyclical output show that a one percent increase in cyclical output will reduce cyclical unemployment to the range between 0.72 (significant at a 1% critical level) and 0.87 percentage points (significant at a 10% critical level), conditioned on periods of sustained economic expansion. Our result aligns with the findings of Marinkov and Geldenhuys (2007), showing that a one percent increase in cyclical output is associated with a reduction in cyclical unemployment by 0.77 percentage points for South Africa, yet being at odds with Kavase and Phiri (2020), who found no evidence of an inverse asymmetric cyclical unemployment–cyclical output nexus in both the long and short run in the Free State province.

12 The existence of the asymmetric long-run relationship between cyclical unemployment and cyclical output observed in the baseline models is further reinforced by the negative and statistically significant coefficients of the one-period lagged error correction terms (ECT_{t-1}) presented in *Table 2*.

Further, our finding on the existence of partial asymmetric and inverse cyclical unemployment–cyclical output nexus is reinforced by the highly significant and negative long-run coefficient estimates L_y^+ of -0.57 and -0.53 for positive cyclical outputs in the baseline model with HP- and CO-filtered gap variables respectively. This inference implies that an economic upturn between 1.73 and 1.88 percent is necessary to reduce unemployment by one percent. Also, this empirical result affirms the existence of Okun's relationship with a trade-off ratio of 2:1 in the Free State province, in keeping with documented findings in previous studies (see e.g. Adanu, 2005; Freeman, 2000; Gordon, 1998).

Interestingly, the estimated long-run coefficients L_y^- for the negative cyclical outputs in the nonlinear models with HP- and CO-filtered variables are 0.41 and 0.31 respectively, reflecting a contradictory positive relationship between negative cyclical output and cyclical unemployment, indicating that a decline in negative output gap between 3.8 and 4.3 percent will lower cyclical unemployment by one percent in the long run; however, these effects are statistically insignificant. This result corroborates those of Kavase and Phiri (2020), who found an insignificant positive relationship between the negative output gap and the unemployment gap in the Free State province, with a percentage decrease in the output gap reducing the unemployment gap by 1.66 percent in the long run.¹³

Although the above finding may be counterintuitive, it still explains the observed positive co-movement between economic growth and unemployment in *Figure 1*, which reflects certain periods (e.g. 1997–1999 and 2009–2013) in the provincial business cycle when there is a simultaneous rise in both economic activity level and unemployment rate.

Overall, in all cases, the estimated short-run coefficients for cyclical variables, Δy_t^{g+} and Δy_{t-1}^{g+} , are negative and statistically significant in both nonlinear (baseline) models, suggesting that changes in cyclical output exert strong contemporaneous effects on cyclical unemployment in the short run in the province being studied. More specifically, a one percent rise in cyclical output (i.e. positive output gap) contemporaneously reduces cyclical unemployment between 1.55 and 1.63 percentage points during an economic downswing. Further, the negative and statistically significant coefficients for one-period lagged short-run cyclical output variables (i.e. Δy_t^{g+} and Δy_{t-1}^{g+}) in the baseline models affirm the existence of asymmetric short-run effects, suggesting that a one percentage increase (decrease) in cyclical output can reduce (raise) cyclical unemployment by 0.52 (+0.83) during an economic downturn (upturn) in the short run, after the impact of the output shock (say about a year).

13 Similar findings on insignificant positive cyclical output–cyclical unemployment nexus in the long run have been documented in previous works exploring the presence of asymmetric Okun's relationship in South Africa: see, for example, Sere (2020) and Marinkov and Geldenhuys (2007).

Taken together, so far, our results suggest the existence of a short-run asymmetric cyclical unemployment–cyclical output relationship in the Free State province during economic downturns and upswings, over the business cycle. Similar findings about short-run asymmetric Okun's relationship have been documented in some South African provinces (Kavase and Phiri, 2020) and in South Africa (Mazorodze and Siddiq, 2018; Marinkov and Geldenhuys, 2007).

As anticipated, the statistically significant and negative coefficients for the ECT_{t-1} terms in the nonlinear baseline models presented in *Table 2* indicate the reversion of the bi-variate nonlinear systems to their long-run equilibrium (or steady state) in the presence of an external shock or an economic perturbation. Additionally, this result reaffirms the previously discussed finding of the existence of asymmetric cointegration between cyclical unemployment and cyclical output in the long run in the focal South African province.

Conversely, the absolute value of the speed of the adjustment μ_s ranges between 1.35 and 1.52 in the baseline models,¹⁴ which is greater than unity but falls within the acceptable range of -1 and -2 to ensure the stability and convergence of the systems consisting of cointegrated cyclical variables, in the aftermath of an economic perturbation or external shock (Johansen, 1995). The implication is that, in the presence of an external shock to the bivariate system, the two cyclical variables will converge to their steady-state equilibrium (or long-run relationship) rapidly (say, in less than a year) following an oscillatory process, instead of the usual monotonic gradual reversion process to long-run equilibrium (Narayan and Symth, 2006).

In all cases, the statistically significant and negative coefficients of the dummy variables in the computed asymmetric models accentuate the vulnerability of the provincial economy and labour market activities to exogenous and structural endogenous shocks, which exert significant influence on changes in cyclical output, as well as the responsiveness of unemployment rate to output shocks. This result heavily stressed the notion that for effective policymaking the government needs to be cognizant of the significant impact of structural shocks on the stability of the existing asymmetric cyclical unemployment–cyclical output trade-off, especially at the provincial level.

Last but not least, the result of the performed diagnostic tests (*Table 3*, lower panel) explicitly shows that the statistic values for the JB normality test, the BG serial correlation test, the ARCH tests, and the RESET tests are statistically insignificant, affirming that the residuals of re-specified dynamic asymmetric models are free from irregular error distribution, serial correlation, heteroscedasticity, and specification bias due to the incorrect functional form of Okun's relationship.

14 Kavase and Phiri (2020: 70) reported relatively large and significant negative coefficients for the speed of adjustments for some South African provinces. Also, see Narayan and Symth (2006: 339) for related results and justification.

The results of the CUSUM and CUSUMSQ tests plotted in *figures 2–3* confirm the stability of estimated coefficients since the regression lines are confined within the 5% critical bounds of parameter stability in the baseline dynamic nonlinear models. Finally, the results of autocorrelation (AC) and partial autocorrelation (PAC) tests performed on both the correlogram of residuals and residuals squared derived from the baseline NARDL models show that these residuals are well-behaved, stationary, and not serially correlated (i.e. they have no pattern) with statistically insignificant p -values (up to 12 lags).¹⁵

Table 3. *Estimation results of the baseline NARDL models for the cyclical unemployment–cyclical output relationship*

Dependent variable: ΔU_t^g							
NARDL model with HP-filtered gap variables				NARDL model with CO-filtered gap variables			
Var.	Coeff.	S. E	t -ratio (p -values)	Var.	Coeff.	S. E	t -ratio (p -values)
Constant	39.62	6.71	5.90 (0.00)	Constant	32.07	9.12	3.51 (0.00)
u_{t-1}^g	-1.52	0.18	-8.13 (0.00)	u_{t-1}^g	-1.35	0.25	-5.35 (0.00)
y_{t-1}^{g+}	-0.87	0.24	-3.56 (0.00)	y_{t-1}^{g+}	-0.72	0.36	-1.97 (0.08)
y_{t-1}^{g-}	0.40	0.24	1.67 (0.12)	y_{t-1}^{g-}	0.31	0.33	0.93 (0.37)
L_y^+	-0.57	0.15	-3.68 (0.00)	L_y^+	-0.53	0.26	-1.97 (0.07)
L_y^-	0.26	0.14	1.86 (0.09)	L_y^-	0.23	0.22	1.01 (0.33)
Δu_{t-1}^g	-0.92	0.14	6.44 (0.00)	Δu_{t-1}^g	-0.93	0.20	4.48 (0.00)
Δy_{t-1}^{g+}	-1.63	0.29	-5.54 (0.00)	Δy_{t-1}^{g+}	-1.55	0.45	-3.39 (0.00)
Δy_{t-1}^{g-}	1.86	0.31	5.89 (0.00)	Δy_{t-1}^{g-}	1.85	0.44	4.13 (0.00)
Δy_{t-1}^{g+}	-0.52	0.17	-3.07 (0.01)	Δy_{t-1}^{g+}	-0.41	0.25	-1.62 (0.13)
Δy_{t-1}^{g-}	-0.83	0.35	-2.37 (0.04)	Δy_{t-1}^{g-}	-0.56	0.46	-1.20 (0.26)
$\gamma_1 D_{t-1}$	-15.34	2.75	-5.56 (0.00)	$\gamma_1 D_{t-1}$	10.39	3.17	-3.27 (0.00)
$\gamma_2 \Delta D_t$	-9.69	2.87	-3.37 (0.04)	$\gamma_2 \Delta D_t$	-7.57	1.93	-3.90 (0.00)
ECT_{t-1}	-1.52	0.14	10.51 (0.00)	ECT_{t-1}	-1.35	0.19	-7.02 (0.00)
Model diagnostics (lower panel)							
W_{LR}	32.56 (0.00)	W_{SR}	5.29 (0.02)	W_{LR}	11.60 (0.00)	W_{SR}	8.80 (0.00)
R^2	0.95	$\bar{R}^2$	0.89	R^2	0.87	$\bar{R}^2$	0.74
F -stat.	17.47 (0.00)	DW	2.04	F -stat.	6.40 (0.00)	DW	2.07
χ_{SC}^2	1.30 (0.52)	χ_{NOR}^2	3.67 (0.15)	χ_{SC}^2	0.80 (0.66)	χ_{NOR}^2	2.96 (0.22)
$\chi_{HET-ARCH}^2$	0.76 (0.38)	χ_{EF}^2	2.62 (0.14)	$\chi_{HET-ARCH}^2$	1.30 (0.25)	χ_{EF}^2	2.12 (0.18)

Notes: Subscripts “+” and “−” denote the positive and negative partial sum processes respectively. L_y^+ (i.e. $\hat{\beta}^{g+} = -\hat{\theta}_k^+ / \hat{\rho}$) and L_y^- (i.e. $\hat{\beta}^{g-} = -\hat{\theta}_k^- / \hat{\rho}$) are the long-run coefficients associated with positive and negative changes in cyclical output y^{g+} respectively. W_{LR} and W_{SR} refer to the Wald test for long-run symmetry (i.e. $L_y^+ = L_y^-$) and the additive short-run symmetry condition (i.e., $\sum_{i=0}^{q-1} \hat{\pi}_k^+ = \sum_{i=0}^{q-1} \hat{\pi}_k^-$).

15 To save space, the AC and PAC test results are not reported here but are available upon request from the author.

χ_{SC}^2 , χ_{H-ARCH}^2 , χ_{NOR}^2 , χ_N^2 , and χ_{FF}^2 are the LM tests for serial correlation, heteroscedasticity, normality, and function form (Ramsey's RESET) respectively. Corresponding p-values are in parentheses.

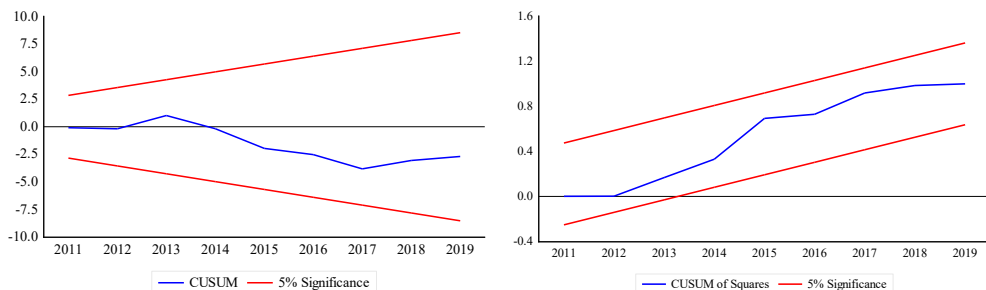


Figure 2. *CUSUM and CUSUMSQ of the baseline NARDL model with HP-filtered cyclical series*

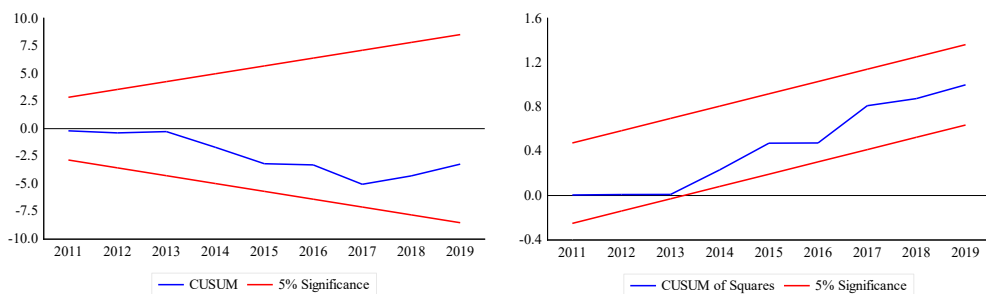


Figure 3. *CUSUM and CUSUMSQ of the baseline NARDL model with CO-filtered cyclical series*

Robustness: How Reliable Is the Asymmetric Okun's Relationship Using Provincial Data?

Hitherto, empirical results in the preceding analyses indicate the existence of the asymmetric cyclical unemployment–cyclical output nexus in the Free State province over the business cycle under consideration. However, intuitively, the results of the computed nonlinear baseline models are expected to be sensitive to specification bias, for instance, when a different measure of provincial output is used. Thus, for robustness, the dynamic asymmetric model specified in Eq. (7) is re-estimated with cyclical components of real GDP per capita (yc_t) and total unemployment (u_t) generated using the HP and CO filters.¹⁶

¹⁶ Figure A3 in the Appendix plots the graphs of the growth rates of cyclical real GDP per capita and cyclical unemployment estimated using the HP and CO filters. Noticeably, these graphs exhibit an oscillatory pattern similar to Figure 1.

Table 4. Results of bounds test for nonlinear cointegration in the sensitivity analysis NARDL models with HP- and CO-filtered cyclical variables

Dependent variable: ΔU_t^g		Function: $\hat{u}_t^g = f(\hat{y}c_t^{g+}, \hat{y}c_t^{g-})$			
Detrending method	Dynamic specification	F -statistic (F_{PSS})		Conclusion	
HP filter	NARDL (2,2,1,1)	14.17898		Cointegration – asymmetric relationship exists	
CO filter	NARDL (2,2,2,0)	6.516974		Cointegration – asymmetric relationship exists	
Asymptotic CVs ($k = 3$) for the estimated models with HP and CO-filtered series					
1%		5%		10%	
$I(0)$	$I(1)$	$I(0)$	$I(1)$	$I(0)$	$I(1)$
5.333	7.063	3.71	5.018	3.008	4.15

Note: See Table 2.

Same as before, the result of the performed unit root tests shows that the cyclical variables yc_t and u_t are $I(1)$ stationary (see *Table 1*). Next, we determine whether u_t and yc_t are cointegrated, making use of the bounds testing procedure; results of the cointegration analysis presented in *Table 4* indicate the existence of an asymmetric long-run relationship between the two cyclical variables since the F -statistics of 14.17 and 6.51, obtained from the re-estimated asymmetric models with HP-filtered and CO-filtered gap variables respectively, exceed the upper bound critical values (at a 1% significance level).

Based on the evidence of asymmetric cointegration between cyclical variables in the re-estimated nonlinear models, we applied the standard Wald test to ascertain the presence of asymmetries among the positive and negative components of the cyclical unemployment and cyclical output in the long run (W_{LR}) and short run (W_{SR}). Specifically, the Wald test results displayed in *Table 5* (lower panel) reveal statistically significant Wald statistics (at a 1% significance level), which rejects the null hypothesis of long-run and short-run symmetries but affirms the existence of asymmetric cyclical unemployment–cyclical output relationships in both the long and the short run. This finding inference corroborates previous results from the nonlinear baseline models (see *Table 3*). Thus, we can firmly conclude the existence of the asymmetric cyclical unemployment–cyclical output nexus for the Free State province both in the long run and the short run.

On the other hand, the empirical results presented in *Table 5* show that changes in cyclical outputs (i.e. positive and negative) have strong asymmetric long- and short-run effects on cyclical unemployment in the re-estimated models. Based on statistically significant results, there is concrete evidence of a “partial” asymmetric long-run relationship between the cyclical output and cyclical unemployment, specifically in the nonlinear model with HP-filtered gap variables. In particular, the empirical result suggests that a percentage rise in “positive” cyclical output

will reduce cyclical unemployment by 0.70 percentage points. Meanwhile, the estimated long-run coefficient (L_y^+) of the “positive” cyclical output is -0.49, implying that an economic upturn of about 2.03 percent is necessary to reduce unemployment by one percent in the focal South African province. This finding agrees with previous evidence for the existence of an Okun's relationship with a trade-off ratio of 2:1, underscoring the cyclical output–cyclical unemployment nexus stressed in some studies (see Adanu, 2005; Attfield and Silverstone, 1998; Moosa, 1997, among others).

In connection with short-run asymmetries, we can observe strong contemporaneous effects of cyclical output on cyclical unemployment, in keeping with the result of the computed nonlinear baseline models. More specifically, the result of the re-estimated models reveals that a one percent increase in “positive” cyclical output would contemporaneously lower cyclical unemployment between 1.06 and 1.49 percentage points in the short run, and these effects are statistically significant at a 1% critical level. Equally, in the short run, a percentage increase in positive (negative) cyclical output would lower (raise) cyclical unemployment by 0.46 (0.99), and these asymmetric impacts are highly significant at a 1% critical level.

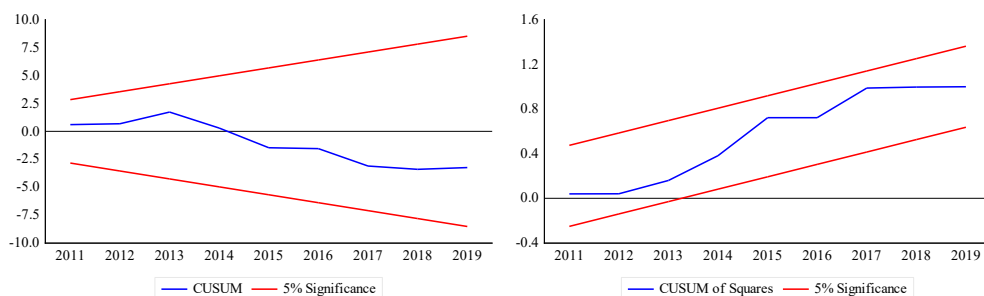
As expected, in all cases, the coefficients of the ECT_{t-1} terms are negative and highly significant, indicating the reversion of re-estimated nonlinear models to long-run equilibrium, after an external shock. Same as the baseline models, the adjustment speed is -1.42 (HP-filtered gap model) and -1.14 (CO-filtered gap model), suggesting a rapid and oscillatory reversion process to a long-run equilibrium. On the other hand, parameters γ_1 and γ_2 denoting the dummy variables are negative and statistically significant (mostly at a 1% critical level) in the re-estimated nonlinear model, accentuating the susceptibility of the evolution of asymmetric cyclical output–cyclical unemployment nexus found in the Free State province to structural endogenous and/or external shocks.

Lastly, considering the result of the performed diagnostic tests (*Table 5*, lower panel), the statistic values for the JB normality test, BG serial correlation test, ARCH tests, and RESET tests are statistically insignificant, affirming that the residuals of re-specified dynamic asymmetric models are free from irregular error distribution, serial correlation, heteroscedasticity, and specification bias due to the incorrect functional form of Okun's relationship. The results of the CUSUM and CUSUMSQ tests plotted in *figures 4–5* indicate the absence of any instability of the parameter coefficients, as the regression lines are confined within the 5% critical bounds of parameter stability in the re-estimated dynamic nonlinear models. The results of autocorrelation (AC) and partial autocorrelation (PAC) tests performed on both the correlogram of residuals and residuals squared derived from the sensitivity analysis NARDL models show that these residuals are stationary and serially uncorrelated with statistically insignificant p -values (up to 12 lags).

Table 5. Estimation results of the NARDL models for cyclical unemployment-cyclical output relationship (sensitivity analysis)

Dependent variable: ΔU_t^g							
NARDL model with HP-filtered gap variables				NARDL model with CO-filtered gap variables			
Var.	Coeff.	S. E	t-ratio (p-values)	Var.	Coeff.	S. E	t-ratio (p-values)
Constant	36.03	7.63	4.71 (0.00)	Constant	21.45	7.35	2.91 (0.01)
u_{t-1}^g	-1.42	0.21	-6.75 (0.00)	u_{t-1}^g	-1.14	0.24	-4.69 (0.00)
yc_{t-1}^{g+}	-0.70	0.27	-2.53 (0.03)	yc_{t-1}^{g+}	-0.31	0.35	-0.91 (0.38)
yc_{t-1}^{g-}	0.50	0.27	1.81 (0.10)	yc_{t-1}^{g-}	0.40	0.35	-0.91 (0.23)
L_{cy}^+	-0.49	0.18	-2.63 (0.02)	L_{cy}^+	-0.27	0.30	-0.90 (0.38)
L_{cy}^-	0.35	0.17	2.04 (0.07)	L_{cy}^-	0.35	0.25	1.41 (0.18)
Δu_{t-1}^g	-0.87	0.16	5.38 (0.00)	Δu_{t-1}^g	-0.72	0.16	4.44 (0.00)
Δyc_{t-1}^{g+}	-1.49	0.34	-4.30 (0.00)	Δyc_{t-1}^{g+}	-1.06	0.25	-4.20 (0.00)
Δyc_{t-1}^{g-}	1.71	0.35	4.88 (0.00)	Δyc_{t-1}^{g-}	1.42	0.32	4.41 (0.00)
Δyc_{t-1}^{g+}	-0.46	0.14	-3.11 (0.01)	Δyc_{t-1}^{g+}	---	---	---
Δyc_{t-1}^{g-}	-0.99	0.22	-4.49 (0.00)	Δyc_{t-1}^{g-}	-0.94	0.28	-3.31 (0.00)
$\gamma_1 D_{t-1}$	-1.498	0.34	-4.30 (0.00)	$\gamma_1 D_{t-1}$	-7.99	3.11	-2.56 (0.02)
$\gamma_2 \Delta D_t$	-10.41	3.43	-3.03 (0.01)	$\gamma_2 \Delta D_t$	---	---	---
ECT_{t-1}	-1.42	0.163	-8.69 (0.00)	ECT_{t-1}	-1.14	0.19	-5.75 (0.00)
Model diagnostics (lower panel)							
W_{LR}	20.91 (0.00)	W_{SR}	10.15 (0.00)	W_{LR}	7.75 (0.00)	W_{SR}	4.22 (0.03)
R^2	0.89	$\bar{R}^2$	0.78	R^2	0.81	$\bar{R}^2$	0.67
F-stat.	7.97 (0.00)	DW	1.71	F-stat.	5.91 (0.00)	DW	2.10
χ_{SC}^2	2.64 (0.26)	χ_{NOR}^2	0.90 (0.63)	χ_{SC}^2	2.73 (0.25)	χ_{NOR}^2	0.27 (0.88)
$\chi_{HET-ARCH}^2$	1.72 (0.18)	χ_{EF}^2	4.16 (0.07)	$\chi_{HET-ARCH}^2$	1.34 (0.24)	χ_{EF}^2	0.26 (0.61)

Notes: See Table 2. Here: L_{cy}^+ and L_{cy}^- represent the long-run coefficients associated with positive and negative changes in cyclical output (yc^{g+}) proxy as real per capita GDP respectively.

**Figure 4.** CUSUM and CUSUMSQ of the sensitivity analysis NARDL model with HP-filtered cyclical variables

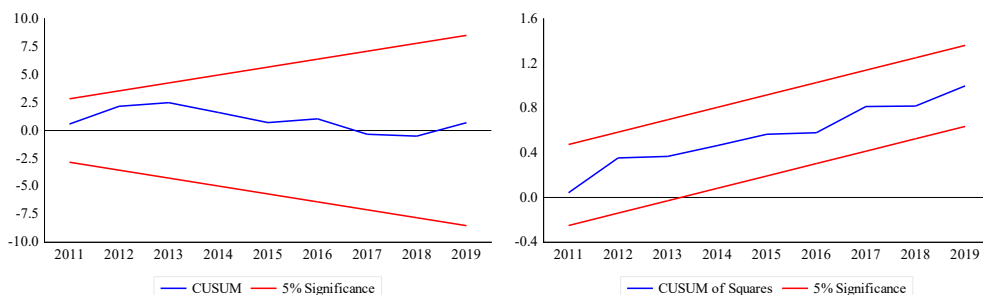


Figure 5. *CUSUM and CUSUMSQ of the sensitivity analysis NARDL model with CO-filtered cyclical variables*

6. Conclusions and Policy Recommendations

This paper contributes to two emergent strands of empirical literature testing for asymmetry in Okun's law and those investigating Okun's relationship at the regional (provincial or state) level. Specifically, we examine whether there is evidence supporting the asymmetric unemployment–output relationship in the Free State province (South Africa) employing the NARDL modelling approach to account for both long- and short-run asymmetries among variables in a coherent manner. In addition, the Hodrick–Prescott and Corbae–Ouliaris detrending techniques were applied to isolate the cyclical components of unemployment and output growth rates in the baseline non-linear models. For sensitivity analysis, the gap variable of real GDP per capita (a different measure of cyclical output) is substituted into the baseline models to determine the robustness of the obtained results. Irrespective of the detrending methods, we find the value of Okun's coefficient to be relatively stable around 2 and strong evidence for asymmetric Okun's relationship in the Free State province given the evidence of a statistically significant asymmetric cyclical unemployment–cyclical output relationship in both the long and short run when the effect of structural break is accounted for.

Summarily, our empirical results align with findings documented in the literature on the existence of nonlinear Okun's relationship, particularly in South Africa. Firstly, we find evidence of a “partial” long-run asymmetry given that only the coefficient of positive cyclical output exhibits a statistically significant inverse relationship with cyclical unemployment. Specifically, our results suggest that a 1 percent increase in positive cyclical output will lower cyclical unemployment between 0.70 and 0.87 percentage points, conditioned on a sustained economic upswing. Secondly, the statistically significant long-run coefficients reveal that a fall in unemployment by one percent in the Free State province requires an economic upswing between 1.88 to 2.03 percent, keeping in line with the proven empirical regularity of Okun's ratio of 2:1 documented in the growing literature. Thirdly, we

find evidence of a strong contemporaneous effect of asymmetric changes in cyclical output on cyclical unemployment in the short run. To this end, the estimates of contemporaneous (i.e. lagged and one-period lagged) coefficients for both the positive and negative cyclical outputs are negative and statistically significant, implying that a one percent increase in positive cyclical output is associated with a decrease in cyclical unemployment between 1.63 and 1.06 percentage points, whereas a one percent decline in negative cyclical output would increase cyclical unemployment between 0.41 and 0.52 percentage points in the Free State province.

Our findings have crucial policy implications. In particular, the evidence of non-linear cyclical unemployment–output nexus explains the ineffectiveness of the nationally ratified pro-poor policies to spur economic growth and lower the prevailing high unemployment rate in South Africa and across its provinces. Meanwhile, the existence of long- and short-run asymmetries between unemployment and output accentuates the policy imperativeness for policymakers to take into account both supply and demand factors influencing economic activity and unemployment, which is typically overlooked during policymaking since the non-linear relationship between these macro-variables emphatically calls for adopting an integrated economic reform that would simultaneously tackle the problem of weak economic performance and rising unemployment rate, rather than the isolated piecemeal policy approach commonly used to deal with these macroeconomic problems individually.

Based on our findings, we put forward some policy prescriptions for both the provincial and national governments to implement macroeconomic reforms that proactively deal with the emergent nonlinear association between economic growth and unemployment, as well as improve the responsiveness of the latter to real output growth in South Africa. Firstly, to effectively address the problem of skill mismatch – the main driver of the unemployment rate in the country coupled with the prevailing highly skilled intensive domestic labour market that mostly absorbs educated workers –, it is imperative for the government (via the provincial economic development department) to proactively promote entrepreneurship and self-employment initiatives, particular among the youth population. Typically, these employment initiatives can be reinforced by providing access to public and private funding for the development of credible business plans and the establishment of small, medium, and micro-enterprises.

Secondly, given the rapid growth and increasing importance of the informal sector in the South African economy as a source of employment and an indirect contributor to economic growth, it is important for policymakers to remove market rigidities associated with, for example, obstructive bureaucratic red tapes to acquire trading (or business) permits, company registration fees, extended turn-around period for company/business registration, and stringent by-laws that hamper business operation in the informal sector. This policy strategy can lead to higher

productivity and competition in the labour market, which in turn will increase the provincial contributions to the domestic economy by raising total productivity and lowering the unemployment rate at the national level.

Finally, to improve the responsiveness of the unemployment rate to economic growth in the short run, given the evidence of short-run asymmetry, the provincial government needs to intensify its investment spending on large infrastructure projects and preventative maintenance of public infrastructures (such as government buildings and road networks) since such effort creates transitory job opportunities, especially for the unemployed unskilled workers which form the largest portion of the total unemployment rate (DPWI, 2020). In the same vein, the government should deepen its efforts to efficiently implement its flagship public employment programmes (PEPs) to prevent moral hazard and rent-seeking problems (e.g. corruption and nepotism practices) associated with the selection of beneficiaries and stipulated participation period. This effort would improve the labour market absorption rate, in effect lowering unemployment and alleviating poverty, as the nationally-driven PEPs are mostly labour-intensive and prioritize skill development (Maphanga and Mazenda, 2019; McCord, 2004, 2005).

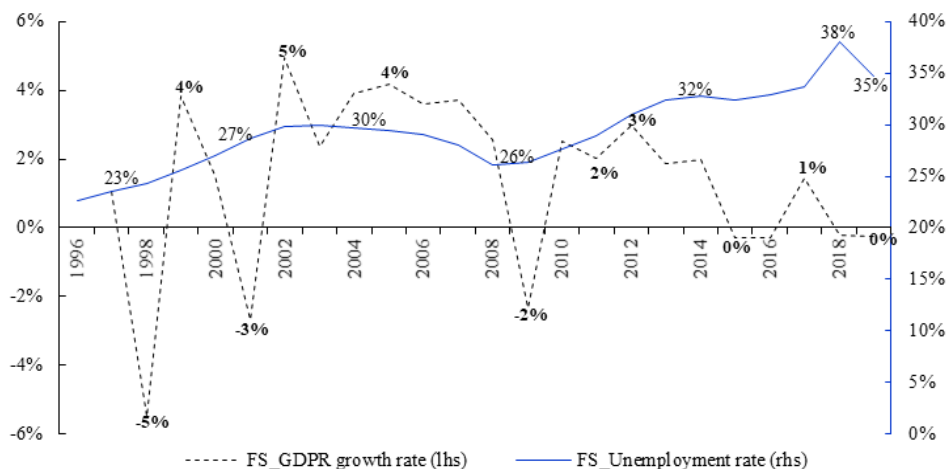
The scope of this study is limited by the paucity of reliable historical time series available for South African provinces, which is evidenced by the scanty provincial-specific studies in the voluminous literature assessing asymmetric Okun's law using provincial (or regional) data. As a result, the dynamic asymmetric model constructed for our analysis consists of few reliable macro-variables.

Future studies can build our work using a similar asymmetric model and incorporating some macroeconomic, fiscal, and institutional variables (for example, employees' working hours, changes in female labour participation, labour productivity, demographic trends, capacity utilization, and wage rate) found in existing country-specific studies as determinants of asymmetric Okun's relationship (see e.g. Ball et al., 2017; Knotek, 2012; Lee, 2000; Moosa, 1997; Prachowny, 1993). A typical empirical analysis would allow policymakers to better understand how unobserved macroeconomic and labour force conditions could influence asymmetric unemployment–output relationship across South African provinces, to develop and implement inclusive macro-policies that improve the responsiveness of unemployment to output growth.

Acknowledgements

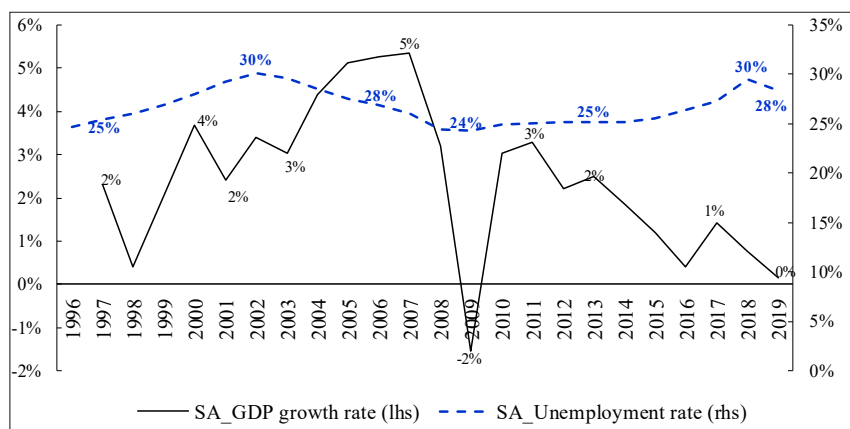
The author is profoundly thankful to the Executive Editor of this Journal and the anonymous referee for their constructive comments that have enhanced the quality of this paper. The opinions expressed herein are those of the author and do not reflect those of the affiliated institution.

APPENDIX A.



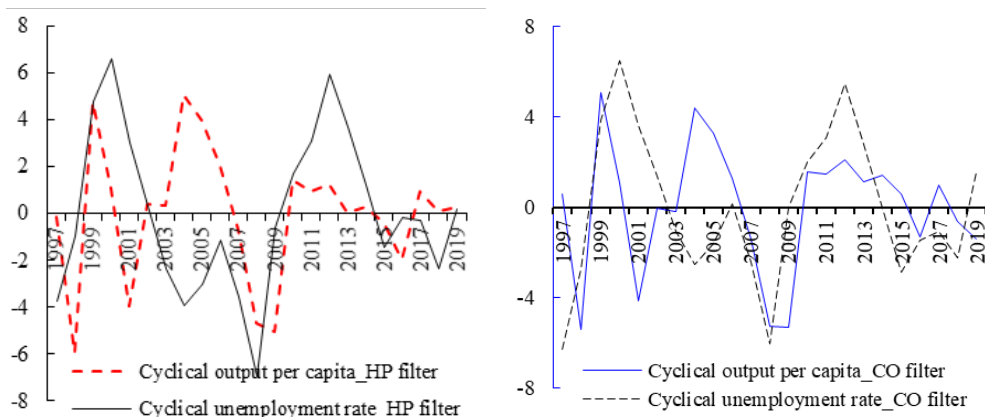
Source: StatsSA (2020); S&P Global Regional eXplorer (ReX); author's estimation

Figure A1. Evolution of annual real GDP and unemployment growth rates in FS Province, 1996–2019



Source: StatsSA (2020); S&P Global Regional eXplorer (ReX); author's estimation

Figure A2. Evolution of annual real GDP and unemployment growth rates in South Africa, 1996–2019



Source: author's estimation using EViews 11

Figure A3. Estimated cyclical components of real output per capita and unemployment using the HP and CO filters (sensitivity analysis models)

Table A1. Summarized descriptive statistics for unobserved components of u_t and y_t (1994–2019)

Description	HP detrending method		CO filter detrending method	
	Cyclical unemployment (%)	Cyclical output (%)	Cyclical unemployment (%)	Cyclical output (%)
	$u_t^g = u_t - u_t^*$	$y_t^g = y_t - y_t^*$	$u_t^g = u_t - u_t^*$	$y_t^g = y_t - y_t^*$
Mean	-1.66e-14	2.24e-14	1.13e-15	7.63e-16
Median	-0.281	0.299	-0.062	0.606
Maximum	6.599	5.040	6.496	5.098
Minimum	-6.929	-5.963	-6.258	-5.402
Std. dev.	3.397	2.849	3.306	2.872
Skewness	0.198	-0.400	0.056	-0.496
Kurtosis	2.526	2.971	2.513	2.743
Jarque–Bera statistics (p -value)	0.366 (0.832)	0.616 (0.734)	0.238 (0.887)	1.006 (0.604)
Sum	-3.81e-13	5.14e-13	2.35e-14	1.73e-14
Sum Sq. Dev.	253.885	178.606	240.575	181.542

Source: author's estimation using EViews 11

Note: p -values in parentheses.

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Audit Committee Characteristics and Firm Performance: Evidence from India

Abhisheck Kumar SINGHANIA

Dhemaji Commerce College, Assam, India

e-mail: abhisecksinghanian@gmail.com; ORCID:

<https://orcid.org/0000-0003-2910-5159>

Abstract. This study examines the impact of audit committee (AC) characteristics on firm performance (FP) in 133 NSE-listed Indian companies over five years. Data from annual reports, Capitaline, Prowess, and NSE websites are analysed using panel-corrected standard error regression. Results show that non-executive directors, AC charter, AC size, multiple directorships, and meeting attendance positively affect ROA and market capitalization. Gender diversity influences ROA, while expertise affects market capitalization, but AC independence negatively impacts market capitalization. The collective effect of all 11 AC characteristics significantly enhances FP. This research provides a comprehensive analysis, with three characteristics not previously studied.

Keywords: audit committee, firm performance, ROA, market capitalization, PCSE, India

JEL Classification: M41

1. Introduction

Worldwide failure of Corporate Governance (CG) and accounting frauds have wiped out many firms from the global market such as Enron and WorldCom from the US and Satyam from India in the first decade of this century. The recent bank fraud in 2022 by ABG Shipyard for 224.82 billion Indian rupees (2.67 billion USD) has shattered the trustworthiness of CG in a firm. The monitoring of the management and the oversight of the reporting process provided by the Board of Directors (BOD), particularly by the Audit Committee, is in question. An Audit Committee (AC) is a sub-committee of the BOD and a vital component of the CG mechanism, which is responsible for the appointment of external auditors, oversight of the financial reporting process, management's surveillance, and the internal control system of the company. The power of the AC to question the

management, oversee the reporting process, and detect fraud depends upon the effectiveness of the committee.

Corporate fraud occurred even after the formation of AC, where the committee failed to discharge its responsibilities properly (Kallamu and Saat, 2015). The effectiveness of AC depends on its characteristics (Akhtaruddin and Haron, 2010; Dhaliwal et al., 2010; Gupta and Mahakud, 2021; Li et al., 2012). Therefore, the regulatory bodies kept changing the characteristics of AC to improve its effectiveness: e.g. the Security and Exchange Board of India's (SEBI) Listing Obligations and Disclosure Requirements (LODR) regulations (2015) changed many characteristics of the Indian Companies Act 2013: e.g. the requirement of independent members in AC were changed from majority to two-thirds of the members, and the presence of at least one financial or accounting expert was added.

While the initial literature emphasized AC characteristics and their effectiveness, recent literature has started focusing on AC's impact on the firm's value and financial performance (FP).

There is a plethora of research on the relationship between CG and FP (Arora and Bodhanwala, 2018; Arora and Sharma, 2016; Bhagat and Bolton, 2008, 2019; Hermuningsih et al., 2020; Sarpong-Danquah et al., 2018). A keyword search of the Scopus index revealed more than six thousand papers on CG and FP. However, the keyword search discloses that the studies on the effect of AC's characteristics on FP are minimal, with around four hundred articles. This is probably because AC is a relatively new concept in comparison to CG. Most papers consider only a partial view of AC effectiveness and treat AC as part of the overall CG construct, where AC effectiveness loses prominence (Leung et al., 2014). Some studies have looked into either a single (Chaudhry et al., 2020; Chijoke-Mgbame et al., 2020; Maji and Saha, 2021) or several characteristics (Fariha et al., 2022; Farooque et al., 2020) of the AC. As a result, some of the AC characteristics remained unobserved. Still other studies considering more AC characteristics have taken the aggregate effect through an index and not their individual effects (Al-ahdal et al., 2020; Haldar and Raithatha, 2017). A country-wise bibliometric analysis of the Scopus index further reveals that most studies have taken place in the US, with 79 papers, followed by Malaysia with 58 papers. India has only 17 research papers on AC and FP. These papers include studies on the overall CG structure, single AC characteristics, or a few characteristics, as well as analyses using an index. The motivation for this paper arises from a research gap in the existing literature – there is a lack of detailed analysis of all identifiable AC characteristics and their impact on FP.

The present study investigates the influence of Audit Committee (AC) characteristics on 133 NSE-listed Indian firms from six different industries for a period of five years from 2016 to 2020. We have used 11 AC characteristics and analysed their individual and aggregate impact on the accounting-based and market-based measures of FP after the regulatory changes made by SEBI's LODR regulations

(2015). We have employed Panel-Corrected Standard Error (PCSE) regression technique to analyse data after identifying heteroskedasticity, autocorrelation, and cross-sectional dependence.

The results indicate that six AC characteristics significantly affect the accounting-based measure of FP, while seven AC characteristics significantly influence the market-based measure of FP. While the extant literature supports these results, this study's uniqueness lies in using three new AC characteristics that were not examined individually in the previous research. Among the three characteristics, the composition of AC by 100% non-executive directors (NEDs) and the presence of AC charter are found to have a significant positive impact on both measures of FP. At the same time, the representation of AC members at board meetings is found not to affect FP.

This study makes several significant contributions to the emerging literature on AC. Firstly, it provides a comprehensive explanation of AC effectiveness by examining eleven specific AC characteristics and their impact on FP, both individually and collectively, offering a holistic perspective on this relationship. Secondly, the study introduces three new AC characteristics into the discourse: the inclusion of non-executive directors on the AC, the presence of an AC charter, and the representation of AC members in board meetings. Our findings reveal that while the non-executive directorship of AC and the presence of an AC charter significantly enhance FP, these factors have been largely overlooked in previous research. Thirdly, in the Indian context, this study addresses the impact of the Securities and Exchange Board of India's (SEBI) Listing Obligations and Disclosure Requirements (LODR) of 2015, which brought about crucial regulatory changes that have a consequential impact on AC effectiveness, rendering prior studies outdated. Despite an extensive search, no literature was found that considers the effect of individual AC characteristics on FP following these regulatory changes. Therefore, this study is the first to analyse both the individual and aggregate effects of AC characteristics on FP, incorporating the most current regulations.

The rest of the paper is designed as follows: Section 2 presents the literature review and hypothesis development; Section 3 deals with the research methodology; Section 4 presents the results and discussion; Section 5 concludes the paper.

2. Literature Review and Hypotheses Development

ACs are responsible for the oversight and quality of the financial reporting process. It is a primary operating committee of the company's Board of Directors (BOD), which ensures that the financial reports of these corporations are accurate (Buchalter and Yokomoto, 2003). Expectations from ACs skyrocketed in the early

2000s, as many corporate scandals like Enron and WorldCom were divulged, and the Sarbanes Oxley Act (SOX) emerged in 2002 (Beasley et al., 2009). The SOX Act (2002) defines AC as “(A) a committee (or equivalent body) established by and amongst the Board of Directors of an issuer to oversee the accounting and financial reporting processes of the issuer and audits of the financial statements of the issuer; and (B) if no such committee exists with respect to an issuer, the entire Board of Directors of the issuer”.

The history of AC dates back to 1939 when the New York Stock Exchange endorsed the concept of AC, and the recommendations and regulations regarding its roles and characteristics started flowing in an evolutionary process. This change in the characteristics of AC was effectuated to improve its effectiveness and regain investors’ trust and confidence in the corporation. Accordingly, it is expected that a company with an effective AC and investors’ confidence will perform better than its counterparts. In this paper, we identified 11 AC characteristics that are expected to influence the effectiveness of AC and, in turn, the overall FP. The characteristics and expected influence on FP are discussed below to form the premise for formulating our hypotheses.

2.1. Non-executive AC Directors

A non-executive director (NED) is not an employee of the company and is not involved in the company’s day-to-day operations. They monitor the activities of the executive directors and the performance of various sub-committees (Mura, 2007) and control the opportunistic and favouritism attitude of the directors (Khan et al., 2021). NEDs bring an independent view to the decision-making process while mentoring and supporting the executive directors.

There are no stringent regulations and legal requirements for the appointment of NEDs in AC. Therefore, under the stewardship theory, it is assumed that the companies will appoint well-qualified, capable, and experienced NEDs who will act in the best interest of the stakeholders. Further, a NED can be a nominee director appointed by organizations who vest interest in the company such as financial institutions or investors. It is more likely that NEDs will perform their duty to oversee and monitor executive management effectively. In both cases, the inclusion of NEDs is likely to improve AC’s effectiveness, leading to a positive effect on FP.

Despite our extensive search in the extant literature, we could not find any earlier research to establish the empirical relationship between NEDs in AC and FP. Therefore, in the light of the aforementioned theoretical argument, we hypothesize that:

H1: AC comprising non-executive directors positively influences FP.

2.2. Independent AC Directors

An independent AC member is likely to execute their responsibility by remaining outside the dominance of the executive managers. Hence, the AC with such member(s) can take an independent view of the financial reporting process, leading to higher audit quality (Kallamu and Saat, 2015). An AC with an independent director is free from any undue influence and remains unbiased; therefore, it reduces the agency problem between the executives and the shareholders (Alqatamin, 2018). An independent AC director improves the quality of auditing and overseeing the executive management, which implies a better monitoring function of the board and an improved financial reporting and disclosures (Farooque et al., 2020). This increases the company's legitimacy and market value, which, in turn, increases FP.

Earlier empirical studies on the relationship between AC independence and FP have reported inconclusive results. While some researchers report a positive relationship (Alqatamin, 2018; Dakhilallh et al., 2020; Hamdan et al., 2013), Barka and Legendre (2017) found a negative relationship. In the Indian context, Bansal and Sharma (2016) find that independent AC does not influence ROA, while it positively influences ROE and negatively influences Tobin's Q.

Based on the above theoretical discussion and empirical outcomes of the earlier research, we hypothesize that:

H2: AC independence positively influences FP.

2.3. The AC Member's Expertise

Expert AC members are better equipped to understand the auditor's judgment and communicate effectively with the internal and external auditors (Abbott et al., 2003; DeZoort et al., 2002). When skilled in accounting and finance or having professional sophistication in financial management, an AC member exhibits a higher capability to detect and prevent financial misstatements (Raghunandan et al., 2001). Not only will expert AC members be in a better position to understand the technical aspects of financial reporting and auditing, but they can also serve better in the event of disputes between external auditors and managers (Hsu et al., 2019). Further, an expert AC member improves the quality of financial reporting and increases the company's legitimacy. This increases the stakeholders' confidence and the inflow of funds into the company, thus increasing its firm value.

The extant literature provides arguments that the presence of experts in AC reduces internal control problems (Zhang et al., 2007), avoids accounting mistakes, reduces regulators' attention towards the company (Kallamu and Saat, 2015), and improves the quality of financial reporting (Abbott et al., 2004). However, the empirical studies relating to the AC member's expertise and FP show mixed results.

While Hamdan et al. (2013) and Dakhllalh et al. (2020) found a significant positive effect of AC expertise on FP, Bendigeri (2021) found a negative effect between the two variables. Interestingly, Alqatamin (2018) and Kallamu and Saat (2015) found an insignificant effect of AC expertise on FP. Given this inconclusive result, we hypothesize in the light of the aforementioned theoretical arguments that:

H3: The expertise of AC members is positively related to FP.

2.4. AC Gender Diversity

Adams and Ferreira (2009) argue, based on agency theory, that women's inquisitive nature makes them more effective monitors of managerial actions than men, thereby helping to reduce agency problems. Women, compared to men, exhibit different leadership styles, skills, knowledge, competencies, and possess feminist personality traits such as being helpful, sympathetic, sensitive, tender, nurturing, and expressive. According to the resource-based view, these traits enable companies to better leverage essential resources (Maji and Saha, 2021). Recognizing the benefits of these psychological traits and feminist management styles, countries like Germany, Norway, Spain, France, Iceland, Italy, Belgium, Finland, and Kenya have recently implemented legislative quotas requiring that 30 to 40 percent of board of directors (BOD) positions be held by women (Brahma et al., 2020).

Over the past decade, researchers have increasingly focused on the impact of female board members on FP. Empirical evidence, with a few exceptions, generally shows a positive relationship between gender diversity and firm performance. Researchers like Brahma et al. (2020), Duppati et al. (2020), Julizaerma and Sori (2012), and Liu et al. (2014) have found that gender diversity on boards significantly enhances firm financial performance. However, Adams and Ferreira (2009) and Matsa and Miller (2013) offer a contrasting view, suggesting that mandatory gender diversity may lead to over-monitoring in well-governed firms or the appointment of inexperienced female board members, resulting in a negative impact on performance.

Empirical studies specifically examining gender diversity in audit committees (AC) are rare. Our extensive search identified only two studies (Alqatamin, 2018; Chijoke-Mgbame et al., 2020), both of which found that gender-diverse ACs have a positive effect on financial performance. Accordingly, we hypothesize that:

H4: Gender diversity in AC positively influences FP.

2.5. AC Charter

An AC charter informs its stakeholders about the roles and responsibilities of the AC and provides authority and direction to AC directors (Böhm et al., 2016). The Blue Ribbon Committee (BRC) (1999) recommends that every listed firm adopt a formal written charter approved by the BOD that specifies AC's

responsibilities. According to the US Securities and Exchange Commission (SEC, 1999), the disclosure of the AC charter will strengthen investors' confidence, as the shareholders can assess the roles and responsibilities of the AC. This will bring in role clarity, enhance role consciousness and role commitment, and consequently improve the effectiveness of the AC. According to Ika and Ghazali (2012), AC responsibilities should be registered in an AC charter, guiding the committee and acting as its power source. All these will culminate in boosting stakeholders' confidence and, in turn, improving FP.

Despite the theoretical linkage between AC effectiveness and FP and the recommendation of regulatory bodies, the variable AC charter has slipped the empirical researcher's attention, who thus omitted the analysis of its impact on FP. An earlier study that considered AC charter used it in an AC index where the impact of AC charter is not determined independently (Al-ahdal et al., 2020). Hence, based on the above theoretical linkages, we hypothesize that:

H5: AC charter or its proxy statements positively influence FP.

2.6. AC Size

The size of AC is a crucial indicator associated with its effectiveness. A larger AC typically has more resources and authority, enabling it to fulfil its responsibilities more effectively (Mangena and Pike, 2005). The diverse knowledge and expertise of a large-sized AC help carry out more reliable and efficient management monitoring (Hamdan et al., 2013). Since all AC members are also directors of the board, a larger AC implies greater representation on the Board of Directors (BOD), which can increase the likelihood that the board will adopt the AC's performance-enhancing recommendations. Further, the division of labour or the expertise of a larger AC brings a specialized focus on its different tasks. However, a larger AC may have a detrimental effect on its effectiveness due to diffusion of responsibility and process loss (Bédard and Gendron, 2010), which might reduce FP.

The empirical studies that examined the relationship between AC size and FP show a mixed result. While Alqatamin (2018), Dakhilallh et al. (2020), and Hamdan et al. (2013) found a significant positive effect of AC size, Al Farooque et al. (2020), Wibawaningsih and Surbakti (2020), and Zhou et al. (2018) found no significant effect of AC size on FP. Based on the mixed theoretical arguments and empirical evidence, we claim a positive effect of AC size on FP.

H6: Larger AC size positively impacts FP.

2.7. Multiple Directorships by AC

The resource-dependency theory posits that directors holding multiple directorships are instrumental in bringing strategic knowledge and other intellectual

resources. According to Kiel and Nicholson (2006), multiple directorships can add value to the firm in three ways: firstly, by acting as a collaborative mechanism to extract resources or support from the external stakeholders vital to corporate performance (Zahra and Pearce, 1989); secondly, by acting as a channel of communication for information to and from the external environment; and, thirdly, by enhancing the organizational legitimacy (Zahra and Pearce, 1989). E.g. a director with multiple directorships may inform a cheaper loan source due to his earlier network or introduce a value-adding governance policy in a replicative mode. On the other hand, in line with the busyness hypothesis (Ferris et al., 2003), such members reduce AC efficiency due to several counter-productive factors that include the possibility of distraction, overloading of information, over-commitments, tendency to undermine management counsels, and over-workload causing paucity of time to carry out duties.

The extant literature on multiple directorships shows contradicting results based on resource dependency theory and the busyness hypothesis. Sarkar and Sarkar (2009) studied 500 companies listed on the Bombay Stock Exchange (BSE) and found a positive impact of multiple directorships on FP. Contrary to the above, a study by Jackling and Johl (2009) on BSE-listed companies and Limbasiya and Shukla (2019) on the Nifty Index found a negative impact of multiple directorships on FP. Further, a study by Saleh et al. (2020) on the Palestine Security Exchange (PSE) finds that multiple directorships of AC do not significantly influence FP. Based on the above, we hypothesize the following:

H7: Multiple directorships of AC members do not influence FP.

2.8. AC Meeting Frequency

The frequency of AC meetings indicates the members' degree of rigour, meticulous involvement, and diligence in discharging their roles and responsibilities. The high frequency of AC meetings widens the scope and opportunities of the members to prepare, ask questions, and pursue answers when dealing with management, internal auditors, external auditors, and other relevant constituents (DeZoort et al., 2002). All else remaining equal, ACs that meet frequently are more likely to achieve their goals on time (Buallay, 2018), as this increases the reliability of the process of financial accounting, which leads to better performance (Abbott et al., 2004). BRC (1999) recommends that the ACs meet more frequently for better communication of the AC members with the external and internal auditors. A frequently meeting AC improves the quality of financial statements (Beasley et al., 2009), enhances the monitoring process (Jackling and Johl, 2009), and motivates the company's managers to perform better – all these culminate in an improvement in FP.

The empirical studies found in the extant literature on AC meetings provide mixed results. Al Farooque et al. (2020) found a positive relationship between AC

meeting frequency and FP, which is in line with the above theoretical argument. However, Alqatamin (2018) found no significant effect of meeting frequency on FP. Contrary to the above, Rahman et al. (2019) found a negative impact of AC meeting frequency on FP. This adverse effect could be because, along with the marginal costs incurred for more meetings, the directors meet more frequently just to comply with the regulatory requirements. Based on the above contradicting empirical outcomes, we hypothesize no relationship between them.

H8: The frequency of AC meetings remains independent of FP.

2.9. Attendance of AC Meetings and Board Meetings by AC Directors

AC directors are expected to attend AC meetings to monitor and supervise the firm or make strategic decisions. If a director fails to attend the meetings, it would mean that he/she is unwilling or unable to fulfil their duties (H. I. Chou et al., 2013). Attendance of directors in meetings shows their individual interest, involvement, and commitment towards the firm (Min and Chizema, 2018). The frequency of meetings is valueless and, at times, defeats the purpose if directors do not attend them. Therefore, the degree of diligence of an AC depends on the attendance of the members. Further, the representation of the AC members in the BOD enhances the probability of getting their recommendations accepted.

The empirical studies on this characteristic are very scarce. While examining the empirical validity of the above theoretical argument, Chou and Buchdadi (2017) and Salim et al. (2016) find a positive association between attendance of AC meetings and FP. When we find no empirical research on the representation of AC members on board meetings and its effect on FP, based on our arguments, the following hypotheses are formulated:

H9: Attendance of AC meetings positively influences FP.

H10: Attendance of AC directors in board meetings is positively related to FP.

2.10. AC Director's Shareholding

In line with agency theory, directors having considerable shareholdings are likely to be more motivated to monitor the management and the reporting process (Shivdasani, 1993). This improves the monitoring and oversight responsibility of the AC, which in turn improves FP. According to Mangena and Pike (2005), shareholding by AC directors could affect their incentive to monitor the financial reporting process. Further, based on their empirical research outcomes, Lin et al. (2014) assert that the director's shareholding is linked with increased board attendance, which has an instrumental effect on a firm's accounting performance.

On the contrary, the director's shareholding compromises their independence and negatively affects FP. Carcello and Neal (2003) argue that AC directors with

higher shareholding may join hands with management to protect their investment. This affects the quality of the monitoring and oversight process. A study by Pant and Pattanayak (2007) finds an inverted U-shaped relationship between shareholding and FP. When the ownership is low, it pushes up FP, but a further increase in shareholding (when substantial) negatively affects the performance and ends up pulling down the FP curve. Based on the above argument, the following hypothesis is formulated:

H11: The AC director's shareholding negatively affects FP.

2.11. AC Effectiveness Index

AC effectiveness is an abstract construct. To concretize the construct, DeZoort et al. (2002) assert, "An effective AC has qualified members with the authority and resources to protect stakeholder interests by ensuring reliable financial reporting, internal controls, and risk management through its diligent oversight efforts." The extant literature on AC affirms that AC effectiveness is primarily a function of its characteristics (Akhtaruddin and Haron, 2010; Bédard and Gendron, 2010; Dhaliwal et al., 2010; Li et al., 2012; Singhania and Panda, 2022, 2024). We have developed an AC effectiveness index by considering all AC characteristics that are likely to have a positive relationship with FP. Hence, we hypothesize that:

H12: AC effectiveness index is positively related to FP.

3. Research Methodology

3.1. Sample Selection

For our study sample, we chose six industries: IT, drugs and pharmaceuticals, chemical, consumer goods, food and agro-based, and metal and metal product industry. The first three industries were chosen because of their high growth and performance and the last three because they are the traditional industries where the highest population is employed. Under the National Stock Exchange of India (NSE), 534 companies belong to these six industries, and it constitutes our population of the study with a total market capitalization of 387,437.00876 billion rupees (5,142.856 billion USD). Our sampling frame is the top 500 NSE-listed companies based on market capitalization as on 31 March 2020. In this context, there are 24 IT companies, 32 drugs and pharmaceutical companies, 28 chemical companies, 23 consumer goods companies, 25 food and agro-based companies, and 19 metal and metal product companies. Out of these 151 companies, 18 were omitted due to a lack of required information. Therefore, our final sample consists of 133 companies for five years from 2016 to 2020, constituting 665 observations. The

total market capitalization of these 133 companies is 366,667.5791 billion rupees (4,867.1617 billion USD), representing around 94.63% of the total population. The data were collected from the Capitaline database, the Prowess database (CMIE), annual reports, and websites. Stata 16 is used to analyse the models.

3.2. Variables and Measurement

3.2.1. Dependent Variables

The dependent variable for our study is firm performance (FP). We have measured FP by two alternative parameters, viz. Return on Assets (ROA) and Market Capitalization [natural log of market capitalization (LMCap)]. ROA is a profitability ratio that measures how well a company generates profits from its total assets. It is the most accepted accounting-based measure of FP (Alqatamin, 2018; Kallamu and Saat, 2015). On the other hand, Market Capitalization is the total market value of all the company's outstanding shares. It refers to the company's value as determined by the stock market. Market Capitalization has been used in its natural logarithm form in previous studies as a market-based measure of FP (Bhat et al., 2018; Madaleno and Vieira, 2020).

3.2.2. Independent Variables

Eleven AC characteristics discussed above are the independent variables of the study. These characteristics are measured using a nominal scale and are presented in a tabular form along with their abbreviations and measurements in *Table 1*.

Table 1. Measures of independent variables

Variables	Abbreviation	Measurement
AC Independence	AC_ind	If 2/3 rd of the members are independent, then 1, otherwise 0.
AC Expertise	AC_expert	A score of 1 is assigned if at least one member is an accounting expert, otherwise 0.
AC Non-executive Members	AC_ned	If all the AC directors are non-executive members, then 1, otherwise 0.
AC Charter	AC_charter	If the company discloses AC charter or its proxy statements explaining AC roles and responsibilities in detail, then 1, otherwise 0.
AC Size	AC_size	If the number of AC members is more than 3, then 1, otherwise 0.
Multiple Directorship	AC_multiDir	If the average multiple directorships of AC members are between 0 to 4, then 0, otherwise 1.

Variables	Abbreviation	Measurement
Gender Diversity	AC_gender	If AC has at least one female director, then 1, otherwise 0.
AC Meetings	AC_meet	If AC meets less than five times a year, then 0, otherwise 1.
AC Meeting Attendance	AC_M_attend	If the attendance in AC meetings is 90% or more, then 1, otherwise 0
Board Meeting Attendance by AC	AC_BM_attend	If AC directors' attendance in board meetings is 90% or more, then 1, otherwise 0.
Shareholding	AC_share	If AC shareholding is less than 2%, then 0, otherwise 1.
AC Effectiveness Index	ACEI	Sum of all the scores obtained from the eleven AC characteristics.

Source: author's own compilation

3.2.3. Control Variables

The control variables for our study are the BOD index (measured as the sum of the scores of board size, the ratio of independent directors, and the frequency of board meetings) and firm-specific characteristics such as firm size, asset turnover, and leverage. The variables, along with their abbreviations and measurements, are presented in *Table 2*.

Table 2. *Measures of control variables*

Variables	Abbreviation	Measurement
Board Size	B_size	If B_size $\leq$ 5, Score = 0.50; if B_size = 6 or 7, Score = 0.65, if B_size = 8 or 9, Score = 0.80, if B_size = 10 or 11, Score = 1.00, if B_size = 12 or 13, Score = 0.95, if B_size $\geq$ 14, Score = 0.90 (Arora and Bodhanwala, 2018; Mishra et al., 2021; Varshney et al., 2015).
The Ratio of Independent Board Directors	B_ind	It is calculated by dividing the total number of outside directors by the total board size (Arora and Bodhanwala, 2018; Mishra et al., 2021; Varshney et al., 2015).
Frequency of Board Meetings	B_meet	A dummy variable equals "1" if a company has held more than four meetings in a financial year and "0" otherwise (Arora and Bodhanwala, 2018; Varshney et al., 2015).
BOD Index	BODindx	B_size + B_ind + B_meet
Firm Size	Firmsize	Natural logarithm of total assets.
Asset Turnover	Asset_tnvr	The ratio of net sales by total assets.
Leverage	Leverage	Ratio to total debt to equity.

Source: author's own compilation

3.3. Research Models

We performed the panel-corrected standard error (PCSE) regression technique to analyse the relationships proposed in the research hypotheses. The four models are as follows.

$$\text{Model 1: ROA} = \beta_0 + \beta_1 \text{AC_ned} + \beta_2 \text{AC_ind} + \beta_3 \text{AC_expert} + \beta_4 \text{AC_gender} + \beta_5 \text{AC_charter} + \beta_6 \text{AC_size} + \beta_7 \text{AC_multiDir} + \beta_8 \text{AC_meet} + \beta_9 \text{AC_M_attend} + \beta_{10} \text{AC_BM_attend} + \beta_{11} \text{AC_share} + \beta_{12} \text{BODindx} + \beta_{13} \text{Firmsize} + \beta_{14} \text{Asset_tnvr} + \beta_{15} \text{Leverage} + \varepsilon_i$$

$$\text{Model 2: ROA} = \beta_0 + \beta_1 \text{ACEI} + \beta_2 \text{BODindx} + \beta_3 \text{Firmsize} + \beta_4 \text{Asset_tnvr} + \beta_5 \text{Leverage} + \varepsilon_i$$

$$\text{Model 3: LMCap} = \beta_0 + \beta_1 \text{AC_ned} + \beta_2 \text{AC_ind} + \beta_3 \text{AC_expert} + \beta_4 \text{AC_gender} + \beta_5 \text{AC_charter} + \beta_6 \text{AC_size} + \beta_7 \text{AC_multiDir} + \beta_8 \text{AC_meet} + \beta_9 \text{AC_M_attend} + \beta_{10} \text{AC_BM_attend} + \beta_{11} \text{AC_share} + \beta_{12} \text{BODindx} + \beta_{13} \text{Firmsize} + \beta_{14} \text{Asset_tnvr} + \beta_{15} \text{Leverage} + \varepsilon_i$$

$$\text{Model 4: LMCap} = \beta_0 + \beta_1 \text{ACEI} + \beta_2 \text{BODindx} + \beta_3 \text{Firmsize} + \beta_4 \text{Asset_tnvr} + \beta_5 \text{Leverage} + \varepsilon_i$$

4. Results and Discussion

Table 3 reports the descriptive statistics of our variables for a sample of 665 firm-year observations. The mean value of ROA is 0.212, with a minimum of -0.964 and a maximum of 1.22. This indicates that the profitability of Indian firms is very low. The mean value and standard deviation (std. dev.) of LMCap are 3.952 and 0.597 respectively, with a minimum of 2.552 and a maximum of 5.875. This indicates a wide variation in the market capitalization of the companies, which is following the firm size of the sample companies with a mean of 3.483 and std. dev. of 0.612. The mean and std. dev. of Asset Turnover ratio is 1.342 and .999 respectively, with a minimum of 0.032 and a maximum of 7.943. This shows that while some companies are very efficient with their assets in generating revenue, others are very inefficient, and there is a wide gap in the efficiency of the companies. The mean and std. dev. of Leverage is 0.398 and 0.822 respectively, with a minimum of 0 and a maximum of 11.43, indicating that while some companies prefer no leverage, others have very high leverage. The mean score of ACEI is 6.538, with a minimum of 2 and a maximum of 10. The std. dev. of ACEI is 1.754, indicating considerable variations in the effectiveness of the AC.

Table 3. *Descriptive statistics (665 observations)*

Variable	Mean	Std. Dev.	Min.	Max.
ROA	0.21	0.17	-0.96	1.22
LMCap	3.95	0.60	2.55	5.87
AC_ned	0.67	0.47	0	1
AC_ind	0.79	0.41	0	1
AC_expert	0.85	0.36	0	1
AC_gender	0.45	0.50	0	1
AC_charter	0.73	0.45	0	1
AC_size	0.70	0.46	0	1
AC_multiDir	0.38	0.49	0	1
AC_meet	0.53	0.50	0	1
AC_M_attend	0.67	0.47	0	1
AC_BM_attend	0.62	0.48	0	1
AC_share	0.15	0.36	0	1
BODindx	2.17	0.45	0.9	2.8
Firmsize	3.48	0.61	1.98	5.11
Asset_tnvr	1.34	0.99	0.032	7.94
Leverage	0.40	0.82	0	11.43
ACEI	6.54	1.75	2	10

Source: Singhania and Panda (2022)

Before running the regression, we tested for multicollinearity, heteroskedasticity, autocorrelation, and cross-sectional dependence. The variance inflation factor (VIF) shows no issue for multicollinearity in our samples. However, the Breusch–Pagan (1979) and white (1980) tests show that all four models suffer from heteroskedasticity. Further, the Durbin and Watson (1950) and Wooldridge (2002) tests confirm first-order autocorrelation in all the models. The Pesaran (2021) test reveals that, while there is no cross-sectional dependence for model 1 and model 2, the test confirms the presence of cross-sectional dependence in model 3 and model 4.

The presence of heteroskedasticity, autocorrelation, and cross-sectional dependence makes econometric analysis difficult. Beck and Katz (1995) suggested using the PCSE regression model for such cases. Chen et al. (2005) found that PCSE is an efficient technique for testing hypotheses. The extant literature on FP has extensively used the PCSE model in the presence of heteroskedasticity, autocorrelation, and cross-sectional dependence (Canarella and Gasparyan, 2008; Islam et al., 2021; Minh Ha et al., 2022; Nguyen and Nguyen, 2020; H. U. Rahman et al., 2021; Singhania and Panda, 2023).

Table 4 presents the results of regression analysis for models 1 and 3. The result shows that NEDs in AC positively influence both ROA ($z = 2.92$, $p < 0.01$) and LMCap ($z = 5.74$, $p < 0.01$) at a 1% significance level. This supports our hypothesis *H1*. AC independence is not associated with ROA; as it negatively affects market capitalization ($z = -3.69$, $p < 0.01$), we reject our hypothesis *H2*. This may be because the market perceives that the independent director has limited firm-specific knowledge compared to an executive director. Further, the BOD may appoint unworthy or less proficient directors with a ticking-the-box attitude to fulfil the regulatory requirement of two-thirds independent directors. This result is consistent with the previous studies (Bansal and Sharma, 2016; Farooque et al., 2020; Zhou et al., 2018), which found no relationship of AC independence with ROA and a negative relationship with market capitalization.

Table 4. PCSE regression for model 1 and model 3

Variables	ROA		Market Capitalization	
	Coef.	P > z	Coef.	P > z
AC_ned	.020	0.003***	.092	0.000***
AC_ind	.001	0.863	-.067	0.000***
AC_expert	.003	0.829	.056	0.001***
AC_gender	.022	0.002***	.021	0.156
AC_charter	.047	0.000***	.221	0.000***
AC_size	.036	0.000***	.086	0.002***
AC_multiDir	.015	0.079*	.093	0.000***
AC_meet	-.010	0.389	-.021	0.357
AC_M_attend	.020	0.010***	.048	0.097*
AC_BM_attend	.010	0.297	.039	0.180
AC_share	-.019	0.122	.004	0.886
BODindx	.003	0.706	.011	0.730
Firmsize	-.046	0.000***	.751	0.000***
Asset_tnvr	.067	0.000***	.166	0.000***
Leverage	-.041	0.034**	-.211	0.000***
_cons	.184	0.000***	.798	0.000***
R-squared		0.310		0.672
Wald chi2		971.75		6727.98

Source: author's own computation

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

The expertise of AC members is insignificant to ROA and is consistent with Alqatamin (2018) and Kallamu and Saat (2015). However, it positively influences the company's market capitalization ($z = 3.20$, $p < 0.01$) at a 1% significance level.

Hence, we reject hypothesis *H3* with ROA as a measure of FP and accept the hypothesis with LMCAp as a measure of FP. The result is in tune with Dakhllalh et al. (2020), who found a positive association between AC expertise and Tobin's Q. This is because, although the companies may appoint experts in AC just to meet the regulatory requirements, without giving proper authority to the expert, the investors perceive that the expert member will improve AC's technical knowledge and monitoring ability.

Gender diversity in AC positively influences ROA ($z = 3.07$, $p < 0.01$) at a 1% significance level but is insignificant to LMCAp. Hence, we fail to reject our hypothesis *H4* while considering ROA, but we reject the said hypothesis while considering LMCAp as a measure of FP. This result is consistent with Alqatamin (2018) and Chijoke-Mgbame et al. (2020), who found a positive association between gender diversity and ROA. This indicates that female members in AC are related to higher FP compared to ACs with no female members. However, the insignificant effect of gender diversity on market capitalization signifies that the market perceives no difference in performance due to the gender of AC's members.

The presence of AC charter or its proxy statement is positively associated with both ROA ($z = 4.03$, $p < 0.01$) and LMCAp ($z = 9.95$, $p < 0.01$) at a 1% level of significance. Hence, we fail to reject our hypothesis *H5*. The size of AC has a positive relationship with both ROA ($z = 5.45$, $p < 0.01$) and LMCAp ($z = 3.08$, $p < 0.01$) at a 1% level of significance. Hence, we fail to reject our hypothesis *H6*. This result is consistent with the previous works of Alqatamin (2018), Dakhllalh et al. (2020), and Hamdan et al. (2013).

The results further manifest that multiple directorships by AC members are positively associated with ROA ($z = 1.76$, $p < 0.10$) at a 10% and with LMCAp ($z = 3.77$, $p < 0.01$) at a 1% significance level respectively. So, we accept our hypothesis *H7*. This result aligns with the resource dependency theory and is supported by Sarkar and Sarkar (2009), but it contradicts Jackling and Johl (2009).

The results further display that the frequency of AC meetings has a negative but insignificant effect on both ROA and LMCAp. Hence, we fail to reject our hypothesis *H8*. This result is congruent with Alqatamin (2018), who failed to find any relationship between the frequency of AC meetings and FP.

Attendance in AC meetings is seen to have a positive effect on both ROA ($z = 2.57$, $p \leq 0.01$) at 1% and LMCAp ($z = 1.66$, $p \leq 0.10$) at 10% significance level respectively. Hence, we accept our hypothesis *H9*. This result is consistent with the previous study of Chou and Buchdadi (2017) and Salim et al. (2016). On the other hand, attendance of board meetings by AC directors has no significant effect on FP, due to which we reject our hypothesis *H10*. Further, shareholding by AC is found to have no significant effect on both measures of FP. Hence, we reject our hypothesis *H11*.

Table 5. PCSE regression for model 2 and model 4

Variables	ROA		Market Capitalization	
	Coef.	P> z	Coef.	P> z
ACEI	.018	0.000***	.056	0.000***
BODindx	-.006	0.545	.004	0.860
Firmsize	-.045	0.000***	.761	0.000***
Asset_tnvr	.067	0.000***	.164	0.000***
Leverage	-.044	0.027**	-.216	0.000***
_cons	.193	0.000***	.788	0.000***
R-squared		0.292		0.647
Wald chi2		453.42		3688.20

Source: author's own computation

Notes: *** p < 0.01, ** p < 0.05, * p < 0.1.

Table 5 presents the PCSE regression results for the AC effectiveness index, which is a sum of all the characteristics of AC. The result indicates that ACEI is highly significant to both ROA ($z = 6.02$, $p \leq 0.01$) and LMCap ($z = 5.47$, $p \leq 0.01$) at a 1% level of significance. Hence, we accept our hypothesis *H12*. It signifies that the characteristics of AC enhance its effectiveness, which in turn improves FP. This result is congruent with the previous studies of Al-ahdal et al. (2020) and Gupta and Mahakud (2021), who analysed the effect of the AC index on FP and found a positive association.

Among control variables, the BOD index has no significant effect on FP. Among firm-specific characteristics, Firm Size is negatively significant to ROA while positively affecting the LMCap. Asset Turnover is positively associated with both ROA and LMCap, and Leverage is negatively associated with both ROA and LMCap at a 1% level of significance.

5. Conclusions

The extant literature on FP focuses on Corporate Governance (CG) and BODs, where the individual effects of the characteristics of a vital sub-committee of BOD, such as the AC, is overlooked. Though a few researchers have established a relationship between AC attributes and FP, they have either taken a few characteristics or considered them in an index, due to which the individual effects of the attributes remain concealed. The methodological soundness in most of the earlier studies, barring a few, was found low owing to either small sample size or period coverage. In order to address the shortcomings, we have considered 11 AC characteristics to analyse their individual and collective effect on accounting and market-based measures of FP.

The findings of this research reveal that six AC characteristics, i.e. AC gender, AC charter, AC size, multiple directorships of AC members, attendance of AC meetings, and presence of NEDs, significantly influence the accounting-based measure (ROA) of FP, while seven AC characteristics, i.e. AC independence, AC expertise, AC charter, AC size, multiple directorships of AC members, attendance of AC meetings, and presence of NEDs, significantly influence the market-based measure of FP. The aggregative effect of 11 AC characteristics captured through ACEI has a significant positive effect on both measures of FP.

This study contributes to the emerging literature on AC in multiple ways. Firstly, it comprehensively explains AC effectiveness by considering 11 AC characteristics and examining their effect on FP individually and collectively, thus providing a holistic approach to the relationship. Secondly, it considers three new AC characteristics: the constitution of AC with non-executive directors, the presence of the AC charter, and the representation of AC members in board meetings. While we found that the non-executive directorship of AC and the presence of AC charter significantly improve FP, these characteristics remained ignored in previous research. Thirdly, in the Indian context, SEBI's LODR (2015) has made crucial changes in the regulations, which have a consequential impact on AC effectiveness, making previous studies obsolete. Despite our extensive search, we could not find any literature considering the effect of individual AC characteristics on FP after the above-mentioned regulatory changes. Hence, our study is the first to consider the individual and aggregate effect of AC characteristics on FP considering up-to-date regulations.

This paper has several managerial and policy implications. While offering a comprehensive conceptual framework to understand AC characteristics influencing its effectiveness and, in turn, FP, the study reveals empirical results beneficial to regulators, management (BOD), and investors. The regulators can benefit from our results by revisiting AC regulations to mandate the requirement of AC charter and non-executive directors of AC, implementing quotas for gender-diverse AC, and reducing the requirement of AC independence. It will assist the managers in taking appropriate measures in increasing AC size and motivating AC directors to attend more meetings. Further, investors can gain from our findings to assess AC effectiveness in value-adding attributes and make investment decisions accordingly.

This study has some limitations. Firstly, the study period is limited from 2015 to the year 2020. This is because of the regulatory changes in AC characteristics by SEBI's LODR (2015) and market instability due to the COVID-19 pandemic. Secondly, the generalizability of the findings is limited to Indian companies. Thirdly, since the study is based in India, where corporate culture is relatively uniform and ownership structures are predominantly family-owned, these characteristics are not controlled. Therefore, future research may consider a more extensive study period and consider the pre-COVID and post-COVID comparison of

the effectiveness of the AC. Further, a cross-country comparison of the influence of AC characteristics on FP can be carried out in order to understand this relationship in different CG settings, cultures, and ownership structures.

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Assessing the Efficiency of Academic Departments: An Application of Data Envelopment Analysis and Tobit Analysis

Rekha HANDA,¹ Mandeep KAUR²

¹ University Business School, Guru Nanak Dev University, Amritsar (India)

e-mail: drrekha.ubs@gndu.ac.in

² University School of Financial Studies, Guru Nanak Dev University, Amritsar (India)

e-mail: mandip87kaur@gmail.com

Abstract. The systematic assessment of academic institutions is necessary in order to assure the achievement of their set objectives by proper utilization of the limited resources. Thus, the current paper focused on examining the efficiency of academic departments. The study has been conducted for a period of ten years. Efficiency scores of the departments have been examined through the application of CCR (Charnes, Cooper, and Rhodes) and BCC (Bankar, Charnes, and Cooper) model of data envelopment analysis. In addition to efficiency evaluation, the factors affecting efficiency have also been analysed by applying Tobit regression analysis, which helps in improving the effectiveness of departments by focusing on significant variables impacting the efficiency. It provides a guide for policy and managerial decision making.

Keywords: efficiency, academic departments, data envelopment analysis, Tobit

JEL Classification: C67, C80

1. Introduction

The present times are characterized by immense change and complexity in the structure of the higher education system due to widespread knowledge. Their evaluation can be useful in managing these instabilities. Universities are the backbone of the higher education system and provide a substantial human resource base for a country's socioeconomic development. To ensure that these universities meet their goals by making the best use of their limited resources, a rigorous evaluation of these institutions is required. When an organization's performance gaps are identified by such an evaluation, the necessary steps can be taken to close

the gaps and achieve the objectives. As a result, establishing a method to assess an organization's performance is crucial to its excellence and advancement (Askari et al., 2019). Furthermore, it is challenging for state university administrations to educate state politicians about how well their schools are performing in achieving their goals. It is the responsibility of university authorities to ensure that the available resources are utilized in such a way that improves the efficiency of the institution (Moreno and Tadepalli, 2002). However, due to the non-profit nature of higher education institutions, it is difficult to evaluate their efficiency. Moreover, these institutions are characterized by multiple input and output variables. In addition to this, there is a lack of price information for the variables in the case of these institutions. Thus, it is challenging to assess the efficiency of these institutions. However, data envelopment analysis is a non-parametric technique used to evaluate the efficiency of higher education institutions, as it does not require any price information related to input and output variables.

Improvements in education and scientific research have allowed India's development to reach a global level (Tyagi et al., 2009). According to the University Grant Commission's (UGC) 2020–21 Annual Report, an increasing number of students pursue Ph.D. degrees. In addition to research activities, student enrolment has also increased in undergraduate, postgraduate, and integrated courses. Thus, the Indian universities serve both the teaching and research motives. In the list of highest graded universities by the National Assessment and Accreditation Council (NAAC), the first name appears as Guru Nanak Dev University, Amritsar, with a score of 3.85 on the scale of 4 as per the rating in 2022. The university was established in 1969. For more than 53 years, the university has been dedicated to advancing research and education. To accomplish the university's goal of advancing education and research, the academic departments have been involved. Examining the academic departments' effectiveness is the goal of the current paper.

The study conducted by Kaur and Bhalla (2021) was also focused on the efficiency of academic departments of Guru Nanak Dev University, Amritsar. However, that study was only focused on the efficiency during one academic year. Moreover, factors of efficiency were not examined in that study. The present study examined the efficiency over a period of ten years. In addition to this, it also examined the various factors affecting the efficiency of academic departments of the university.

No doubt, efficiency studies have been carried out on academic departments and on a variety of universities. Various viewpoints provide a great deal of room for additional research. Nonetheless, a university's total efficiency is a direct result of its departments' effectiveness. Therefore, the efficiency assessment of university departments was the main emphasis of the current study.

The rest of the paper is organized as follows. Section 2 presents a literature review. Section 3 discusses research methodology, including the methods, variables, and datasets employed in the analysis. Section 4 presents the empirical findings, while Section 5 discusses implications and concludes.

2. Review of Literature

There are a number of studies that examined the efficiency and its determinants among the higher education institutions. It has been observed that most of the studies focused on the efficiency of universities (Adamu et al., 2016; Agasisti and Pohl, 2012; Albayatey et al., 2021; Al-tyeb, 2017; Bangi, 2014; Barra et al., 2015; Foltz et al., 2012; Ismail, 2015; Kaur and Bhalla, 2021; Kempkes and Pohl, 2010; McMillan and Datta, 1998; Quiroga-Martínez et al., 2018; Sav, 2013; Selim and Bursalioglu, 2013; Selim and Bursalioglu, 2015; Tran and Villano, 2018; Türkan and Özel, 2017; Wildani et al., 2023; Zhang and Kim, 2018). Moreover, factors affecting departmental efficiency have been examined by Agha et al. (2011), Kounetas et al. (2011), and Sharma and Mehra (2019). Moreover, there are also some studies available that analysed the factors affecting the efficiency of different higher education institutions. These studies include Al-Bagoury (2013), Bangi and Sahay (2014), Bradley et al. (2010), Gromov (2017), Salas-Velasco (2020), Sav (2017), Soummakie and Wegener (2024), Wolszczak-Derlacz (2017), and Wolszczak-Derlacz and Parteka (2011). Thus, most of the efficiency-based studies focused on the factors affecting the efficiency of universities, and there is a dearth of literature relating to the efficiency and its determinants among the academic departments.

The efficiency has been evaluated by applying data envelopment analysis in the case of the higher education sector. After the evaluation of efficiency scores, factors affecting efficiency have been examined by using different techniques. Most of the studies employed the Tobit regression analysis to examine the factors affecting efficiency (Adamu et al., 2016; Agasisti and Pohl, 2012; Al-Bagoury, 2013; Al-tyeb, 2017; Bangi, 2014; Bangi and Sahay, 2014; Gromov, 2017; Ismail, 2015; Kempkes and Pohl, 2010; Kounetas, et al., 2011; McMillan and Datta, 1998; Sav, 2017, 2013; Selim and Bursalioglu, 2013; Selim and Bursalioglu, 2015; Sharma and Mehra, 2019; Türkan and Özel, 2017; Zhang and Kim, 2018). Besides this, Quiroga-Martínez et al. (2018) employed fixed-effect regression model to examine the factors affecting efficiency. Ordinary least square has been employed by Bradley et al. (2010). Another technique, i.e. multiple linear regression, has been used by Agha et al. (2011). Truncated regression has also been used to analyse the factors affecting efficiency (Barra et al., 2015; Wolszczak-Derlacz and Parteka, 2011). Foltz et al. (2012) examined the factors affecting efficiency through the application

of probit regression and Tran and Villano (2018) examined the factors affecting efficiency through the employment of fractional regression. However, it has been observed that Tobit regression analysis has been used as statistical technique in most of the studies. This is due to the censored nature of the dependent variable, i.e. efficiency scores.

The findings indicated that mean efficiency score evaluated by different studies was more than 50%. The studies, including Bangi (2014) (83.67%), Halkos et al. (2010) (84.7%), Sav (2013) (86.7% to 87.9%), and Tyagi et al. (2009) (86.8%), have recorded mean efficiency scores between 80% and 90%. Other studies experienced efficiency scores less than 80%, but none of the studies recorded a mean technical efficiency score less than 50%.

The studies related to efficiency have been conducted in various universities (Adamu et al., 2016; Agasisti and Pohl, 2012; Bangi, 2014; Barra et al., 2015; McMillan and Datta, 1998) and academic departments (Askari et al., 2019; Aziz et al., 2013; Halkos et al., 2010; Kounetas et al., 2011; Moreno and Tadeipalli, 2002). Different perspectives leave a lot of scope for further exploration. However, efficient departments within a university lead to the overall efficiency of the university. Thus, the current study focused on the efficiency evaluation of specific departments within a university.

Due to a dearth of literature relating to the efficiency of academic departments and the factors affecting efficiency, the current study focused on examining the efficiency of academic departments of a state university. Moreover, as the literature reveals, most of the studies evaluating efficiency have applied data envelopment analysis and Tobit regression analysis. The detailed explanation of these techniques is presented in the next section.

3. Research Methodology

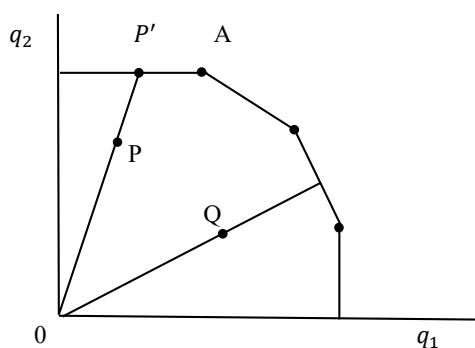
With the object of measuring the efficiency of academic departments, data envelopment analysis has been applied. In the first step, efficiency scores for the university departments have been derived, and in the second step the potential determinants of efficiency of the academic departments have been examined by regressing the efficiency scores against various institutional factors.

Step 1: Estimating the efficiency scores through data envelopment analysis

Data envelopment analysis is a linear-programming-based non-parametric technique to evaluate the relative efficiency of non-profit organizations. The organizations for which the efficiency scores are evaluated through the application of data envelopment analysis are known as decision-making units. DEA (data

envelopment analysis) requires data of input and output variables of decision-making units in order to calculate the efficiency scores. DEA was originated by Farrel in 1957. It was modified by Charnes, Cooper, and Rhodes in 1978 known as the CCR model. It assumes constant returns to scale while calculating efficiency scores. The model was further extended by Bankar, Charnes, and Cooper in 1984 known as the BCC model. This model assumes variable returns to scale while evaluating the efficiency of decision-making units. The main aim of the technique is to develop a frontier for efficient decision-making units and to find out the distance between inefficient units from this frontier. The units that lie on the efficient frontier developed by data envelopment analysis are known as efficient units.

Data envelopment analysis can be input-oriented or output-oriented. Input-oriented approach of data envelopment analysis focuses on the minimum usage of input resources to produce a given level of outputs, whereas under output orientation, DEA aims to produce maximum output with a given level of input. Output-oriented models are appropriate for higher education institutions, as input resources used in these institutions can be fixed, and they cannot influence their inputs, at least in the short run (Barra and Zotti, 2016). However, they can improve their outputs with given inputs. So, in the current case, an output-oriented model is more appropriate (Tyagi et al., 2009). Thus, output-oriented CCR and BCC models of data envelopment analysis have been employed to achieve the objectives of the present study.



Source: Coelli et al., 2005

Figure 1. Output-oriented data envelopment analysis

Figure 1 depicts the example of output-oriented data envelopment analysis with two outputs. The curve shows the efficient frontier. The units below the curve indicate inefficient units. For example, in the figure, P and Q indicate the inefficient units as they lie below the efficient frontier. In order to become efficient, these units must lie on an efficient frontier.

An output-oriented CCR model of data envelopment analysis can be represented mathematically as follows:

$$\text{Max } TE_{CRS}^k = \delta_k$$

subject to

$$\sum_{j=1}^n \omega_j y_{ij} \geq \delta y_{ik}$$

$$\sum_{j=1}^n \omega_j x_{rj} \leq x_{rj}$$

$$\omega \geq 0,$$

where δ_k represents the efficiency of k^{th} decision-making unit, ω denotes the weight assigned to the DMU (decision-making unit), and y_{ij} denotes the amount of i^{th} output of j^{th} decision-making unit. Similarly, y_{ik} represents the amount of i^{th} output of k^{th} DMU, x_{rj} indicates the amount of r^{th} input of j^{th} DMU. The BCC model of data envelopment analysis includes one more constraint in the above mathematical formulation. An output-oriented BCC model of data envelopment analysis can be represented mathematically as follows:

$$\text{Max } TE_{VRS}^k = \delta_k$$

subject to

$$\sum_{j=1}^n \omega_j y_{ij} \geq \delta y_{ik}$$

$$\sum_{j=1}^n \omega_j x_{rj} \leq x_{rj}$$

$$\sum_{j=1}^n \omega_j = 1$$

$$\omega \geq 0.$$

3.1. Input/output specification

In the case of higher education institutions, multiple input resources are utilized, which includes financial, human, and physical resources (Kantabutra and Tang, 2006; Selim and Bursalioğlu, 2015). Financial and human resources are the most important input resources in the case of higher education institutions (Watt, 2001). Thus, in order to evaluate the efficiency of the departments, the current study uses two input variables, i.e. academic staff and non-academic staff, representing human resources, and one variable, i.e. expenditure, representing financial resources. On the other hand, the main outputs produced in higher education institutions are teaching and research. The output variables selected in the study are number of students representing teaching output and research publications and research grants representing research outputs. A number of studies also used graduates as output variable such as Aziz et al. (2013), Koksall and Nalcaci (2006), or Sagarra et al. (2016). But this variable ignores the education of those students who have attended the courses but have not graduated (McMillan and Datta, 1998). Therefore, the current study uses student enrolment variable representing teaching output.

Further, the selection of input and output measures for data envelopment analysis is based on a rule of thumb given by Banker et al. (1984), which is:

$$n/3 \geq I + O,$$

where n represents the sample size, I is the number of inputs, and O is the number of outputs. By satisfying the above condition, three input and three output variables have been considered in the present study.

Inputs:

(i) *Academic staff*: It comprises professors, associate professors, and assistant professors. Weights have been assigned to each category of academic staff in order to get the standardized value. The weights have been assigned with same distance between two ranks (Barra et al., 2015; Barra and Zotti, 2013; Halkos et al., 2010; Kao and Hung, 2008).

Academic staff = $1 * \text{professors} + 0.67 * \text{associate professors} + 0.33 * \text{assistant professors}$.

(ii) *Non-academic staff*: The second input variable used in the present study is non-academic staff, which includes superintendent, stenographer, senior assistant, steno typist, clerk, helper, peon, waterman, and attendant.

(iii) *Expenditure*: Another input variable, namely expenditure, represents the salaries and operating expenses of a department.

Outputs:

(i) *Number of students*: Number of students comprises of students enrolled in graduation and post-graduation. Again, weights have been assigned to get standardized value (Halkos et al., 2010 and Tyagi et al., 2009).

Number of students = $1 * \text{postgraduate enrolment} + 0.5 * \text{undergraduate enrolment}$.

(ii) *Research Publications*: It represents the number of publications by a particular department.

(iii) *Research grant*: It constitutes the grant received by departments for different research schemes and grant received by teachers for research projects.

Step 2: Examining the determinants of efficiency through the application of the Tobit model

The efficiency scores evaluated in the first stage can be further used to examine the impact of explanatory variables. The efficiency scores ranged from 0 to 1. This accounts for limited dependent variable. Due to the censored nature of the dependent variable (efficiency scores), the Tobit regression model has been employed. Moreover, studies conducted by a large body of researchers (Adamu et al., 2016; Agasisti and Pohl, 2012; Al-Bagoury, 2013; Bangi, 2014; Bradley et al., 2010; Gromov, 2017; Kempkes and Pohl, 2010; Kounetas et al., 2011; Liu et al., 2012; McMillan and Datta, 1998; Sav, 2013, 2017; Selim and Bursalioğlu, 2013, 2015) also suggest the application of the Tobit regression model in order to examine the factors affecting efficiency scores. The fixed-effect Tobit regression model cannot be applied due to a lack of statistics that allows the fixed effects to be conditioned out of the likelihood (Stata Press Publications, 2021). An unconditional fixed-effect model may be fit with the command of the Tobit model with individual indicator. However, these estimates are biased (Stata Press Publications, 2021).

Thus, the factors affecting technical efficiency, pure technical efficiency, and scale efficiency have been examined by applying the random-effects panel Tobit model. The random-effects panel model can be represented as the following equation:

$$y_{it} = \beta x_{it} + v_i + \varepsilon_{it}$$

$$i = 1, 2, \dots, n$$

$$t = 1, 2, \dots, T,$$

where y_{it} represents the dependent variable, x_{it} is the vector of independent variables, and β is the vector of coefficients of the independent variables. The error term u_{it} is split into time-varying idiosyncratic random error (ε_{it}) and time-invariant random effect (v_i):

$$u_{it} = v_i + \varepsilon_{it}$$

The measured variable for left-censored and right-censored observations is:

$$y_{it}^* = \begin{cases} y_{it} & \text{if } y_{it} > 0 \\ 0 & \text{otherwise} \end{cases}$$

$$y_{it}^* = \begin{cases} y_{it} & \text{if } y_{it} < 1 \\ 0 & \text{otherwise} \end{cases}$$

Thus, in the present study, the factors affecting technical efficiency, pure technical efficiency, and scale efficiency have been examined through the application of random-effects panel Tobit regression model.

The dependent variables used for this study are efficiency scores under both CCR and BCC models. After analysing the existing literature, the independent variables used in the study are student : teacher ratio, the ratio of female to total students, teaching staff : non-teaching staff, professors : total teaching staff, tuition fees, operating expenses, and age. *Table 1* summarizes the explanatory variables of the departments' efficiency scores.

Table 1. *Description of the variables used as determinants of efficiency*

Variable	Symbol	Description
Student : teacher ratio	STUD	Total number of students in the department : total number of teachers in the department
Ratio of female students to total students	FEMALE	Number of female students in the department : total number of students in the department
Teaching staff : non-teaching staff ratio	TEACH	Number of teachers in the department : total number of non-teaching employees in the department
Professors : total teaching staff	PROF	Number of professors : total number of teachers in the department
Tuition fees	TUT	Fees charged by a department for teaching, instruction, or other services
Operating expenses	OEX	Ongoing costs of a department
Age	AGE	Number of years a department has been in existence

3.2. Dataset

The study is aimed at examining the efficiency of the academic departments at Guru Nanak Dev University, Amritsar. The study has been conducted for a period

of ten years between 2008-09 and 2017-18. To achieve the objective of identifying the factors affecting efficiency, the Tobit analysis can only be applied on balanced data. In order to get balanced data, two criteria have been used in selecting the sample. First of all, only departments with a continuous operation during the period of study were included in the sample. There were two demergers during the period of study. The Department of Commerce and Business Management was demerged into the Department of Commerce and the University Business School, and the Department of Computer Science and Engineering was demerged into the Department of Computer Engineering and Technology and the Department of Computer Science. These departments have been excluded from the study. Moreover, one new department, namely the Department of Education, has also been excluded from the study, as it came into existence after 2014-15. Secondly, the study focused only on departments providing degree courses. Thus, the final sample comprised of 30 academic departments that fulfil the above criteria.

4. Results of the empirical analysis

Efficiency of Academic Departments

In the first step, the efficiency scores of the departments have been assessed under the assumption of both CCR and BCC models. *Tables 2–3* represent the efficiency scores under the CCR and BCC models respectively.

It is clear from *Table 2* that heterogeneity in the results of efficiency scores under the CCR model has been observed. The mean efficiency under the assumption of constant returns to scale varied from 53.8% to 69.7%. It is also worth mentioning that only one department, i.e. the Department of Physical Education, was found to be efficient across all the years (2008-09 – 2017-18). The reason could be the lowest departmental expenditure as compared to other university departments. Also, empirical findings suggest that the Department of Food Science and Technology, Zoology, Architecture, Guru Ramdas School of Planning, Punjab School of Economics, History, Political Science, Psychology, Sociology, English, Punjabi, Sanskrit Pali, and Prakrit, Laws, Music and Guru Nanak Studies failed to achieve an efficiency score of 1 in any year of the study period. In other words, these departments were not able to produce as much output as they were expected to produce from their existing inputs.

Table 2. Efficiency scores (CCR) of the departments (from 2008-09 to 2017-18)

Departments (DMUs)	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18
1 Chemistry	1	0.81	0.903	0.672	1	0.869	1	0.896	0.819	0.83
2 Mathematics	0.886	1	1	0.721	0.444	1	0.939	0.606	0.57	0.587
3 Physics	1	1	1	0.658	0.743	0.785	0.626	0.461	0.528	0.717
4 Pharmaceutical Sciences	0.613	0.952	0.857	0.703	0.417	1	1	1	0.891	1
5 Food Science and Technology	0.913	0.668	0.714	0.425	0.67	0.952	0.998	0.527	0.811	0.525
6 Biotechnology	1	0.826	1	1	1	1	1	1	1	1
7 Botanical and Environmental Sciences	1	1	0.766	1	0.969	0.916	1	1	1	1
8 Human Genetics	0.689	0.703	1	1	0.706	0.63	0.689	0.419	0.587	0.575
9 Microbiology	1	1	1	1	1	1	1	0.887	0.912	0.705
10 Molecular Biology and Biochemistry	0.355	0.502	0.609	0.789	0.716	1	1	0.753	0.837	0.475
11 Zoology	0.881	0.641	0.665	0.628	0.832	0.822	0.848	0.913	0.757	0.586
12 Electronics Technology	1	1	1	1	0.676	1	0.728	1	1	1
13 Architecture	0.314	0.279	0.458	0.269	0.259	0.157	0.343	0.336	0.355	0.323
14 Guru Ramdas School of Planning	0.255	0.372	0.392	0.312	0.192	0.298	0.199	0.19	0.233	0.239
15 Punjab School of Economics	0.803	0.548	0.685	0.431	0.332	0.809	0.475	0.748	0.705	0.578
16 History	0.167	0.1	0.152	0.195	0.175	0.272	0.328	0.311	0.497	0.244
17 Library and Information Science	1	1	1	0.409	0.342	0.783	0.792	0.646	1	0.951
18 Political Science	0.505	0.383	0.382	0.388	0.517	0.673	0.664	0.564	0.889	0.665
19 Psychology	0.482	0.421	0.69	0.407	0.25	0.377	0.214	0.362	0.55	0.347
20 Sociology	0.384	0.399	0.575	0.388	0.607	0.416	0.311	0.391	0.446	0.549
21 School of Social Science	1	1	1	1	1	0.792	1	1	1	1
22 English	0.427	0.385	0.331	0.27	0.21	0.303	0.192	0.249	0.197	0.229
23 Hindi	0.178	0.6	0.501	0.303	0.265	0.652	0.283	0.534	0.288	1
24 Punjabi	0.287	0.211	0.317	0.281	0.212	0.374	0.196	0.406	0.39	0.354
25 Sanskrit, Pali, and Prakrit	0.126	0.529	0.228	0.137	0.135	0.517	0.067	0.442	0.076	0.162
26 Physical Education	1	1	1	1	1	1	1	1	1	1
27 Laws	0.556	0.641	0.562	0.498	0.2	0.38	0.497	0.722	0.737	1
28 Music	0.213	0.269	0.217	0.213	0.263	0.473	0.466	0.489	0.552	0.704
29 Guru Nanak Studies	0.483	0.289	0.261	0.148	0.269	0.662	0.516	0.379	0.403	0.337
30 Sports Medicine and Physiotherapy	1	0.9	1	0.785	0.74	1	1	0.701	0.949	0.647
Mean	0.651	0.648	0.675	0.568	0.538	0.697	0.646	0.631	0.666	0.651
Percentage of efficient departments	33.33%	26.67%	33.33%	23.33%	16.67%	26.67%	30%	20%	20%	26.67%

Table 3. Efficiency scores (BCC) of the departments (from 2008-09 to 2017-18)

Departments (DMUs)	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18
1 Chemistry	1	1	1	1	1	1	1	1	1	1
2 Mathematics	0.913	1	1	0.723	0.586	1	0.939	0.606	0.603	0.589
3 Physics	1	1	1	1	1	1	0.894	0.689	0.754	1
4 Pharmaceutical Sciences	0.646	0.965	0.938	0.737	0.495	1	1	1	0.988	1
5 Food Science and Technology	0.95	0.748	0.741	0.66	0.818	1	1	0.631	0.815	0.566
6 Biotechnology	1	0.839	1	1	1	1	1	1	1	1
7 Botanical and Environmental Sciences	1	1	0.829	1	0.976	1	1	1	1	1
8 Human Genetics	0.712	0.739	1	1	0.855	0.709	0.718	0.458	0.59	0.596
9 Microbiology	1	1	1	1	1	1	1	0.891	1	0.716
10 Molecular Biology and Biochemistry	0.37	0.507	0.611	0.791	0.74	1	1	0.761	0.876	0.475
11 Zoology	1	0.658	0.673	0.646	0.846	0.822	0.873	0.944	0.979	0.609
12 Electronics Technology	1	1	1	1	1	1	1	1	1	1
13 Architecture	0.38	0.36	0.514	0.432	0.439	0.181	0.482	0.403	0.502	0.621
14 Guru Ramdas School of Planning	0.375	0.537	0.524	0.465	0.408	0.323	0.315	0.286	0.324	0.347
15 Punjab School of Economics	0.804	0.709	0.726	0.65	0.743	0.935	0.896	0.996	0.761	0.794
16 History	0.215	0.128	0.152	0.222	0.271	0.276	0.345	0.343	0.534	0.251
17 Library and Information Science	1	1	1	0.617	0.363	0.986	0.825	0.743	1	1
18 Political Science	0.518	0.448	0.448	0.446	0.549	0.705	0.667	0.606	0.968	0.675
19 Psychology	0.586	0.474	0.71	0.438	0.351	0.387	0.286	0.364	0.685	0.351
20 Sociology	0.463	0.414	0.592	0.434	0.703	0.479	0.326	0.397	0.492	0.565
21 School of Social Science	1	1	1	1	1	1	1	1	1	1
22 English	0.527	0.475	0.331	0.332	0.365	0.345	0.316	0.345	0.253	0.266
23 Hindi	0.205	0.729	0.509	0.304	0.282	0.758	0.355	0.586	0.296	1
24 Punjabi	0.376	0.327	0.439	0.461	0.468	0.462	0.46	0.5	0.462	0.56
25 Sanskrit, Pali, and Prakrit	0.629	0.692	0.246	1	0.143	0.661	0.083	0.493	0.078	0.177
26 Physical Education	1	1	1	1	1	1	1	1	1	1
27 Laws	0.78	0.774	0.636	0.67	0.4	0.477	0.845	1	1	1
28 Music	0.216	0.271	0.224	0.215	0.306	0.605	0.533	0.507	0.559	0.714
29 Guru Nanak Studies	0.504	0.393	0.282	0.156	0.397	0.725	0.519	0.391	0.433	0.342
30 Sports Medicine and Physiotherapy	1	0.988	1	0.83	1	1	1	0.826	0.966	0.653
Mean	0.706	0.706	0.704	0.674	0.65	0.761	0.723	0.692	0.731	0.696
Percentage of efficient departments	36.67%	30%	36.67%	33.33%	26.67%	43.33%	36.67%	26.67%	30%	36.67%

The findings of the efficiency scores under the BCC model have been presented in *Table 3*. The mean efficiency under variable returns to scale varied from 65% to 73.1%. The Department of Chemistry, Electronics Technology, School of Social Sciences and Physical Education have been rated as efficient in all the years considered in the study, i.e. from 2008-09 to 2017-18. This indicates that these departments are producing the expected outputs by optimally utilizing their existing resources. It has also been observed that the pure technical efficiency score of 1 has never been attained by the Department of Architecture, Guru Ramdas School of Planning, Punjab School Economics, History, Political Science, Psychology, Sociology, English, Punjabi, Music and Guru Nanak Studies in any of the academic years (2008-09 to 2017-18). Thus, there is no proper utilization of resources in these departments.

Determinants of Efficiency Scores of the Academic Departments

After assessing the efficiency differences among various academic departments, we examine the various institutional factors affecting their efficiency. The factors affecting efficiency have been examined with the help of the Tobit regression model. Before running the models, assumptions have been checked. The data has been found normal. While checking the multicollinearity between the independent variables, it has been found that the values fall within the limits (1.106 to 1.816), indicating that there is no multicollinearity problem. Values greater than 10 indicate collinearity problem. However, the values for all variables were below 10. Moreover, the data were also free from autocorrelation. The findings of the Tobit regression under both the CCR and BCC models are presented in *Table 4*.

It has been observed that the random model is better, as reflected by rho and the likelihood ratio (LR) test under both the CCR and BCC models. If the value of rho is zero, it indicates that the panel level component is unimportant. In the present model, rho is not equal to zero. Thus, the panel model is better than the pooled model. Moreover, the probability value (Prob > Chi2) indicates that the overall model is fit. The student : teacher ratio (STUD) reveals the significant positive impact on technical efficiency at 1% level of significance, which indicates that the efficiency of a department increases when teachers serve more students. The results are supported by Bradley et al. (2010) and Sharma and Mehra (2019), as significant positive relationship was found between efficiency and STUD in these studies. The relationship between efficiency and the ratio of female students to total students (FEMALE) was found as insignificant. Similar findings were revealed by Sharma and Mehra (2019). Positive association has been observed between teaching staff : non-teaching staff ratio (TEACH) and the efficiency of the university departments, which is significant at 1% level of significance. This implies that a greater proportion of teaching staff as compared to non-teaching staff leads to increase in efficiency. A negative relationship has been found between professors : total teaching staff and efficiency of the departments.

This may be attributed to the lower level of commitment of experienced teachers (professors) as compared to new teachers (assistant professors) towards teaching and research activities. In addition to this, tuition fees (TUT) have a negative impact on efficiency scores. The results are found consistent with the study conducted by Sav (2013). Positive relationship has been found between operating expenses and efficiency of academic departments. Age (AGE) also suggests a negative association with efficiency, which is statistically significant at 1% level of significance. This indicates that younger departments were found to be more efficient as compared to departments operating for a longer period of time. Barra et al. (2015), Kounetas et al. (2011), and Wolszczak-Derlacz (2017) also found significant negative association between age and efficiency. The findings imply that the university departments should focus on statistically significant variables in order to achieve higher efficiency.

Table 4. Results of the panel Tobit regression

Explanatory variables		CCR Model			BCC Model		
Variable name	Symbol	Coeff.	Std. Err.	P > Z	Coeff.	Std. Err.	P > Z
Student : teacher ratio	STUD	.0166*	.0025	0.000	.0200*	.0034	0.000
Ratio of female students to total students	FEMALE	-.0023	.0950	0.981	.0045	.0986	0.964
Teaching staff : non-teaching staff ratio	TEACH	.0914*	.0256	0.000	.0747*	.0279	0.007
Professors : total teaching staff	PROF	-.2849*	.1034	0.006	-.2704**	.1085	0.013
Tuition fees	TUT	-9.38e-09*	2.48e-09	0.000	-4.47e-09	3.65e-09	0.221
Operating expenses	OEX	6.28e-08**	2.66e-08	0.018	9.42e-08*	3.28e-08	0.004
Age	AGE	-.0093*	0.0031	0.002	-.0118*	.0034	0.000
Constant		.576319	.1551524	0.000	.7237	.1698	0.000
Prob. > chi2			0.000			0.000	
Rho			.6430			.6523	
LR test (Prob.)			0.000			0.000	
Censored observations			77			101	
Uncensored observations			223			199	

Note: * and ** indicate significance at 1% and 5% level of significance respectively.

5. Conclusions

The present study examined the efficiency and factors affecting the efficiency of academic departments of a state university through the application of data envelopment analysis and Tobit regression model. It has been observed that several of the departments operated efficiently during the study period. However,

in case of the inefficient departments, the faculty members and administrators can redirect their efforts to areas that require attention. In addition to this, the identification of factors affecting academic departments' efficiency also helps in improving the effectiveness of departments by focusing on significant variables. The departments can improve their efficiency by increasing the student : teacher ratio, the teaching : non-teaching staff ratio, and operating expenses. However, an increased number of professors as compared to total teaching staff leads to a decrease in the efficiency of the departments. It has also been observed that an increase in tuition fees leads to less efficient departments. This may be due to the increased pressure among the students to pay greater fees, which ultimately results in their lower efficiency. Departments operating for a long period of time have also been found less efficient. This may be attributed to the lower level of commitment of older departments towards teaching and research activities as compared to newly established departments. It is important for the departments to focus on the significant variables in order to improve their efficiency. Moreover, the findings of the study enable administrators to make informed policy decisions such as allocating additional resources to either reward high-performing units or support struggling ones. In addition to this, identifying inefficiencies within an academic unit presents a valuable opportunity for the faculty and administrators to redirect their efforts towards areas requiring improvement. The present study also provides a way for other universities to examine their performance in terms of efficiency.

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