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Testing the Price Bubbles in Cryptocurrencies using Sequential Augmented Dickey-Fuller (SADF) Test Procedures: A Comparison for Before and After COVID-19

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Abstract: Bubbles in asset prices have attracted the attention of economists for centuries. Extreme increases in asset prices, followed by their sudden decline, create a turbulent effect on the economy and even invite crises in time. For this reason, some measurement techniques have been employed to investigate the price bubbles that may occur. This study explores the possible speculative price bubbles of Bitcoin, Ethereum, and Binance Coin cryptocurrencies, compares them with the pre-and post-COVID-19 period, and examines asymmetric causality relationships between variables. Therefore, we analyzed the price bubbles of these cryptocurrencies using the closing price for daily data between 16.01.2018 and 31.12.2021 by the Supremum Augmented Dickey-Fuller (SADF) and the Hatemi-J (2012) asymmetric causality test. In this context, 1446 observations, 723 of which were before COVID-19 and 723 after COVID-19, were employed in the study. Looking at the SADF analysis results, we detected 103 price bubbles before COVID-19 for the three cryptocurrencies, while we determined 599 price bubbles after COVID-19. The common finding in the asymmetric causality test results is that there is a causality relationship between the negative shocks faced by one cryptocurrency and the positive shocks faced by the other cryptocurrencies.

Keywords: price bubbles; COVID-19; SADF; Asymmetric Causality.

JEL classification: A1; C01; E37.

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1. INTRODUCTION

Throughout history, the characteristic of money has changed in parallel with economic activities and technological developments. At the beginning of the economic activity, commercial activity was carried on through barter. In this period, commodity money was used, that is, the exchange of goods with goods was the center of commercial activities. Then there are various materials utilized as money such as stones and seashells. Afterward, metal coins were employed in the processing of precious metals. Over time, as social requirements increased and trade activities developed, the usage of money through mines was replaced by paper money or banknotes. Nowadays, it can be said that digital currencies, and especially cryptocurrencies, are gaining popularity (Anbugeetha & Nandhini, 2021; König, 2021; Ogachi *et al*., 2021). This situation has created the conditions for many academic studies examining cryptocurrencies from various aspects in recent years (Aliu *et al*., 2020; Aliu *et al*., 2021; Y. Liu *et al*., 2022; Lucey *et al*., 2022). Cryptocurrencies are generally not issued or controlled by any government or other central authority. Cryptocurrencies are managed by peer-to-peer networks of computers running free and open-source software. In short, it is a computer-based decentralized currency that is not under the control of the government or any authority. The fact that it is open to manipulation and speculation due to its decentralized structure leads to the formation of price bubbles that can deeply affect investors. For this reason, examining the existence of price bubbles in cryptocurrencies is also important for portfolio managers, investors, and monetary authorities. In this study, we examined Bitcoin (BTC), Ethereum (ETH), and Binance Coin (BNC) cryptocurrencies, which have an important place in terms of transaction volume. Looking at the development process of related cryptocurrencies, respectively, BTC, a mystery person named Satoshi Nakamoto published a manifesto in 2009. Nakamoto mentioned Peer to Peer and the blockchain system, which we used to know before. According to Nakamoto, "what is needed is an electronic payment system based on cryptographic proof instead of trust, allowing any two willing parties to transact directly with each other without the need for a trusted third party" (Nakamoto, 2009). BTC has the highest market share compared to other cryptocurrencies today. BTC is created through a computational process called mining. ETH is the second-largest cryptocurrency by market share. Like Bitcoin, Ethereum is a public blockchain network. They both rely on a blockchain to operate. "Ethereum is a technology that allows you to send cryptocurrency to anyone for a small fee. It also powers applications that everyone can use and no one can take down" (Ethereum, 2022). Finally, BNC has its chain, although it primarily uses the Ethereum network that is called the Binance Chain (Investopedia, 2022).

As stated, the fact that cryptocurrencies are open to risk and speculation, especially due to their decentralized nature, highlights the necessity of detecting price bubbles. In economic theory, price bubbles are defined as a market phenomenon, which is expressed as the rise in asset prices to levels significantly above the intrinsic value of the asset). (Kindleberger, 1996; Jarrow *et al*., 2010). Extreme increases in asset prices and they explode after a certain point bring along vital problems in the economy. There have been many important price bubbles in history, caused by the extreme increase in asset prices. Tulip Speculative Frenzy in the Netherlands in 1637 (Goldgar, 2007; Thompson, 2007); The South Sea Bubble, which occurred in the 1720s, was caused by the overvaluation of the stock prices of the South Sea Company, which aims to continue trade with South America more profitably (Paul, 2011; Frehen *et al*., 2013), the Mississippi Bubble in the French in the 1720s (Quinn & Turner,

2020), the pre-Great Depression price bubble and the Wall Street crash (Galbraith, 2009), the Dotcom tech bubble that started before the Millennium (Ljungquist & Wilhelm, 2003; Ofek & Richardson, 2003), the Mortgage crisis caused by the real estate bubble in the US (Mayer, 2011; McCarthy *et al*., 2013) and lastly, the Chinese bubble that occurred in the stock market covering the period 2007-2015 (Quinn & Turner, 2020) are the best-known examples of price bubbles. From a historical viewpoint, it can be said that the first place where the crises showed themselves was the finance and banking sector, and then it was reflected in the real sector. Price bubbles also burst after a certain stage in their nature. The time when price bubbles burst, they undoubtedly affected the real sector at a very high level and destroyed the financial markets. It even leads to the formation of crisis conditions. If the economic structure is considered as a whole, it is seen that when there is a malfunction in any element of this structure, it is reflected in other sectors and markets. Price bubbles and volatility trends in financial markets reveal the level of uncertainty and risk, and then the dynamics of the crisis. In this respect, price bubbles that are not easy to catch can be detected with the help of econometric techniques. These techniques are predictive dating algorithms that not only detect occurring outcomes but also provide market actors or policy-makers with an early warning diagnosis that can assist them in monitoring the market (Phillips *et al.*, 2015). It should also be noted that some researchers emphasize that econometric techniques are insufficient to detect price bubbles (Gürkaynak, 2008).

The originality of this study is to examine the price bubbles in cryptocurrencies with increased risk levels and high price volatility, together with their pre- and post-COVID-19 effects. The empirical detection of price bubbles in cryptocurrencies is of vital importance, especially in terms of investors avoiding risk and preventing possible bankruptcies. For this reason, in particular, this study is expected to contribute theoretically to investors, portfolio managers, businesses, and individuals that use cryptocurrencies in their transactions.

This study aims to investigate the potential speculative price bubbles in the Bitcoin, Ethereum, and Binance Coin cryptocurrencies with the right-tailed unit root tests proposed by Phillips and Yu (2011) and Phillips *et al.* (2015). For this purpose, we analyze the price bubbles employing the Supremum Augmented Dickey-Fuller (SADF) test for price bubble detection, while we observe the asymmetric causality analysis between variables applying the Hatemi-J (2012) test. In this context, the study continues with a literature review. Following that, the empirical method is discussed and then the data set and analysis results are presented. The study is completed with the discussion, conclusion, and recommendations sections.

2. LITERATURE REVIEW

In the literature, we can find lots of examples that investigate price bubbles in different markets. After the Mortgage Crisis studies cluster around the housing market. Pavlidis *et al.* (2017) used the SADF and Generalized Supremum Augmented Dickey-Fuller Test (GSADF) unit root tests of Phillips and Yu (2011). The study focuses on different levels of aggregation by using simulated data and actual housing data for both U.S. metropolitan areas and international housing markets (Pavlidis *et al*., 2017). Similarly, Güler and Gökçe focus on price bubbles in housing markets. They find that the legal procedures and the percentage share of house sales to foreigners in total house sales create price bubbles (Güler & Gökçe, 2020). We can witness multiple bubbles in crude oil prices from 1990 to 2019. Herrera and Tourinho (2019) used the SADF and GSADF right-tail unit root tests to study multiple bubbles in WTI

and Brent petroleum prices from January 1990 to March 2019. The result of the study showed many price bubbles for both series. The results of the GSADF test were found to be more successful in detecting price bubbles compared to the results of the SADF test.

On the other side, price bubbles are also an important research topic for financial markets, another area where price volatility is relatively high. "When a stock market bubble bursts, it can trigger financial crises that spread to the real economy." (Z. Liu *et al*., 2016). Çağlı and E. (2018) examined the multiple rational bubbles in developed and emerging stock markets employing the GSADF unit root test. The findings of the study show that rational bubbles exist in all markets except Brazil, Chile, India, and South Korea. Z. Liu *et al*. (2016) focused on the Shanghai A-share index, they find out the origins and evolution of each periodically collapsing bubble. Chang *et al*. (2016) used the BRICS stock market as a case study. The results based on the GSADF test statistic indicate that there are multiple bubbles in the BRICS countries, and the bubbles in the stock markets have important policy implications. El Montasser *et al*. (2018) acknowledged the differences between rational speculative bubbles and explosive fundamentals in the US Stock market using the SADF unit root test.

Arshanapalli and Nelson (2016) examined price bubbles in historical stock prices from 1871 through 2014. They explored the characteristics of every price bubble through historical data. Another historical analysis of price bubbles was applied by Phillips, Shi, & Yu. Empirical tests were conducted on S&P 500 stock market data over the period from January 1871 to December 2010 (Phillips *et al*., 2015). Monschang and Wilfling (2021) investigated the performance of the SADF, GSADF, and backward SADF (BSADF) tests for detecting and date-stamping financial bubbles by using the NASDAQ data period of 45 years.

Mete *et al*. (2019) analyzed the formation of speculative bubbles in Bitcoin, Ethereum, and Ripple cryptocurrencies employing SADF and GSADF methods. The results showed that Bitcoin is particularly susceptible to speculative movements, with price bubbles formed between 2013-2014, 2017-2018 and 2019, Ethereum in 2013-2016 and 2017-2018, and Ripple between 2014-2015 and 2017-2018.

Şak (2021) investigated the investment motives of cryptocurrencies by employing Hatemi-J Asymmetric Causality Analysis. As a result of the analysis, it has been observed that people can diversify their investment instruments, especially in the winning periods, and invest in cryptocurrencies, which are seen as less risky in the losing periods. During negative shock periods, the most preferred cryptocurrencies are Ripple, Binance coin, Bitcoin cash, and Monero; during periods of positive shock, they are Bitcoin, Ripple, Binance coin, Dash, and Bitcoin cash. Özdemir (2021) investigated the bubble behavior in the prices of selected five cryptocurrencies (Bitcoin, Ethereum, Ripple, Stellar, and Tether) using daily data of the closing level during the COVID-19 pandemic. The time interval was chosen from January 2, 2020, to January 2, 2021. The empirical results highlight that bubble behavior is not a diverse and stable feature of Bitcoin, Ethereum, Ripple, and Stellar prices, except for Tether prices, which indicates the emergence of a potential crisis through an increased degree of financial risk in the digital assets market. instability.

Güleç and Aktaş (2019) conducted a study on the eight most traded cryptocurrencies. The existence of speculative price bubbles in the 8 most traded cryptocurrencies in the market was subjected to the Sup Augmented Dickey-Fuller test, which was verified with 1000 repetitions of Monte Carlo Simulation using daily frequency data. As a result of the study, they determined the existence of non-speculative price bubbles in the market. Cryptocurrencies have similarities with precious metals in theory, but the volatility of crypto

markets increases the potential risks. Mensi *et al*. (2019) showed evidence of significant volatility spillover effects between Bitcoin and precious metals. According to the conclusion of the article, it greatly affects the good and bad volatility of Bitcoin, which is in its good and bad volatility. Cryptocurrencies can be used universally, they are not national currencies. So they can work as so-called reserve money. Mokni and Ajmi (2021) compared cryptocurrencies to US dollars for the time span between January 1, 2018, and September 26, 2019, applying Granger causality analysis. The COVID-19 pandemic has had a significant impact on the relationship between cryptocurrencies and has established an important place for cryptocurrencies in the financial system. Another research about asymmetric relationships between BTC and other financial assets is studied by Erdaş and Çağlar (2018). This study investigates the asymmetric causality relationship between Bitcoin and Brent oil, the U.S. dollar, S&P 500, and BIST 100 indices employing the Hatemi-J (2012) test. The time range was chosen between November 2013 and July 2018. The result showed that According to the results of the analysis, there is a one-way causality relationship from the Bitcoin price to S&P 500 index. Bouri *et al*. (2019) analyzed the date-stamp price explosivity in leading cryptocurrencies and revealed that all cryptocurrencies investigated here were characterized by multiple explosivity. In the study, date-stamp price explosiveness in seven large cryptocurrencies revealed evidence of multiple periods of explosivity in all cases, especially in 2017. In particular, it can be seen that Bitcoin was exposed to long-lived explosions.

Price bubbles are studied in many different areas in the literature. The commodity market is one of these areas. Yildirim (2021) examined a study on the commodity market. In the study in which the SADF test was used, price bubbles were found in 2 commodities, but not in 14 commodities. Cryptocurrency markets are volatile and they are getting bigger so studies are focusing on bubbles in cryptocurrencies. Enoksen *et al*. (2020) examined which variables can determine the price bubbles of the eight cryptocurrencies. According to the result, it was observed that studies were conducted, especially during 2017 and 2018. Corbet *et al*. (2018) examined the existence and dates of pricing bubbles in Bitcoin and Ethereum, two popular cryptocurrencies using the methodology. The results helped form an idea for the analysis of the main explanatory variables. Geuder *et al*. (2019) studied bubble behavior in Bitcoin prices. The time interval was chosen between 2016 and 2018. Two distinct testing methodologies (PSY, LPPL) were used. The main problem of the study is what caused these episodes of bubble behavior. Many other reasons are not needed to explain Bitcoin price behavior. Reasons such as government restrictions and the use of other financial assets can impact Bitcoin price behavior. Kayral (2021) researched price bubbles in cryptocurrencies during the COVID-19 period and before. According to the results of the analysis, found that cryptocurrencies are speculative assets for new investments. When the entire analysis period is evaluated, the highest price bubble was detected in Chainlink with a total of 234 days. Also, Bitcoin showed the longest continuous price bubble with 131 days, followed by Theta and Ethereum.

Kyriazis *et al*. (2020) showed that several bubble stages occurred in Bitcoin prices between 2013 and 2017. They also mentioned that as of 2018, academic studies on the bitcoin price bubble have decreased. The price bubble can affect not only cryptocurrencies but also central bank currencies. Yildirim *et al*. (2022) found that the GSADF test results have concluded that there are price bubbles in the dollar exchange rate of countries other than the US Dollar (USD)/Indian Rupee (INR). Wang *et al*. (2022) have studied price bubbles in the NFT and DeFi markets. They used SADF and GSADF tests as methods. As a result of the

study, they found periods when bubbles could not be detected, and they said that these markets have some intrinsic value and that bubbles can be ignored.

Li *et al*. (2021) examined Bitcoin price bubbles with the GASDF test. As a result of the study, they encountered too many speculative bubbles. The main reason for the emergence of bubbles was found to be global events or policies. They revealed that speculative behavior can be exhibited in an environment with policy risk.

3. METHODOLOGY

In the analysis phase, we used the SADF unit root test, which is based on the supremum statistics Augmented Dickey–Fuller-type regressions estimated using recursive windows from the right-tail tests (Phillips *et al*., 2011), to detect the price bubbles of cryptocurrencies. It can be said that the right-tailed unit root test like SADF, GSADF, and, BSADF provide a great advantage in analyzing and detecting speculative price bubble dates. We have witnessed there have been many studies using this test procedure. For instance, Sharma and Escobari (2018) have used this test procedure to analyze price bubbles in the energy sector index, while Li *et al*. (2021) have analyzed stock price bubbles in medical masks. In another study, Pan (2019) investigated housing price bubbles in China, while Etienne *et al*. (2014) tested food product price bubbles. This test is based on the recurring estimation of the ADF model on a forward-widening set of samples. It reaches the sup value of the ADF statistical display harmonizing with the test.

Under this condition, the window size (fraction) (r_w) extends from (r_0) to 1. While r_0 states the smallest sample window width fraction, 1 indicates the total simple size. 0 is fixed as the starting point (r_1) of the sample sequence. Thereby the endpoint of each sample (r_2) is equal to (r_w) but varies from (r_0) to 1. ADF_0^2 represents the ADF test statistic for a sample running from 0 to r_2. The SADF test procedure is obviously described as (Phillips *et al*., 2015):

$$SADF(r_0) = \sup ADF_0^2;\ r_2 \in [r_0, 1] \tag{1}$$

Following that, we also applied the asymmetric causality test developed by Hatemi-J (2012), which focuses on the causality relationship between positive and negative shocks between variables. Asymmetric causality test analyses the presence of asymmetric information by separating the negative and positive shocks in the variables. In this respect, it is seen that it makes an important contribution to the literature. The methodological background of the relevant test should be briefly examined. The causality relationship between two integrated variables, y_{1t} and,y_{2t} are described as a subsequent random walk process (Hatemi-J, 2012, p. 449):

$$y_{1t} = y_{1t-1} + \varepsilon_{1t} = y_{1,0} + \sum_{i=1}^{t} \varepsilon_{1i} \tag{2}$$

$$y_{2t} = y_{2t-1} + \varepsilon_{2t} = y_{2,0} + \sum_{i=1}^{t} \varepsilon_{2i} \tag{3}$$

where t = 1, 2, …,T; $y_{1,0}$ and $y_{2,0}$ represent the initial values of the constant terms, ε_{1i} and ε_{2i} the white noise error term. Positive shocks are stated as ε_{1i}^{+} = max $(\varepsilon_{1i}, 0)$, ε_{2i}^{+} = max $(\varepsilon_{2i}, 0)$, while negative shocks are defined as ε_{1i}^{-} = min $(\varepsilon_{1i}, 0)$, ε_{2i}^{-} = min $(\varepsilon_{2i}, 0)$. Therefore, it can be explained as $\varepsilon_{1i} = \varepsilon_{1i}^{+} + \varepsilon_{1i}^{-}$ whereas $\varepsilon_{2i} = \varepsilon_{2i}^{+} + \varepsilon_{2i}^{-}$.

$$y_{1t} = y_{1t-1} + \varepsilon_{1t} = y_{1,0} + \sum_{i=1}^{t} \varepsilon_{1i}^{+} + \sum_{i=1}^{t} \varepsilon_{1i}^{-} \quad (4)$$

$$y_{2t} = y_{2t-1} + \varepsilon_{2t} = y_{2,0} + \sum_{i=1}^{t} \varepsilon_{2i}^{+} + \sum_{i=1}^{t} \varepsilon_{2i}^{-} \quad (5)$$

Finally, the cumulative sum of the positive and negative shocks of each variable is $y_{1t}^{+} = \sum_{i=1}^{t} \varepsilon_{1i}^{+}$, $y_{1t}^{-} = \sum_{i=1}^{t} \varepsilon_{1i}^{-}$, is expressed as $y_{2t}^{+} = \sum_{i=1}^{t} \varepsilon_{2i}^{+}$.$y_{2t}^{-} = \sum_{i=1}^{t} \varepsilon_{2i}^{-}$ Next, the causality aspect of positive and negative shocks can be employed (Hatemi-J, 2012, p. 449).

For this test, the information criterion is as follows (Hatemi-J, 2012, p. 450):

$$\text{HJC} = \ln(|\widehat{\Omega}_j|) + j\left(\frac{n^2 lnT + 2n^2 \ln(lnT)}{2T}\right) \quad (6)$$

In Equation 6, the $\widehat{\Omega}_j$ symbol in the equation is the determinant of the predicted variance-covariance matrix of the error terms in the VAR model based on the *j* lags level; the n represents the number of equations in the VAR model, and T represents the number of observations. Additionally, the hypothesis of this test is as follows:

The null hypothesis (H_0) indicates that there is no causality relationship between variables, while the alternative hypothesis (H_1)states that there is causality relationship between variables. Accordingly, if the estimated WALD test statistic is greater than the critical value, the null hypothesis can be rejected. Additionally, when the estimated WALD test statistic is less than the critical value, the null hypothesis is not rejected.

4. DATA AND ECONOMETRIC ANALYSIS

Bubbles, collapses and financial crises have been the recurring phenomena of the markets in certain periods, from the initial establishment phase to the modern age, for the financial side (Brunnermeier & Oehmke, 2013) as well as in the economy in general. In our study, we examined the price bubbles for cryptocurrencies. It attracts the attention of economists as price bubbles also affect real sector activities. In the simplest terms, bubbles refer to a situation where asset prices are much higher than their real price. After a stage, the bubble bursts when investors encounter a sudden and excessive sales wave. This situation affects both the investors and the economy at a significant level. In our study, the price bubbles of cryptocurrencies, which are the new instruments of financial markets, were examined. For this purpose, we analyzed the potential price bubbles of the three selected cryptocurrencies (Bitcoin, Ethereum, Binance Coin) for daily data between 16.01.2018 and 31.12.2021. In this context, 1446 observations, 723 of which were before COVID-19 and 723 after COVID-19, were employed in the study. Note that we have split these 1446 observations into two parts based on the date the first case of COVID-19 in the USA was seen. In addition, we then examined the causality relationship between the negative and positive shocks these cryptocurrencies were exposed to. Table no. 1 presents the SADF test results used for detecting price bubbles.

Table no. 1- SADF Test Results

Cryptocurrency	Window Size	Include in test equation		
		None	Constant	Constant and Trend
Bitcoin	83	6.04*	7.99*	6.48*
Ethereum	83	7.11*	7.42*	5.84*
Binance Coin	83	12.21*	18.64*	19.80*
Test Critical Values	1%	3.44	2.02	1.13
	5%	2.87	1.62	0.69
	10%	2.54	1.35	0.45

Note: *sign illustrates that the series is statistically significant at 1%. It means that there is a price bubbles. In addition, test critical values are based on Monte Carlo simulation.

Table no. 1 indicates that SADF test statistics for cryptocurrencies examined in the study are above critical values for Bitcoin, Ethereum, and Binance Coin cryptocurrencies. In other words, the results indicate that these cryptocurrencies have a bubble formation. Table no. 2 presents the price bubble dates and price bubble times of each cryptocurrency. It has been determined that price bubble dates have increased, especially in the post- COVID-19 period.

Table no. 2- Price Bubbles for Bitcoin, Ethereum and Binance Coins

Price Bubbles	Bitcoin	Ethereum	Binance Coin
Panel A. None			
Bubble 1	22.12.2020-15.05.2021	07.02.2021-22.02.2021	17.05.2019-07.06.2019
Bubble 2	14.10.2021-31.10.2021	09.03.2021-10.03.2021	17.06.2019-02.07.2019
Bubble 3	01.11.2021-17.11.2021	04.04.2021-17.05.2021	04.02.2021-02.03.2021
Bubble 4	-	03.09.2021-12.09.2021	07.03.2021-16.03.2021
Bubble 5	-	23.10.2021-18.11.2021	27.03.2021-23.05.2021
Panel B. Constant			
Bubble 1	29.11.2020-30.11.2020	07.02.2021-22.02.2021	21.04.2019-22.04.2019
Bubble 2	19.12.2020-20.05.2021	09.03.2021-10.03.2021	17.05.2019-06.07.2019
Bubble 3	08.08.2021-19.09.2021	04.04.2021-17.05.2021	01.02.2021-18.05.2021
Bubble 4	05.10.2021-02.12.2021	03.09.2021-12.09.2021	24.08.2021-05.09.2021
Bubble 5	-	23.10.2021-18.11.2021	03.11.2021-20.11.2021
Bubble 6	-	-	02.12.2021-08.12.2021
Panel C. Constant and Trend			
Bubble 1	17.06.2019-13.07.2019	29.12.2020-25.05.2021	16.04.2019-04.05.2019
Bubble 2	09.08.2019-10.08.2019	15.08.2021-16.08.2021	14.05.2019-06.07.2019
Bubble 3	16.12.2020-15.05.2021	29.08.2021-12.09.2021	03.02.2021-20.05.2021
Bubble 4	19.10.2021-20.10.2021	22.10.2021-18.11.2021	11.11.2021-12.11.2021
Bubble 5	13.11.2021-14.11.2021	25.11.2021-26.11.2021	-
Bubble 6	-	30.11.2021-31.11.2021	-

Note: The dates given in the table reflect the price bubbles.

Table no. 2 indicates that there are serious differences when the price bubbles of cryptocurrencies are compared with those two-years before COVID-19. It has been proven that the speculation created by the post- COVID-19 uncertainty environment and the extreme volatility in asset prices also contributed to the formation of serious price bubbles for cryptocurrencies. In this context, Table 3 presents the number of price bubbles before and after COVID-19.

Table no. 3- Number of Price Bubbles before and after COVID-19

Cryptocurrency	Before COVID-19	After COVID-19
Bitcoin	33	270
Ethereum	-	190
Binance Coin	70	139
Total	103	599

Table no. 3 indicates that there is a significant difference in the number of price bubbles between pre- and post- COVID-19. Accordingly, while 103 price bubbles were detected before COVID-19 for the three cryptocurrencies, the existence of 599 price bubbles was determined after COVID-19 as a whole. The number of price balloons for Bitcoin, which we examined separately, reached 33 before COVID-19 and 270 after COVID-19. While no price bubble was detected for Ethereum before COVID-19, 190 price bubbles were detected after COVID-19. Finally, while 70 price bubbles were detected for Binance Coin before COVID-19, 139 price bubbles were detected after COVID-19. At this point we differ with the study of Güleç and Aktaş (2019). Additionally, this result have demonstrated that cryptocurrencies are an asset with high risks and are highly sensitive to speculative movements. Our findings are similar to Özdemir (2021) findings on these points. As a result of his work, due to the increasing financial instability, a potential crisis has emerged in the digital asset market, apart from Tether prices. A recurring and common bubble behavior is observed in Bitcoin, Ethereum, Ripple and Stellar prices. These results are also consistent with the study of Mete *et al*. (2019). As a result, it can be said that the post- COVID-19 process has caused many price bubbles in cryptocurrencies. Additionally, this result demonstrates that cryptocurrencies are an asset with high risks and are highly sensitive to speculative movements. The price bubbles for Bitcoin, Ethereum and Binance Coin can be shown in Figures no. 1-9.

Table no. 4 indicates the asymmetric causality test results between variables. In this framework, the causality relationship results between cryptocurrency prices are explained in three ways. First, the findings indicate a causality relationship from positive shocks in Bitcoin price to positive shocks in Binance Coin price. This result means that positive changes in Bitcoin prices have a positive impact on Binance Coin prices. Additionally, it was found that there is a casual relationship from negative shocks in Bitcoin prices to positive shocks in Binance Coin price. Accordingly, negative changes in Bitcoin prices have a positive impact on Binance Coin price. Similarly, a causal relationship is detected between negative shocks in Binance Coin price and positive shocks in Bitcoin price. The second result is related to the relationship between Bitcoin and Ethereum prices. As can be seen, there is a causality relationship between positive shocks in Bitcoin prices and positive shocks in Ethereum prices. However, a causality relationship is determined from positive shocks in Bitcoin prices to negative shocks in Ethereum prices. This result can be interpreted as the demand for Bitcoin negatively affecting Ethereum prices in terms of the substitution effect. Furthermore, a similar causality relationship is valid from Ethereum to Bitcoin. Additionally, it can be mentioned that there is a causality relationship from negative shocks in Ethereum prices to positive shocks in Bitcoin prices.

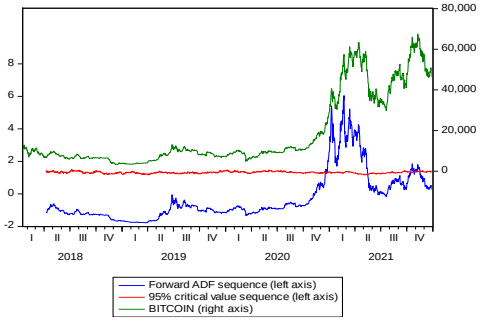

Figure no. 1 - SADF test results with no constant term and no trend for Bitcoin

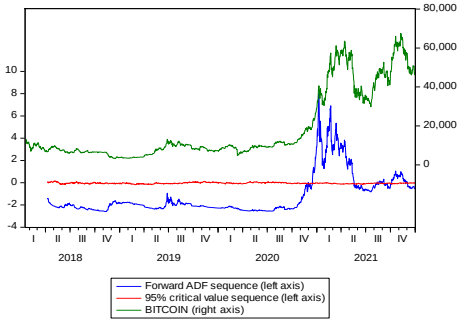

Figure no. 2 – SADF test results with constant term for Bitcoin

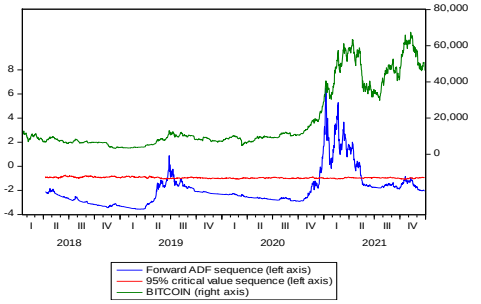

Figure no. 3 – SADF test results with constant term and trend for Bitcoin

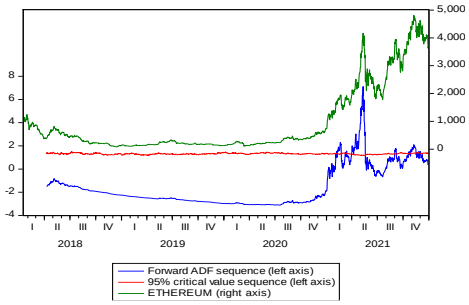

Figure no. 4 – SADF test results with no constant term and no trend for Ethereum

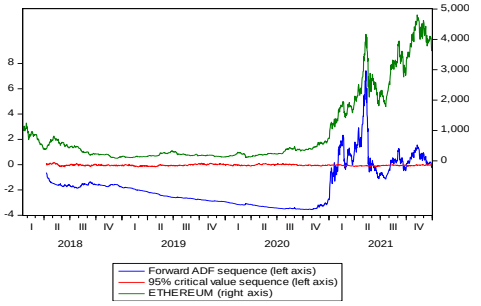

Figure no. 5 - SADF test results with constant term for Ethereum

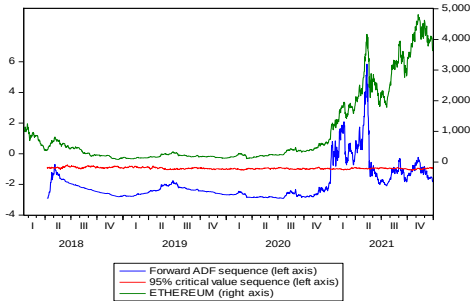

Figure no. 6 - SADF test results with constant term and trend for Ethereum

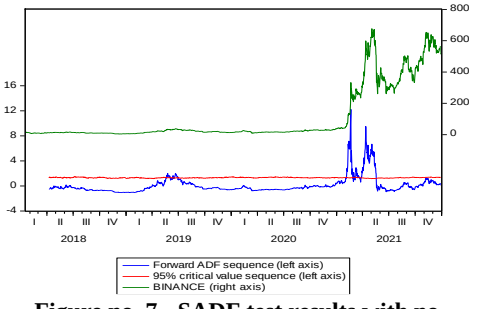

Figure no. 7 - SADF test results with no constant term and no trend for Binance

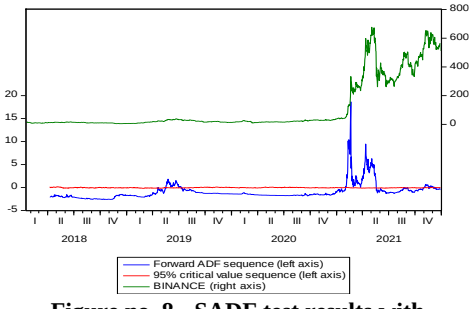

Figure no. 8 - SADF test results with constant term for Binance

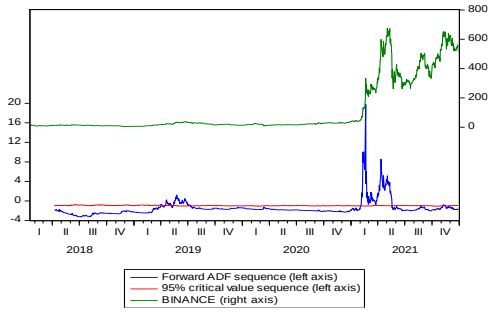

Figure no. 9 - SADF test results with constant term and trend for Binance

Note: The blue line on the figures represents the Forward ADF sequence, the red line represents the 95% confidence interval, and the green lines represent cryptocurrencies. In addition, we used the Eviews 12 to generate the figure.

Table no. 4 - Hatemi-J (2012) Asymmetric Causality Test Results

Null Hypothesis (H_0)	MWALD	Critical Values			Optimal Lags
		1%	5%	10%	
$\boldsymbol{BTC^{+} \neq > BNC^{+}}$	4.317**	6.903	3.808	2.686	1
$BTC^{+} \neq > BNC^{-}$	2.046	9.328	6.125	4.660	2
$BTC^{-} \neq > BNC^{-}$	0.410	6.608	3.768	2.637	1
$\boldsymbol{BTC^{-} \neq > BNC^{+}}$	22.272***	10.152	5.995	4.528	2
$BNC^{+} \neq > BTC^{+}$	1.254	6.911	3.847	2.703	1
$BNC^{+} \neq > BTC^{-}$	2.215	6.899	3.828	2.630	1
$BNC^{-} \neq > BTC^{-}$	0.148	6.905	3.860	2.654	1
$\boldsymbol{BNC^{-} \neq > BTC^{+}}$	3.675*	6.925	3.857	2.679	1
$\boldsymbol{BTC^{+} \neq > ETH^{+}}$	2.934*	6.582	3.816	2.664	1
$\boldsymbol{BTC^{+} \neq > ETH^{-}}$	4.459**	6.501	3.760	2.707	1
$BTC^{-} \neq > ETH^{-}$	0.449	6.685	3.746	2.603	1
$\boldsymbol{BTC^{-} \neq > ETH^{+}}$	4.875**	6.765	3.813	2.666	1
$\boldsymbol{ETH^{+} \neq > BTC^{+}}$	4.612**	6.763	3.803	2.629	1
$\boldsymbol{ETH^{+} \neq > BTC^{-}}$	5.036**	7.180	3.768	2.635	1
$ETH^{-} \neq > BTC^{-}$	0.149	6.696	3.826	2.599	1
$\boldsymbol{ETH^{-} \neq > BTC^{+}}$	7.659***	6.682	3.742	2.630	1
$BNC^{+} \neq > ETH^{+}$	1.044	7.127	3.802	2.613	1
$BNC^{+} \neq > ETH^{-}$	1.884	6.644	3.841	2.657	1
$BNC^{-} \neq > ETH^{-}$	0.112	6.839	3.867	2.670	1
$\boldsymbol{BNC^{-} \neq > ETH^{+}}$	4.311**	6.674	3.854	2.664	1
$\boldsymbol{ETH^{+} \neq > BNC^{+}}$	3.316*	6.692	3.683	2.681	1
$ETH^{+} \neq > BNC^{-}$	1.277	6.637	3.844	2.651	1
$ETH^{-} \neq > BNC^{-}$	0.943	6.865	3.738	2.603	1
$\boldsymbol{ETH^{-} \neq > BNC^{+}}$	15.630***	7.286	3.959	2.643	1

Note: $^{-}$, $^{+}$ state the positive and negative shocks, respectively. In addition *, ** and, *** display significance at and 10%, 5%, 1% level, respectively.

Looking at the asymmetric causality relationship between Binance Coin and Ethereum, a causality relationship is found from negative shocks in Binance Coin prices to positive shocks in Ethereum prices, while a causality relationship is also detected between positive shocks in the price movements of both cryptocurrencies. Finally, we found a causality relationship from

negative shocks in Ethereum prices to positive shocks in Binance Coin prices. Note that all interpreted results are statistically significant. In addition, analyzing cryptocurrencies, positive and negative shocks are also encountered in other studies. As Şak (2021) mentioned, it was determined that investors shifted their investments to Ripple, Binance coin, Bitcoin cash and Monero, which they saw less risky among cryptocurrencies during negative shock periods. It has been observed that different types of cryptocurrencies are used when investing in cryptocurrencies during periods of positive shocks, and investments are mostly directed towards Bitcoin, Ripple, Binance coin, Dash and Bitcoin cash.

5. CONCLUSION

Price bubbles in the market are a crucial indicator in terms of being a harbinger of crisis conditions. The formation of speculative price bubbles and the subsequent bursting of these bubbles can cause serious fluctuations in the economy, and if these fluctuations are exorbitant high, eventually it may create a crisis condition. For instance, especially the sharp decline in the crypto money market in 2022 has economically harmed many crypto money investors.

Analysis results show that the number of price bubbles that emerged in the post-COVID-19 period is much higher than before COVID-19. Expansionary monetary and fiscal policies implemented by countries, especially in the post-COVID-19 period, have created a significant demand for cryptocurrencies. These implementations also led to the emergence of price bubbles. In addition, a causal relationship is determined between the negative and positive external shocks to which the variables are exposed. It is expressed as a policy proposal that mechanisms that can protect crypto money investors must be developed to prevent sharp price movements and high-level volatility. In this direction, it should be demonstrated that the detection of cryptocurrency price bubbles can also support precautionary policies that economic decision-makers can develop.

For future studies, the volatility levels of the cryptocurrency market and other financial instruments can be analyzed and compared, simultaneous analysis of many cryptocurrencies based on various features can be made for price bubble analysis, and it can be researched whether cryptocurrencies will be an alternative investment tool to centralized and more controllable world stock markets, gold and foreign exchange markets.

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ICT Leapfrogging Amidst Labour Force-Economic Growth Nexus in EAP and ECA Regions

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Abstract: Towards achieving the 2030 United Nations Sustainable Development Goals, this study revisits the information and communication technology (ICT) leapfrogging hypothesis of Steinmueller (2001), and Fong (2009) to expand the literature by testing its relevance in the labour force-growth dynamics in Asia. To achieve this, the study addresses four objectives: (i) test the ICT leapfrogging hypothesis; (ii) investigate the growth-enhancing impact of labour; (iii) examine whether ICT enhances or distorts the productivity of labour on economic growth; and (iv) if these effects differ by economic development. The study uses an unbalanced panel data on 81 countries located in East Asia and Pacific (EAP) and Europe and Central Asia (ECA) from 2010 to 2019. Two estimation techniques, namely panel spatial correlation consistent fixed effects (PSCC-FE) and random effects instrumental variables two-stage least squares (RE-IV2SLS), are deployed. To appraise if the impact differs by economic development, the study engages income group analysis. Among other findings: the leapfrogging hypothesis holds; labour is a significant predictor of economic growth; mobile phones usage is a more potent ICT indicator with more leapfrogging potentials relative to fixed telephones subscription; the net effect of labour on growth is mostly positive in the mobile phones' models.

Keywords: economic growth; labour force; leapfrogging; ICT usage; moderation; EAP; ECA.

JEL classification: G20; I21.

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1. INTRODUCTION

The information and communication technology (ICT) "leapfrogging" hypothesis has been represented and explained in diverse ways. According to Steinmueller (2001), ICT "leapfrog" is interpreted to mean when developing economies use ICT to bypass key developmental stages to narrow the productivity gaps between developed and developing economies. In other words, these economies use ICT to jump-start their development goals. A slight deviated interpretation is provided by Fong (2009) who defined ICT "leapfrog" as a situation where ICT being an advanced and state-of-the-art technology is applied to an area previously not deployed to achieve some spontaneous development. Given these submissions, this study aligns with both arguments as they aid in actualising the main objective of this paper which is to test if ICT usage influences the labour-growth dynamics. The leapfrog potentials of ICT permeate all paths of the 2030 United Nations Sustainable Development Goals (SDG)[1].

It is established that ICT can enhance financial inclusion by enabling mobile banking services (Asongu & Tchamyou, 2015; Ofori *et al.*, 2022). This can reduce poverty and inequality (SDG 1 and 10). Through the dissemination of information on agricultural yield, soil composition, and weather forecasts ICT contributes to the reduction of hunger and aids in sustaining food security (Issahaku *et al.*, 2018; Ejemeyovwi *et al.*, 2021) satisfying SDG 2 and 12 in addition to enhancing the wellbeing of the population (SDG 3). ICT drives inclusive education via connectivity such that learning resources and opportunities are available to those initially excluded (SDG 4). It also empowers women and girls through ICT-powered education and online trainings (SDG 5) (George *et al.*, 2021a; George *et al.*, 2021b; Adeleye *et al.*, 2022a). Among others, ICT provides the tools and applications required to manage water and sanitation (SDG 6); helps organisation monitor energy usage (SDG 7) which curbs carbon emissions, reduce environmental degradation ensuring a green environment (SGG 11) and protecting the ecosystem (SDG 13, 14, and 15). ICT innovation and usage connects SDG 8 (providing decent work and economic growth) and SDG 9 (innovation an infrastructure) via improving employment opportunities and the productivity of labour (Grigoli *et al.*, 2020; Ngoa & Song, 2021; Olurinola *et al.*, 2021); drives inclusive industrialisation, globalisation and economic growth (Adeleye & Eboagu, 2019; Adeleye *et al.*, 2021a; Adeleye *et al.*, 2021b; Anser *et al.*, 2021) to satisfy SDG 17. Lastly, ICT adoption strengthens institutions by improving the quality of governance via sharing information to the general public (Zuiderwijk & Janssen, 2014; Sassi & Ali, 2017) satisfying SDG 16.

Also, labour is essential to the production and marketing value chain and several studies have shown that it is a significant contributor to economic growth (Tsani *et al.*, 2013; Liu, 2014; Docquier *et al.*, 2019; Cylus & Al Tayara, 2021; Hou *et al.*, 2021; F. Zhang *et al.*, 2021; X. Zhang & Wang, 2021). Labour is needed in all spheres of the economy as the labour force participation[2] rate measures the active workforce of an economy calculated by the sum of all workers that are employed or actively seeking employment divided by the number of the working-age population. Some studies have also connected the ICT-labour nexus to show that ICT enables the performance of labour (Ceccobelli *et al.*, 2012; Herman, 2020; Kim *et al.*, 2021; F. Zhang *et al.*, 2021).

However, this paper deviates to explore if ICT moderates the impact of labour on economic growth in Asia. In other words, does ICT influence the labour-growth dynamics in Asia? This, to the best of our knowledge, is a gap in the labour-growth literature. Following Hayes (2015), the moderating role of ICT on the labour-growth nexus is graphically illustrated

in Figure no. 1. To satisfy the four study objectives: (i) Path A tests the Steinmueller (2001), Fong (2009), Sein *et al.* (2019) and Avgerou (2017) ICT leapfrogging hypothesis; (ii) Path B probes the growth-enhancing impact of labour force; (iii) Path C evaluates if ICT enhances or distorts the productivity of labour on economic growth; and (iv) examines if paths A-C is heterogeneous by income groups.

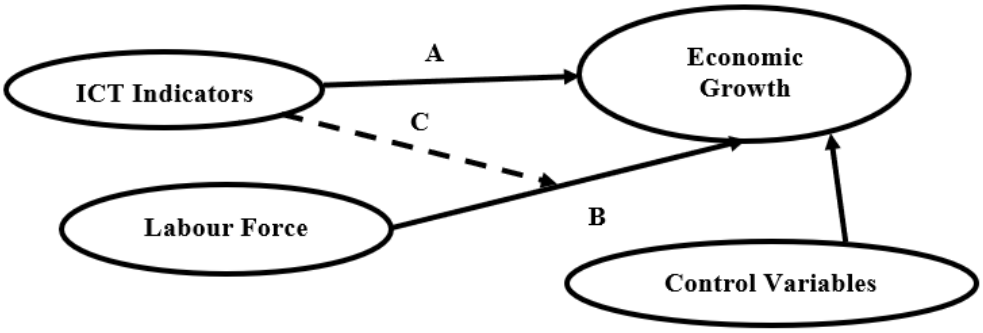

Figure no. 1 – Schema on the ICT-Labour-Economic Growth Dynamics

To probe the discourse, data on 81 countries[3] located in East Asia and Pacific (EAP) and Europe and Central Asia (ECA) from 2010 to 2019 is used. The main variables of interest are per capita GDP (proxy for economic growth); mobile phones and fixed telephone subscriptions as indicators of ICT and total labour force participation rate. ICT is a general term that captures any communication device or application encompassing cellular phones, fixed wireless, broadband, computers, network hardware and software, satellite systems etc. (Fong, 2009; Adeleye & Eboagu, 2019). This current study restricts to using mobile subscriptions (given its ease of carriage and portability the mobile phone is used by everyone), fixed telephone subscriptions (common with corporate establishments) as ICT indicators. For the most part, the results from our study align with previous studies. Outcomes reveal that ICT exerts a nonlinear U-shaped relationship with economic growth satisfying that the leapfrogging hypothesis holds, labour significantly predicts economic growth; the net effect of labour is consistently positive in mobile phones models; mobile phone is a more potent ICT indicator to jumpstart economic progress and lastly, the results from the income groups are heterogeneous. The rest of the study is organised as follows: Section 2 reviews the literature; Section 3 outlines the data and model; Section 4 discusses the results while Section 5 concludes with policy recommendations.

2. BRIEF EMPIRICAL REVIEW

This section reviews the extant literature on the link between ICT and economic growth by expounding on the leapfrogging hypothesis of Steinmueller (2001), Avgerou (2017) and Sein *et al.* (2019); further to this we draw empirical findings on the labour force-economic growth nexus from Jarmołowicz and Knapińska (2011) labour market theories; lastly we find empirical validations to situate the interaction of ICT and labour force. Table no. 1 summarizes the reviewed literature on ICT and economic growth (1-15), labour force and economic growth (16-25), and ICT and labour force (26-40).

Table no. 1 – Summary of Reviewed Literature on ICT, Labour Force and Economic Growth

S/N	Author(s)	Scope	Technique	Outcome
1	Adeleye *et al.* (2021a)	53 African countries, 2005-2015	BLSDV, DGMM	ICT ↑ EG and IG
2	Appiah-Otoo and Song (2021)	122 countries, 2002-2017	IV-GMM	ICT ↑ EG in both rich and poor countries but ICT revolution ↑ EG in poor countries.
3	Arvin et al. (2021)	G20 countries, 1961-2019	PGCM	ICT ↑ EG
4	Hussain et al. (2021)	South Asia, 1995-2016	FMOLS, Panel VECM	ICT ↑ EG
5	Kallal et al. (2021)	Tunisia, 1997-2015	PMG-ARDL	ICT ↑ EG
6	Kim et al. (2021)	22 countries, 2011-2016	POLS, FE	Mobile ICT ↑ NP in DCs; no impact of wired ICT for either DCs or LDCs.
7	Ofori and Asongu (2021)	SSA, 1980-2019	SGMM	ICT ↑ IG
8	Usman et al. (2021)	South Asia, 1990-2018	BT, ECM	ICT ↑ EG in India only
9	Ejemeyovwi and Osabuohien (2020)	WA, 2004-2014	SGMM	ICT has no effect on IG
10	Jung and Lopéz-Bazo (2020)	27 Brazilian states, 2007-2011	OLS, IV-FE	ICT ↑ EG
11	Myovella et al. (2020)	41 SSA, 33 OECD countries, 2006-2016	OLS, FE, GMM	ICT ↑ EG
12	Nguyen et al. (2020)	13 G-20 countries, 2000-2014	FMOLS, QR	ICT ↑ EG
13	Adeleye and Eboagu (2019)	54 African countries, 2005-2015	POLS, SGMM	ICT ↑ EG
14	Donou-Adonsou (2019)	45 SSA countries, 1993-2015	FE, GMM	ICT ↑ EG
15	Sepehrdoust and Ghorbanseresht (2018)	OPEC, 2002-2015	GMM	ICT ↑ EG
16	Acheampong et al. (2021)	23 EE, 1970-2015	IV-GMM	LF ↓ EG
17	Adeleye *et al.* (2021b)	15 industrialised countries, 1976-2018	FE, RE	LF ↑ Output
18	Anyanwu et al. (2021)	Nigeria, 1981-2015	OLS	Female LF ↓ EG
19	Ogundipe et al. (2021)	Nigeria, 1981-2018	JCT	LF ↑ EG
20	Olarewaju et al. (2021)	Manufacturing firms in Nigeria	MDS	LF ↑ Output
21	Yıldırım and Akinci (2021)	MIC, 2001-2016	POLS, FE, DGMM, SGMM	U-shape nexus between female LF and EG
22	X. Zhang and Wang (2021)	China, 1985-2014	FE	LF growth rate ↓ EG
23	Appiah et al. (2020)	15 ECOWAS countries, 1996-2017	SGMM	LF ↯ EG
24	Rahman et al. (2020)	5 South Asian countries, 1990-2017	PGCM, FMOLS, DOLS, GMM	LF ↑ EG
25	Ruiters and Charteris (2020)	South Africa, 2008-2018 (quarterly)	ARDL	Female LFP ↯ EG
26	Ejemeyovwi *et al.* (2021)	7634 households, Nigeria, LSMIS,	Logit	ICT ↑ food security of farming households.
27	Ngoa and Song (2021)	48 African countries, 2001-2017	FE, SGMM	ICT ↑ female LFP

S/N	Author(s)	Scope	Technique	Outcome
28	Shahnazi (2021)	28 EU countries, 2007-2017	SDM	ICT spill-overs ↑ LFProd.
29	F. Zhang et al. (2021)	China, 2004-2006	FE	Enterprise ICT ↓ LF income and demand.
30	Grigoli et al. (2020)	24 European economies, 2000-2016	Driscoll and Kraay (1998) PSCC	Automation ↓ LFP
31	Herman (2020)	Romania, 2008-2018	DS	Low digital economy ↓ LFP
32	Koutroumpis et al. (2020)	9,474 European firms, 2004-2013	GMM	R&D ICT ↑ TFP
33	Gal et al. (2019)	20 OECD countries plus Turkey, 2010-2015	ECM	ICT ↑ TFP
34	Chung (2018)	Korea, 1996-2015	DGEM	ICT ↑ growth
35	Pieri et al. (2018)	OECD industries, 1973-2007	SFM	ICT ↓ PI
36	Edquist and Henrekson (2017)	50 Swedish industries; 1993-2013	OLS	ICT ↯ TFP
37	Liao et al. (2016)	24 USA ICT-using industries, 1977–2005	MCMC	ICT ↑ TFP
38	Luo and Bu (2016)	6,236 from 27 EE, 2007	HLM	ICT ↑ productivity
39	Mitra et al. (2016)	India, 1994-2010	FMOLS, PC, DPDM	ICT ↑ TFP
40	Strobel (2016)	Germany and the USA	OLS	ICT ↑ TFP

Note: ↑: Increases/improves/stimulates; ↓: Reduces/reduction/declines; ↯: No effect; ARDL: Autoregressive distributed lag model; BLSDV: Bootstrapped least squares dummy variables; BT: Bounds testing; CGEM: Computable General Equilibrium Modeling; DCs: Developing countries; DGEM: Dynamic general equilibrium model; DGMM; Difference generalised method of moments; DOLS: Dynamic ordinary least squares; DPDM: Dynamic panel data model; DS: Descriptive statistics; ECM: Error correction model; ECOWAS: Economic Community of West African States; EE: Emerging Economies; EG: Economic growth; EU: European Union; FE; Fixed effects; FMOLS: Fully modified ordinary least squares; GM: Gravity model; HLM; Hierarchical linear modeling; ICT: Information and communication technology; IG: Inclusive growth; IV-GMM: Instrumental variables-generalised method of moments; JCT: Johansen cointegration technique; LDCs: Less developed countries; LFP: labour force participation; LFProd: Labour force productivity; LSMIS: Living Standard Measurement Integrated Survey; MCMC; Markov Chain Monte Carlo; MDS: Micro-Data Survey; MIC: Middle-Income countries; NP: national productivity; OECD: Organisation for Economic Cooperation and Development; OPEC: Organisation of Petroleum Exporting Countries; PC: Panel cointegration; PGCM: Panel-Granger causality model; PI: Production inefficiency; PMG: Pooled mean group; POLS: Pooled ordinary least squares; PSCC: Panel-spatial correlation consistent; QR: Quantile regression; R&D: Research and Development; RE: Random effects; SGMM: System generalised method of moments; SDM: Spatial Durbin Model; SFM: Stochastic Frontier Model; SSA: Sub-Saharan Africa; VECM: Vector error correction model; WA: West Africa

Source: authors' compilation

Our study differs from those highlighted in Table no. 1 with the introduction of moderation modelling technique as none of these studies used this approach to investigate the relationship between economic growth and labour force. Hence, we contribute to the body of knowledge by examining the moderation effect of ICT on the labour-growth nexus. We further engage robust analyses with aggregated and dis-aggregated samples to probe the discourse.

3. DATA AND MODEL

3.1 Variables, Justification and Expectations

To probe the discourse, an unbalanced panel data of eight variables on 81 countries located in East Asia and Pacific (EAP) and Europe and Central Asia (ECA) from 2010 to 2019 is used. The peculiarity of these regions, their cosmopolitan nature and diverse income structure are the motives for choosing both regions the scope. For instance, (1) both EAP and ECA have semblance of Asian countries; (2) Oceanic countries can be separated from the EAP region; (3) some parts of Europe are in the ECA region; and (4) both regions have diverse income groups. To allow for more countries, we expanded the scope such that only those without sufficient observations on the variables of interest are excluded from the sample. All the variables are obtained from World Bank (2020) – World Development Indicators (WDI). The dependent variable is per capita GDP (PC) which is the proxy for economic growth; the main independent variables are ICT indicators - mobile cellular subscription (MOB), and fixed telephone subscription (FTEL), and labour force participation (LF). There are four control variables: individuals using the Internet (NET), education index (EDUC), institutional quality index (IQI), and gross fixed capital formation (GFCF). Lastly, two interaction terms: the square of ICT is included to test the leapfrogging hypothesis and LAB*ICT is incorporated to test if ICT improves or distorts the impact of labour force participation on economic growth.

On a *priori* expectations, ICT has a positive relationship with economic growth (Sein *et al.*, 2019; Adeleye *et al.*, 2021a; Olurinola *et al.*, 2021; Haldar *et al.*, 2022; Adeleye, 2023). Coupled with that, the leapfrogging hypothesis states that ICT is the platform upon which developing economies can skip developmental stages (Steinmueller, 2001; Sein & Harindranath, 2004; Avgerou, 2017; Adeleye *et al.*, 2022a; Adeleye *et al.*, 2022b). Labour is an critical element for growth (Shahid, 2014; Olarewaju *et al.*, 2021; X. Zhang & Wang, 2021), Internet usage contributes to economic productivity (Visser, 2019; Shahnazi, 2021), education which is human capital exerts a positive impact on growth (Čadil *et al.*, 2014; Pelinescu, 2015), quality institutions provide the enabling environment for growth to thrive (Acemoglu & Robinson, 2010; Bahamonde & Trasberg, 2021), and lastly capital is a vital growth input (Lach, 2010; Ahmed *et al.*, 2016; Adeleye *et al.*, 2021b). The variables description, sources and a priori expectations are shown in Table no. 2.

Table no. 2 – Variables, Description and Signs

Variable	Description	Signs
PC	GDP per capita (constant 2010 US$)	N/A
LAB	Labor force participation rate, total (% of total population ages 15-64) (modeled ILO estimate)	+
MOB	Mobile cellular subscriptions (per 100 people)	+
FTEL	Fixed telephone subscriptions (per 100 people)	+
NET	Individuals using the Internet (% of population)	+
EDUC	Education Index	+
IQI	Institutional Quality Index	+
GFCF	Gross capital formation (% of GDP)	+

Source: authors' compilations

3.2 Theoretical Framework and Empirical Model

To address the increasing impact of ICT innovation on economic growth, our study draws from the leapfrogging hypothesis that ICT innovation is the platform upon which developing economies skip developmental stages (Steinmueller, 2001; Niebel, 2018). Linked to that is the ICT4D theoretical frameworks of Sein *et al.* (2019) and Avgerou (2017) which posit that ICT innovation drives rapid output growth and labour productivity across countries. Several studies have shown that ICT investments exert positive impact on the economy (Adeleye & Eboagu, 2019; Ejemeyovwi & Osabuohien, 2020; Adeleye *et al.*, 2021a; Kim *et al.*, 2021). Secondly, from the theory of economic growth (Jones, 1975), output is a direct function of capital, labour and technology which provides sufficient justification for the interaction of labour and ICT in order to evaluate the overall impact of labour on growth. To this end, this study conjectures that (1) ICT will exert an increasing monotonic effect on growth, and (2) ICT may improve the overall impact of labour force on economic growth such that productivity improves with more ICT innovation and adoption. Hence, to address these suppositions the empirical approach of Adeleye *et al.* (2021a) is modified into three distinct models.

To test the leapfrogging hypothesis (Path A of Figure no. 1), the first objective specifies economic growth as an increasing function of ICT (given the inclusion of the square of ICT) and a set of control variables:

$$\ln PC_{it} = \varphi_0 + \varphi_1 \boldsymbol{ICT'}_{it} + \varphi_2 \boldsymbol{ICT'^2}_{it} + \phi \boldsymbol{K'}_{it} + \mu_i + \gamma_t + v_{it} \quad (1)$$

Holding ICT and other control variables constant, the second objective introduces labour force into Equation (1) to observe its impact on growth (Path B of Figure no. 1):

$$\ln PC_{it} = \eta_0 + \eta_1 \boldsymbol{ICT'}_{it} + \eta_2 \boldsymbol{ICT'^2}_{it} + \eta_3 \ln LAB_{it} + \omega \boldsymbol{R'}_{it} + \mu_i + \delta_t + \tau_{it} \quad (2)$$

To achieve the third objective, Equation (2) is augmented to accommodate the interaction of labour force and each ICT to examine the interaction effects on economic growth (Path C of Figure no. 1):

$$\ln PC_{it} = \psi_0 + \psi_1 \ln \boldsymbol{ICT'}_{it} + \psi_2 \ln LAB_{it} + \psi_3 (\ln LAB_{it} * \ln \boldsymbol{ICT'})_{it} + \alpha \boldsymbol{W'}_{it} + \mu_i + \rho_t + s_{i,} \quad (3)$$

where, ln = natural logarithm; PC_{it} = real per capita GDP (proxy for economic growth); $\boldsymbol{ICT'}_{it}$ = vector of ICT indicators (MOB, FTEL); LAB_{it} = labour force; $\varphi_i, \eta_i, \psi_i$ = parameters to be estimated; $\phi \boldsymbol{K'}_{it}$, $\omega \boldsymbol{R'}_{it}$, $\alpha \boldsymbol{W'}_{it}$ = vector of control variables (NET, EDUC, GFCF, and IQI) and their corresponding parameters; μ_i = individual fixed effects; $\gamma_t, \delta_t, \rho_t$ = year dummies; and $v_{it}, \tau_{it}, s_{it}$ = general error terms. Equations (1) to (3) are further modified for income groups analysis to satisfy the fourth objective.

From Equation (1), (i) $\varphi_1 < 0, \varphi_2 > 0$ reveals a U-shaped relationship and affirms that the leapfrogging hypothesis holds; (ii) $\varphi_1 > 0, \varphi_2 < 0$ shows an inverse U-shaped relationship; (iii) $\varphi_1 > 0, \varphi_2 > 0$ illustrates a monotonically increasing linear relationship; (vi) $\varphi_1 < 0, \varphi_2 < 0$ depicts a monotonically decreasing linear relationship; and (vii) $\varphi_1 = 0, \varphi_2 = 0$ indicates no relationship.

Note, from Equation (3) the expectation is that $\psi_1 > 0$ and $\psi_2 > 0$ and the sign of the coefficient of the interaction term, ψ_3, gauges if the interaction of ICT innovation with labour boosts or alters the impact of labour force on economic growth. A positive (negative) ψ_3 shows that ICT improves (distorts) the performance of labour force on growth. However, the net effect of labour force on economic is evaluated at values of ICT innovation and the formula is given as:

$$\frac{\partial \ln PC}{\partial \ln LAB} = \psi_2 + \psi_3 \ln \boldsymbol{ICT}' \tag{4}$$

So, if $\psi_3 > 0$ it implies that ICT usage enables labour performance on economic growth. However, if $\alpha_3 < 0$, the overall impact of labour force on growth depends on the magnitude of the negative. If the negative sign of ψ_3 outweighs the positive sign of ψ_2 then ICT usage distorts the impact of labour force on growth. On the contrary, if the negative sign of ψ_3 is less than the positive sign of ψ_1 it suggests that the distortionary effect of ICT is not sufficient to constrain the positive effect of labour force on economic growth. Finally, if $\psi_3 = 0$ implies the interaction of ICT usage with labour force has no significant impact on growth.

3.3 Estimation Techniques

The estimation techniques are panel spatial correlation consistent fixed effects estimator (PSCC-FE) and the random effects instrumental variables two-stage least squares (RE-IV2SLS). To control for cross-sectional dependence and possible endogeneity, Equations (1) to (3) are estimated with the Driscoll and Kraay (1998) panel spatial correlation consistent (PSCC) standard errors fixed effects (FE-within) regression technique. The procedure corrects the standard errors of the coefficient estimates for possible dependence (Cameron & Trivedi, 2005; Hoechle, 2007). Finally, in the event of possible endogeneity and on the assumption that the regressors are orthogonal to the error terms, the two-stage least-squares random-effects estimator (RE-IV2SLS) which uses the Baltagi EC2SLS random-effects estimator (Baltagi, 2013) is deployed.

4. RESULTS AND DISCUSSIONS

4.1 Summary Statistics

Table no. 3 shows the historical properties among the variables. With emphasis on GDP/capita, mobile phones subscriptions, fixed telephone subscriptions, and labour force participation rate, the average GDP/capita in the data is US$21,899.94 with a standard deviation of 23209.84 indicating that countries in the sample are widely dispersed from the mean. Luxembourg (ECA, high income) has the highest GDP/capita of US$111,043.50 in 2019. The country consistently tops the highest per capita income from 2010 to 2019 while Cambodia (EAP, lower-middle income) has the lowest at US$785.50 in 2010. On the ICT indicators, the average mobile phones users per 100 people is 45,253,575 and China (EAP, upper-middle income) consistently has the highest number of persons from 2010 to 2019 while the country with the lowest mobile phone users is Tuvalu (EAP, upper-middle

income) with 1,600 in 2010. The average number of fixed telephone subscriptions is 9,069,212 with China (EAP, upper-middle income) consistently has the highest number of persons from 2010 to 2019 while the country with the lowest fixed telephone users is Nauru (EAP, upper-middle income) with zero values from 2010 to 2019. Lastly, the average labour force participation rate is 70.271 and the country with the highest labour force participation is Iceland (ECA, high income) with 89.09 while the lowest is Moldova (ECA, lower-middle income) with 43.72.

Table no. 3 – Summary Statistics

Variable	*Full Sample*			*High Income*		
	Obs	**Mean**	**Std. Dev.**	**Obs**	**Mean**	**Std. Dev.**
PC	796	21899.944	23209.839	388	39954.334	21421.275
MOB	760	45253575	1.57E+08	382	22949493	34438905
FTEL	768	9069212	29269308	387	8388941.6	14544185
GFCF	705	23.62	6.486	371	21.687	4.538
LAB	740	70.271	8.557	380	73.52	5.457
NET	720	60.713	26.438	366	79.632	11.88
EDUC	733	0.761	0.129	360	0.855	0.055
IQI	784	0.049	2.178	374	1.984	1.195
Variable	***Lower-Middle Income***			***Upper-Middle Income***		
	Obs	**Mean**	**Std. Dev.**	**Obs**	**Mean**	**Std. Dev.**
PC	180	2333.212	1082.029	228	6623.226	2873.096
MOB	168	42476325	81647796	210	88047562	2.82E+08
FTEL	168	2984897.4	6527967.8	213	15104092	51126873
GFCF	150	27.109	7.724	184	24.675	7.276
LAB	160	68.878	10.917	200	65.212	8.515
NET	150	27.912	20.117	204	50.89	19.686
EDUC	170	0.603	0.127	203	0.728	0.062
IQI	180	-2.089	1.057	230	-1.424	1.066

Note: PC = GDP per capita; MOB = Mobile cellular subscription; FTEL = Fixed telephone subscription; GFCF = gross fixed capital formation; LAB = Labour force participation; NET = Individuals using the Internet; EDUC = Education index; IQI = Institutional quality index; 1.57E+08 = 157,000,000.00.

Source: authors' computations

4.2 Pairwise Correlation Analysis

From the pairwise correlation presented in Table no. 4, all the independent variables apart from gross fixed capital formation have positive and statistically significant association with GDP/capita. Though the correlation coefficient for EDUC/NET is 0.814 and that of IQI/EDUC is 0.784, their respective variance inflation factors (VIF) are 2.02, 2.03 and 2.04 which are below the benchmark of 10 from which multicollinearity becomes a concern (see Annex Table 1B).

Table no. 4 – Pairwise Correlation Analysis

Variables	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
(1) lnPC	1.000							
(2) lnMOB	0.152***	1.000						
(3) lnFTEL	0.365***	0.916***	1.000					
(4) lnGFCF	-0.312***	0.054	-0.095**	1.000				
(5) lnLAB	0.368***	0.237***	0.225***	-0.062	1.000			
(6) lnNET	0.736***	0.253***	0.423***	-0.325***	0.260***	1.000		
(7) EDUC	0.811***	0.139***	0.388***	-0.347***	0.275***	0.814***	1.000	
(8) IQI	0.876***	0.006	0.183***	-0.284***	0.380***	0.642***	0.748***	1.000

Note: *** p<0.01, ** p<0.05, * p<0.1; ln = Natural logarithm; PC = GDP per capita; GFCF = gross fixed capital formation; NET = Individuals using the Internet; IQI = Institutional quality index; EDUC = Education index; LAB = Labour force participation.

Source: authors' computations

4.3 Full Sample Results

There is evidence of the leapfrogging hypothesis from the results displayed in Table no. 5. Holding the control variables constant, columns [1] and [4] reveal that mobile phones and fixed telephones usage show a statistically significant U-shaped relationship with economic growth. It is inferred that at the initial stage of ICT innovation due to the learning curve and adoption, economic growth slows down (negative level term) but as people become skilled in the application of ICT apparatus for productive economic activities intensifying its usage, economic growth speeds up (positive squared term). Specifically, these findings align with Ghosh (2016), Kumar *et al.* (2016), Haftu (2019) and Myovella *et al.* (2020) who establish that mobile telephony and fixed telephone usage have contributory impact on economic growth. Overall, this outcome supports the Steinmueller (2001), Sein *et al.* (2019) Sein et al. (2018) and Avgerou (2017) leapfrogging conjectures that ICT can be used to jumpstart economic growth as well as related studies that find ICT as a positive and significant predictor of growth (Adeleye & Eboagu, 2019; Visser, 2019; Appiah *et al.*, 2020; Asongu & Odhiambo, 2020; Adeleye *et al.*, 2021a; Adeleye *et al.*, 2021b; Appiah-Otoo & Song, 2021; Kim *et al.*, 2021). This outcome satisfies our first objective.

From columns [2] and [5], the results indicate that labour force is a statistically significant positive predictor of economic growth at the 1% level. it indicates that the elasticity of contribution of labour to growth is between 0.55 and 0.67 percent, on average, ceteris paribus. This conforms with previous positive labour-growth relation established by Yıldırım and Akinci (2021), Ngoa and Song (2021), Ruiters and Charteris (2020), Grigoli *et al.* (2020), and Adeleye and Eboagu (2019). These results confirm that labour work is an essential input in the production process such that an active workforce will exert a positive impact on output. Also, the positive impact of labour is evident despite controlling for the nonlinearity of ICT amongst other covariates. With this outcome, the second objective is achieved.

Table no. 5 – Full Sample Results

Variables	PSCC-Fixed Effects, Main						Random Effects IV-EC2SLS, Robustness					
	Mobile Cellular Subscription			Fixed Telephone Subscription			Mobile Cellular Subscription			Fixed Telephone Subscription		
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]
lnICT	-0.320***	-0.941***	0.408***	-0.00512	-0.0111	0.576*	-0.0230	-0.394*	2.404**	0.00398	0.0852**	8.730***
	(-4.767)	(-10.32)	(3.937)	(-0.710)	(-0.880)	(1.747)	(-0.211)	(-1.875)	(2.227)	(0.175)	(2.093)	(6.564)
lnICTSQ	0.00956***	0.0288***		0.00455**	0.00380		7.69e-05	0.0117*		0.00737	-0.0219**	
	(4.782)	(10.20)		(2.372)	(1.431)		(0.0222)	(1.802)		(1.298)	(-2.248)	
lnNET	0.0687***	0.0963***	0.0771***	0.0532***	0.0626***	0.0660***	0.0704***	0.0923***	0.0790***	0.0688***	0.173***	0.0939***
	(9.845)	(12.83)	(12.35)	(7.357)	(8.201)	(9.428)	(4.865)	(6.402)	(5.200)	(4.757)	(6.853)	(5.571)
lnGFCF	0.100***	0.0802***	0.0747***	0.0743***	0.0725***	0.0731***	0.0756***	0.0613***	0.0407	0.109***	0.0765**	0.0863***
	(10.73)	(5.922)	(5.609)	(5.808)	(5.345)	(5.398)	(3.154)	(2.616)	(1.527)	(4.194)	(2.340)	(2.650)
EDUC	0.424***	0.422***	0.673***	0.610***	0.632***	0.678***	1.752***	1.640***	1.956***	2.571***	3.070***	2.880***
	(5.419)	(8.407)	(6.435)	(6.816)	(6.888)	(6.821)	(7.473)	(7.265)	(8.115)	(8.296)	(8.323)	(8.423)
IQI	0.0561***	0.0638***	0.0636***	0.0522***	0.0628***	0.0633***	0.0924***	0.0991***	0.0981***	0.0881***	0.128***	0.126***
	(3.826)	(4.145)	(4.057)	(3.494)	(3.981)	(3.992)	(8.330)	(9.257)	(8.436)	(7.806)	(8.338)	(8.376)
lnLAB		0.672***	2.157***		0.550***	0.944***		0.877***	9.900**		3.534***	7.720***
		(4.533)	(5.998)		(3.919)	(2.847)		(6.290)	(2.439)		(7.316)	(7.256)
lnLAB*lnICT			-0.101***			-0.132*			-0.571**			-2.010***
			(-4.278)			(-1.728)			(-2.249)			(-6.550)
Net Impact			**0.58%**			**-0.89%**			**0.98%**			**-20.20%**
Constant	11.08***	13.17***	-0.468	8.413***	6.080***	4.312***	7.910***	7.154***	-34.22**	6.741***	-9.068***	-26.82***
	(19.61)	(28.10)	(-0.291)	(147.0)	(10.67)	(3.052)	(8.649)	(3.830)	(-1.982)	(22.92)	(-3.917)	(-5.642)
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	635	626	626	633	625	625	565	558	558	563	556	556
Countries	70	68	68	69	68	68	69	68	68	69	68	68
F/Wald Statistic	196747	248438	234307	43256	101044	93518	903.3	1026	934.5	881.2	573.6	600.0

Note: *** p<0.01, ** p<0.05, * p<0.1; t-statistics in ( ); PC = GDP per capita; GFCF = gross fixed capital formation; NET = Individuals using the Internet; IQI = Institutional quality index; EDUC = Education index; LAB = Labour force participation; VIF = Variance inflation factor.

Source: authors' computations

Next, the results in columns [3] and [6] computes the net impact of labour force on economic growth conditioned on average values of ICT[4]. In essence, these outcomes show if ICT enhances or distorts the impact of labour on economic growth. At face value, the interaction effect on economic growth is negative statistically significant across all model specification but further examination reveals that labour force has a positive (negative) net effect on growth for mobile phones (fixed telephones). Following from Equation (4) the net effect is computed as:

[2.157+(-0.101*15.615)] = 0.58% for mobile phones; and
[0.944+(-0.132*13.891)] = -0.89% for fixed telephone, respectively.

Deductively, it suggests that labour force contributes positively to growth when mobile phone adoption is accounted relative to the negative outcome observed with fixed telephone usage. These outcomes are not only plausible but lend credence to the following conclusions: (1) an individual may be more productive using a mobile phone than a fixed telephone; (2) mobile phones usage has more advantages than a fixed telephone such as easy-to-carry around, affordability and reduced time/costs enabling sellers to advertise and connect to many consumers at the same time (Adeleye & Eboagu, 2019; Adeleye *et al.*, 2021a); and (3) mobile phones usage is most common among individuals unlike fixed telephone that is common with corporate organisations. The net outcomes of labour on growth after accounting for mobile phones and fixed telephones show that ICT is an important growth factor (Kim *et al.*, 2021; Ngoa & Song, 2021). This is another angle to the contributory role of ICT on economic growth and addresses our third objective.

Robustness is tested using the random effects IV-2SLS technique which accounts for any possible endogeneity in the model. The results shown in columns [7] to [12] are not significantly different from the main analysis. In columns [7] and [10] the effect of ICT on growth is inconclusive due to statistically insignificant coefficients. Columns [8] and [11] reveal that the growth-inducing impact of labour force is sustained and lastly the interaction effect, though negative, shows that the net impact of labour conditioned on average value of mobile phone (fixed telephone) is 0.98% (-20.20%). Again, it is observed that labour's productivity is enhanced when mobile phone usage is intensified relative to fixed telephones. This gives some validation to the results obtained from the main analysis.

4.4 Income Groups Results

The results of the income groups are displayed in Table no. 6 (High Income), Table no. 7 (Lower-middle Income) and Table no. 8 (Upper-middle Income) and their interpretations are taken in turns. Like Table no. 5, interpretation is restricted to the variables of interest. From Table no. 6, the nonlinear U-shaped relationship between ICT and growth is evident mostly for the mobile phone models. The output elasticity is higher from mobile phone usage which gives the indication that it is a more potent ICT indicator relative to fixed telephone which may jumpstart growth in developed economies. These results situate previous studies who find that ICT increases output in developed high income economies (Ceccobelli *et al.*, 2012; Mačiulytė-Šniukienė & Gaile-Sarkane, 2014; Niebel, 2018; Appiah-Otoo & Song, 2021). As expected, the effect of labour force on growth is positive and statistically significant in seven out of eight models suggesting that labour force enhances output in developed economies (Docquier *et al.*, 2019; Ruiters & Charteris, 2020). The interaction coefficient is

negative and statistically significant only in column [3] while it is zero[5] in the rest models. Hence, the net impact of labour force on growth when ICT[6] is accounted for at the mean value is computed as 1.72%, 2.12%, and 1.94% for mobile phones and fixed telephones, respectively. These outcomes support the labour-enhancing effect of ICT (Ceccobelli *et al.*, 2012; Grigoli *et al.*, 2020; Ngoa & Song, 2021).

For the results of lower-middle income countries shown in Table no. 7, ICT reveals a significant U-shaped relation to economic growth in six out of eight models. Again, it is inferred that the leapfrog hypothesis holds in developing economies (Steinmueller, 2001; Sein & Harindranath, 2004; Adeleye & Eboagu, 2019; Sein *et al.*, 2019). The impact of labour force is positive and statistically significant in three models mostly for the main analysis. Thus, we find evidence to support the growth-enhancing properties of labour force in developing and emerging economies (Roa *et al.*, 2011; Tsani *et al.*, 2013; Cylus & Al Tayara, 2021; Ngoa & Song, 2021).

On whether ICT enhances the impact of labour on growth, the interaction coefficient is negative and statistically significant in three out of four models. Computing the net effect of labour force on growth at the mean values of ICT[7] yields 0.57%, -4.37%, and -3.74%, respectively. Cursory observation indicates that while labour force exerts positive outcomes on growth when interacted with mobile phones, the opposite occurs when fixed telephone is interacted. Similar to the conclusion made on the full sample, these outcomes suggest that mobile phone usage has positive attributes to economic growth relative to fixed telephones. Lastly, the results for upper-middle income countries which are displayed in Table no. 8 provide evidence of a U-shaped ICT relation with economic growth only in columns [1] and [2]. This again validates the ICT leapfrog hypothesis using mobile phones (Ghosh, 2016; Myovella *et al.*, 2020). The impact of labour force is asymmetric (columns 3 and 9). The interaction effect (columns 3 and 9) is also asymmetric and the net impact of labour force at the mean values of ICT[8] is 0.13% and 0.15% which is evident when labour force is interacted with mobile phone usage.

What stands out from the income group analyses is that the U-shaped ICT-growth relation is consistent with mobile phones model. This is an indication that mobile phone usage has more growth-enhancing properties than fixed telephone usage. Also, the growth-stimulating impact of labour force is consistently positive only in high income countries while asymmetric in other groups. Lastly, though the interaction effect is mostly negative across the income groups, the computation of the net effects of labour force at the mean values of ICT reveals that mobile phones is more growth-complementary than fixed telephones. These mixed outcomes justify the engagement of income groups analysis since an aggregated sample may not exactly reveal these intrinsic relationships among the variables and across the sub-groups in the panel.

Table no. 6 – High Income Sample Results

Variables	PSCC-Fixed Effects, Main						Random Effects IV-EC2SLS, Robustness					
	Mobile Cellular Subscription			Fixed Telephone Subscription			Mobile Cellular Subscription			Fixed Telephone Subscription		
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]
lnICT	-1.044***	-0.787***	0.747***	-0.0172	0.104***	0.581	-0.892*	-0.843*	-2.144	-0.0174	0.0818	0.459
	(-5.589)	(-10.51)	(3.633)	(-0.580)	(5.222)	(0.647)	(-1.824)	(-1.872)	(-1.534)	(-0.188)	(0.994)	(0.347)
lnICTSQ	0.0292***	0.0231***		0.0100	-0.0176***		0.0263*	0.0256*		0.00876	-0.0133	
	(5.371)	(10.23)		(1.410)	(-4.062)		(1.740)	(1.845)		(0.544)	(-0.919)	
lnNET	-0.0941**	-0.0738**	-0.114***	-0.183***	-0.108***	-0.115***	-0.0536	-0.0397	-0.0837*	-0.113*	-0.0706	-0.0698
	(-2.642)	(-2.302)	(-3.902)	(-4.284)	(-3.471)	(-3.755)	(-0.946)	(-0.795)	(-1.676)	(-1.888)	(-1.335)	(-1.327)
lnGFCF	0.198***	0.176***	0.151***	0.169***	0.156***	0.155***	0.168***	0.157***	0.160***	0.152***	0.143***	0.143***
	(11.43)	(9.714)	(7.148)	(8.505)	(7.698)	(7.957)	(4.780)	(5.051)	(4.633)	(4.309)	(4.617)	(4.586)
EDUC	0.552*	0.687*	0.685**	0.560*	0.737**	0.719*	0.901***	0.840***	0.968***	0.799***	0.811***	0.808***
	(1.922)	(1.976)	(2.051)	(1.973)	(2.144)	(2.027)	(3.158)	(3.340)	(3.476)	(2.738)	(3.153)	(3.142)
IQI	0.0724***	0.0686***	0.0694***	0.0725***	0.0711***	0.0711***	0.0857***	0.0744***	0.0878***	0.0897***	0.0791***	0.0797***
	(3.643)	(3.743)	(3.735)	(3.425)	(3.643)	(3.660)	(5.247)	(5.142)	(5.308)	(5.528)	(5.512)	(5.537)
lnLAB		1.649***	4.569***		1.739***	2.120***		1.600***	-6.370		1.579***	1.943*
		(8.213)	(4.946)		(7.965)	(3.284)		(8.132)	(-1.217)		(7.560)	(1.862)
lnLAB*lnICT			-0.181***			-0.131			0.490			-0.103
			(-3.988)			(-0.642)			(1.518)			(-0.342)
Net Impact			**1.72%**			**2.12%**			**0%**			**1.94%**
Constant	18.74***	9.038***	-9.399**	9.959***	2.030*	0.523	16.79***	9.304**	37.37*	9.655***	2.600**	1.104
	(12.62)	(7.705)	(-2.278)	(38.91)	(1.919)	(0.198)	(4.348)	(2.416)	(1.655)	(24.96)	(2.560)	(0.241)
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	338	338	338	337	337	337	303	303	303	301	301	301
Countries	35	35	35	35	35	35	35	35	35	35	35	35
F/Wald Statistic	78040	23986	1.579e+06	33633	882759	437451	437.6	640.9	545.7	427.2	606.3	614.8

Note: *** p<0.01, ** p<0.05, * p<0.1; t-statistics in ( ); PC = GDP per capita; GFCF = gross fixed capital formation; NET = Individuals using the Internet; IQI = Institutional quality index; EDUC = Education index; LAB = Labour force participation.

Source: authors' computations

Table no. 7 – Lower-Middle Income Sample Results

Variables	PSCC-Fixed Effects, Main						Random Effects IV-EC2SLS, Robustness					
	Mobile Cellular Subscription			Fixed Telephone Subscription			Mobile Cellular Subscription			Fixed Telephone Subscription		
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]
lnICT	-0.146*	-0.344**	0.808**	-0.0488***	-0.0657***	1.947***	-0.137	-0.644***	1.244	-0.0421**	-0.0439	1.304*
	(-1.857)	(-2.820)	(2.977)	(-3.335)	(-3.455)	(5.087)	(-1.437)	(-3.081)	(1.525)	(-2.082)	(-1.335)	(1.840)
lnICTSQ	0.00418	0.0105**		0.0226***	0.0256***		0.00417	0.0197***		0.0206***	0.0202**	
	(1.701)	(2.698)		(5.062)	(5.061)		(1.362)	(3.053)		(3.290)	(2.246)	
lnNET	0.0205***	0.0314***	0.0274**	0.00396	-0.000165	0.0137***	0.0230	0.0450**	0.0321*	0.00784	-0.000149	-0.00915
	(3.862)	(3.560)	(2.716)	(0.895)	(-0.0309)	(3.553)	(1.405)	(2.367)	(1.672)	(0.564)	(-0.00745)	(-0.298)
lnGFCF	0.0396*	0.0263	0.0227	0.00564	0.0173	0.0294	0.0429	-0.00910	0.0145	0.0261	0.0127	-0.00483
	(1.873)	(1.015)	(0.854)	(0.236)	(0.780)	(1.215)	(1.406)	(-0.250)	(0.398)	(0.911)	(0.319)	(-0.0715)
EDUC	1.189*	1.564***	2.091***	2.564***	2.562***	2.111***	1.347**	1.748***	2.112***	2.253***	2.191***	1.535***
	(1.887)	(3.105)	(3.832)	(11.32)	(9.153)	(5.405)	(2.531)	(3.322)	(3.977)	(4.833)	(4.883)	(3.893)
IQI	0.0712**	0.0656**	0.0587**	0.0407**	0.0507***	0.0591***	0.0603***	0.0609**	0.0668***	0.0478**	0.0797***	0.173***
	(2.627)	(2.703)	(2.530)	(2.579)	(3.096)	(3.964)	(2.581)	(2.547)	(2.694)	(2.420)	(3.217)	(5.790)
lnLAB		0.547**	3.596***		0.382	1.287***		0.198	4.949		-0.0232	0.364
		(2.452)	(3.905)		(1.517)	(4.027)		(0.673)	(1.590)		(-0.0790)	(0.723)
lnLAB*lnICT			-0.194***			-0.444***			-0.297			-0.294*
			(-3.064)			(-5.063)			(-1.536)			(-1.781)
Net Impact			**0.57%**			**-4.37%**			**0%**			**-3.74%**
Constant	7.964***	6.982***	-8.839*	5.936***	4.340***	0.602	7.926***	11.02***	-14.33	6.323***	6.614***	5.579**
	(8.137)	(4.749)	(-2.095)	(31.17)	(4.364)	(0.475)	(8.347)	(4.809)	(-1.084)	(19.95)	(4.774)	(2.472)
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	128	120	120	128	120	120	113	106	106	113	106	106
Countries	15	14	14	15	14	14	15	14	14	15	14	14
F/Wald Statistic	365641	232601	18028	6800	20716	582.2	542.1	507.9	456.3	597.8	377.8	219.8

Note: *** p<0.01, ** p<0.05, * p<0.1; t-statistics in ( ); PC = GDP per capita; GFCF = gross fixed capital formation; NET = Individuals using the Internet; IQI = Institutional quality index; EDUC = Education index; LAB = Labour force participation.

Source: authors' computations

Table no. 8 – Upper-Middle Income Sample Results

Variables	PSCC-FE						Random Effects IV-EC2SLS, Robustness					
	Mobile Cellular Subscription			Fixed Telephone Subscription			Mobile Cellular Subscription			Fixed Telephone Subscription		
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]
lnICT	-0.346**	-0.347**	-0.174**	-0.280*	-0.265*	-0.348	0.184	0.201	1.387*	-0.169	-0.205	1.503
	(-2.308)	(-2.370)	(-2.108)	(-2.042)	(-1.897)	(-0.547)	(0.756)	(0.912)	(1.896)	(-0.700)	(-0.847)	(1.076)
lnICTSQ	0.0153***	0.0157***		0.0412	0.0389		-0.00242	-0.00306		0.0274	0.0332	
	(3.416)	(3.765)		(1.650)	(1.501)		(-0.328)	(-0.455)		(0.640)	(0.776)	
lnNET	-0.0468	-0.0413	-0.0505	0.0158	0.00994	0.0121	-0.0139	-0.00598	-0.0321	0.0414	0.0449	0.0557
	(-1.445)	(-1.190)	(-1.374)	(0.937)	(0.450)	(0.494)	(-0.299)	(-0.124)	(-0.619)	(0.834)	(0.876)	(1.006)
lnGFCF	-0.00521	-0.0150	-0.0205	0.00781	0.0120	0.0145	0.0302	0.0269	-0.00431	0.0474	0.0398	0.0508
	(-0.116)	(-0.308)	(-0.428)	(0.225)	(0.328)	(0.418)	(0.763)	(0.634)	(-0.0912)	(1.120)	(0.912)	(1.196)
EDUC	-0.578	-0.567	-0.655*	-0.237	-0.258	-0.279	-0.333	-0.228	0.0349	-0.167	-0.156	-0.0867
	(-1.504)	(-1.503)	(-1.854)	(-0.805)	(-0.831)	(-0.753)	(-1.013)	(-0.677)	(0.0932)	(-0.481)	(-0.445)	(-0.226)
IQI	-0.0333*	-0.0280	-0.0360**	-0.0374**	-0.0402**	-0.0377**	-0.0246*	-0.0210	-0.0216	-0.0235	-0.0206	-0.0248
	(-1.895)	(-1.682)	(-2.232)	(-2.189)	(-2.182)	(-2.305)	(-1.650)	(-1.277)	(-1.288)	(-1.481)	(-1.216)	(-1.485)
lnLAB		0.171	-1.204***		-0.0893	-0.330		0.0341	4.854*		0.115	1.082
		(1.505)	(-3.049)		(-0.530)	(-0.610)		(0.181)	(1.766)		(0.565)	(1.060)
lnLAB*lnICT			0.0867***			0.0710			-0.305*			-0.359
			(4.202)			(0.464)			(-1.761)			(-1.091)
Net Impact			**0.13%**			**0%**			**0.15%**			**0%**
Constant	10.76***	9.946***	11.30***	9.184***	9.551***	10.28***	6.774***	6.419***	-13.01	8.944***	8.520***	4.032
	(9.196)	(6.750)	(7.393)	(27.17)	(11.24)	(4.152)	(3.344)	(3.280)	(-1.126)	(17.24)	(8.553)	(0.881)
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	169	168	168	168	168	168	149	149	149	149	149	149
Countries	20	19	19	19	19	19	19	19	19	19	19	19
F/Wald Statistic	5.810e+09	100411	1.311e+06	5.539e+06	85078	371212	406.8	382.9	361.0	341.5	348.1	374.3

Note: *** p<0.01, ** p<0.05, * p<0.1; t-statistics in ( ); PC = GDP per capita; GFCF = gross fixed capital formation; NET = Individuals using the Internet; IQI = Institutional quality index; EDUC = Education index; LAB = Labour force participation.

Source: authors' computations

5. CONCLUSION AND POLICY RECOMMENDATIONS

This study is original and novel as it provides evidence about the role information and communications technology (ICT) plays in the actualization of the 2030 United Nations Sustainable Development Goals most especially SDG 8 which is "Sustained, inclusive and sustainable economic growth, employment and decent work" since labour force is a crucial input of production and economic growth. Given this, we have expanded the frontiers of knowledge to: (i) test the ICT leapfrogging hypothesis; (ii) probe the growth-enhancing impact of labour force participation; (iii) assess the net effect of labour force on economic growth; and (iv) evaluate if the impact is heterogeneous by income groups. To probe the discourse, an unbalanced panel data from 81 countries located in Europe and Central Asia (ECA) and East Asia and the Pacific (EAP) from 2010-2019 is used. Also, to observe if the outcomes differ by the state of economic development, the full sample is divided along four income delineations and analyzed using two robust estimations (PSCC-FE and RE-IV2SLS). Some novel results that emerge are as follows: (i) the ICT leapfrogging hypothesis holds for the full sample and consistent for high income countries; (ii) economic growth is an increasing function of labour force participation; (iii) the net effect of labour force on economic growth is mostly positive with mobile phones as the ICT indicator; and (iv) there are mixed effects across income groups.

Policy recommendations are not far-fetched. With ICT as an enabler of economic growth, we recommend that stakeholders and respective government should channel resources that will enable the population to have unfettered access to ICT apparatus. With labour as a significant growth determinant, we suggest that policies (health and education) be put in place to enable "labour" to become more economically productive. Lastly, the results from the income groups suggest that a uniform policy will be out-of-place. Hence, the state of developments of these countries must be considered in crafting the most-fit policies that will trigger the optimal productivity of ICT and labour force on economic growth. This study is limited by data to test if institutional quality influences the impact of ICT on the labour-growth dynamics. Hence, future studies may want to investigate this nexus subject to data availability.

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ANNEX 1

Table no. 1A – List of Countries and Classifications

S/No.	Country	Region	Group	S/No.	Country	Region	Group
1	Albania	ECA	UMI	42	Malaysia	EAP	UMI
2	Armenia	ECA	UMI	43	Marshall Islands	EAP	UMI
3	Australia	EAP	HI	44	Moldova	ECA	LMI
4	Austria	ECA	HI	45	Mongolia	EAP	LMI
5	Azerbaijan	ECA	UMI	46	Montenegro	ECA	UMI
6	Belarus	ECA	UMI	47	Myanmar	EAP	LMI
7	Belgium	ECA	HI	48	Nauru	EAP	UMI
8	Bosnia and Herzegovina	ECA	UMI	49	Netherlands	ECA	HI
9	Brunei Darussalam	EAP	HI	50	New Zealand	EAP	HI
10	Bulgaria	ECA	UMI	51	North Macedonia	ECA	UMI
11	Cambodia	EAP	LMI	52	Norway	ECA	HI
12	China	EAP	UMI	53	Palau	EAP	HI
13	Croatia	ECA	HI	54	Papua New Guinea	EAP	LMI
14	Cyprus	ECA	HI	55	Philippines	EAP	LMI
15	Czech Republic	ECA	HI	56	Poland	ECA	HI
16	Denmark	ECA	HI	57	Portugal	ECA	HI
17	Estonia	ECA	HI	58	Romania	ECA	UMI
18	Fiji	EAP	UMI	59	Russian Federation	ECA	UMI
19	Finland	ECA	HI	60	Samoa	EAP	UMI
20	France	ECA	HI	61	San Marino	ECA	HI
21	French Polynesia	EAP	HI	62	Serbia	ECA	UMI
22	Georgia	ECA	LMI	63	Singapore	EAP	HI
23	Germany	ECA	HI	64	Slovak Republic	ECA	HI
24	Greece	ECA	HI	65	Slovenia	ECA	HI
25	Guam	EAP	HI	66	Solomon Islands	EAP	LMI
26	Hong Kong SAR, China	EAP	HI	67	South Korea	EAP	HI
27	Hungary	ECA	HI	68	Spain	ECA	HI
28	Iceland	ECA	HI	69	Sweden	ECA	HI
29	Indonesia	EAP	LMI	70	Switzerland	ECA	HI
30	Ireland	ECA	HI	71	Thailand	EAP	UMI
31	Italy	ECA	HI	72	Timor-Leste	EAP	LMI
32	Japan	EAP	HI	73	Tonga	EAP	UMI
33	Kazakhstan	ECA	UMI	74	Turkey	ECA	UMI
34	Kiribati	EAP	LMI	75	Turkmenistan	ECA	UMI
35	Kosovo	ECA	LMI	76	Tuvalu	EAP	UMI
36	Kyrgyz Republic	ECA	LMI	77	Ukraine	ECA	LMI
37	Lao PDR	EAP	LMI	78	United Kingdom	ECA	HI
38	Latvia	ECA	HI	79	Uzbekistan	ECA	LMI
39	Lithuania	ECA	HI	80	Vanuatu	EAP	LMI
40	Luxembourg	ECA	HI	81	Vietnam	EAP	LMI
41	Macao SAR, China	EAP	HI				

Note: EAP = East Asia and the Pacific; ECA = Europe and Central Asia; HI = High Income; LMI= Lower-middle Income; UMI = Upper-middle Income.

Source: authors' compilations

Table no. 1B – Variance Inflation Factor

			Mobile Phones Models		
Variable	**VIF**	**1/VIF**	**Variable**	**VIF**	**1/VIF**
EDUC	3.71	0.269473	EDUC	3.6	0.277528
lnNET	3.3	0.303372	lnNET	3.34	0.299093

		Mobile Phones Models			
Variable	**VIF**	**1/VIF**	**Variable**	**VIF**	**1/VIF**
IQI	2.61	0.383647	IQI	3.21	0.311708
y8	1.9	0.52642	y8	1.92	0.520256
y7	1.87	0.534747	y7	1.9	0.526025
y6	1.84	0.542434	y6	1.87	0.53603
y5	1.83	0.54525	y5	1.85	0.540818
y4	1.81	0.551753	y4	1.82	0.549002
y3	1.81	0.55224	y3	1.81	0.551297
y2	1.79	0.558609	y9	1.81	0.552538
y9	1.76	0.567816	y2	1.79	0.558278
y10	1.67	0.597376	y10	1.72	0.58177
lnGFCF	1.18	0.846752	lnLAB	1.38	0.725742
lnMOB	1.12	0.891127	lnGFCF	1.18	0.848123
			lnMOB	1.15	0.869338
Mean		**2.02**	**Mean**		**2.02**
		Fixed Telephones Models			
Variable	**VIF**	**1/VIF**	**Variable**	**VIF**	**1/VIF**
EDUC	3.78	0.264714	EDUC	3.66	0.273328
lnNET	3.34	0.299615	lnNET	3.37	0.296338
IQI	2.59	0.386544	IQI	3.14	0.318423
y8	1.91	0.523268	y8	1.94	0.51417
y7	1.89	0.529528	y7	1.92	0.520958
y6	1.86	0.538785	y6	1.88	0.532349
y5	1.84	0.542402	y5	1.86	0.537949
y3	1.81	0.55141	y9	1.83	0.546308
y4	1.8	0.554382	y3	1.82	0.550347
y2	1.79	0.558538	y4	1.81	0.551392
y9	1.78	0.56221	y2	1.79	0.558087
y10	1.69	0.591421	y10	1.74	0.574837
lnFTEL	1.24	0.807776	lnLAB	1.33	0.749375
lnGFCF	1.18	0.850761	lnFTEL	1.2	0.832059
			lnGFCF	1.18	0.850459
Mean		**2.04**	**Mean**		**2.03**

Note: y2, y3,…,y10 are Year Dummies.

Source: authors' computations

Notes

[1] Ericsson and the Earth Institute Report https://www.ericsson.com/assets/local/news/2016/05/ict-sdg.pdf.

[2] The labour force participation rate is the fraction of the population within a particular age group either working or looking for work. In the rest of the paper, "labour force participation" and "labour" are used interchangeably.

[3] See Annex Table 1A for the list of countries and their respective classifications.

[4] The mean values of lnMOB and lnFTEL for the full sample are 15.615 and 13.891, respectively.

[5]Non-significant interaction term implies that the coefficient is significantly not different from zero. Hence, the marginal effect equates to the net effect.

[6]The mean values of lnMOB and lnFTEL for high income countries are 15.735 and 14.406, respectively.

[7]The mean values of lnMOB and lnFTEL for lower-middle income countries are 15.578 and 12.732, respectively.

[8] The mean values of lnMOB and lnFTEL for upper-middle income countries are 15.426 and 13.858, respectively.

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Foreign Direct Investment-Growth Nexus in BRICS: How Relevant are the Absorption Capacities?

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Abstract: This study examined the impact of foreign direct investment on economic growth in BRICS using fixed effects, dynamic ordinary least squares (DOLS) and fully modified ordinary least squares (FMOLS). Panel data ranging from 1991 to 2019 was used for the purposes of this study. The same study also explored whether financial sector and human capital development are necessary absorption capacities that enhance economic growth in BRICS. To a larger extent, foreign direct investment had a negative impact on economic growth in BRICS, consistent with the dependency theory. Financial development was also found to be the channel through which economic growth is enhanced by foreign direct investment. Although the influence was observed to be non-significantly negative, human capital development improved the influence of foreign direct investment on economic growth. BRICS authorities are therefore urged to implement human capital and financial development enhancement policies to ensure significant foreign direct investment's positive influence on economic growth.

Keywords: foreign direct investment; economic growth; panel data; BRICS.

JEL classification: F21; F43; P2.

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1. INTRODUCTION

Foreign direct investment's influence on economic growth is well documented in the literature (Solow, 1956; Swan, 1956; Romer, 1986; Sanchez-Robles & Bengoa-Calvo, 2002; Adams, 2009; Zhang *et al.*, 2010; Fu *et al.*, 2011). Their argument is that foreign direct investment brings to the host country a whole lot of economic growth enhancing resources, like skills, managerial expertise, physical capital, human capital development, technology, among others. Others like Amin (1974) noted that foreign direct investment retards economic growth of the host country. Others argued for economic growth to be enhanced by foreign direct investment, certain preconditions must exist in the host country. Several empirical researchers on the subject matter also produced results which are divergent, inconsistent, mixed and far from reaching consensus. Some supported the positive foreign direct investment led growth hypothesis, others agree with the negative foreign direct investment led growth rationale whilst few produced results which show that the availability of certain absorption capacities in the host country is necessary if economic growth is to be enhanced by foreign direct investment. These mixed results, lack of consensus and divergent views on the economic growth impact of foreign direct investment prompted the author to carry out this study to contribute to literature and fill in these gaps.

The choice of BRICS as a unit of analysis is based on three reasons. Firstly, BRICS nations are emerging markets which have attracted significant amount of foreign direct investment inflows during the last two decades, consistent with Soumaré and Tchana Tchana (2015). Secondly, BRICS is an economic group of countries which have consistently and uniformly attracted huge amounts of foreign direct investment inflows.

The following four ways in which this study contributed towards literature are discussed. Majority of similar empirical research wrongly assumed that the foreign direct investment-growth nexus is a linear relationship. This study considered the fact that the relationship between economic growth and foreign direct investment is non-linear in nature. This study investigated the absorption capacities (financial development, human capital development) that are necessary for foreign direct investment's significant positive influence on economic growth. Most of the earlier similar empirical research on the subject matter did not focus on the aspect of absorption capacities. Unlike earlier related empirical research work, this study used the most recent panel data (1991-2019). Majority of relevant empirical literature focused on a single country analysis, of which the results are narrow focused. This study filled in that gap by using panel data analysis.

The remaining sections of the study are divided into eight. Section 2 deals with the literature review. Section 3 explains the influence of explanatory variables on the dependent variable. The research methodology is described and explained in Section 4. Main data analysis (correlation analysis, descriptive statistics, panel stationary tests, panel co-integration tests, final data analysis) is in Section 5. Section 6 concludes the study.

2. LITERATURE REVIEW

There are five theories and or theoretical rationales that explains the influence of foreign direct investment on economic growth. These include the endogenous growth theory, modernisation theory, neoclassical theory, dependency theory and the non-linear theoretical rationale.

According to Romer (1986), important ingredients for economic growth such as skills, managerial experience, technology and development of human capital flow alongside foreign direct investment into the host country. The modernisation theory argued that foreign direct investment forces (1) the host country's governments to liberalize both the financial and commodity markets, (2) enables social stability through creating employment opportunities and (3) promotes education of the people thereby stimulating economic growth (Sanchez-Robles & Bengoa-Calvo, 2002).

Proponents of the neoclassical theory, Solow (1956) and Swan (1956) argued that foreign direct investment's ability to bring along with it and adding physical capital stock not only improves liquidity levels in the host country but stimulates economic growth as well. The dependency theory propounded by Amin (1974) noted that an economy which is not controlled by its own local citizens cannot organically growth and is fragile and prone to instability. Such a scenario causes foreign direct investment to have a deleterious effect on the economy of the host country.

The non-linear theoretical rationale argues that the host country should have certain absorption capacities that enable foreign direct investment to enhance economic growth (Adams, 2009; Zhang *et al.*, 2010; Fu *et al.*, 2011; Tanggapan *et al.*, 2011). Tanggapan *et al.* (2011), Baharumshah and Almasaied (2009) and Shahbaz and Rahman (2010) noted that financial sector and human capital development were the existing preconditions in the host country that enhanced significant economic growth.

Apart from human capital and financial development, other absorption capacities which were observed to improve foreign direct investment's impact on the economy are technological advancement (Bailliu, 2000), smooth regulatory environment (Lean, 2008; Xie & Wang, 2009), favourable macroeconomic business environment (Adams, 2009; Azam & Ahmed, 2014; Pegkas, 2015), infrastructural development (Adams, 2009; Xie & Wang, 2009), excellent corporate governance practices (Adeoye, 2007).

The existing empirical research results falls into four categories. Firstly, is the foreign direct investment inspired positive economic growth view which was supported by Awolusi and Adeyeye (2016), Moudatsou (2003), Tshepo (2014), Chaudhury *et al.* (2020), Ayenew (2022), Gui-Diby (2014), Bekere and Bersisa (2018), Nguyen (2020), Mehdi (2011), Forte and Moura (2013), Gochero and Boopen (2020), Zain (2019) and Gudaro *et al.* (2012), among others.

In the context of Africa, Awolusi and Adeyeye (2016) using the generalised methods of moments (GMM) with panel data spanning from 1980 to 2013 explored the influence of foreign direct investment on the growth of the economy in Africa. Foreign direct investment had an insignificant enhancing influence on economic growth in Africa. Using panel data (1980-1996) analysis, Moudatsou (2003) examined the relationship between foreign direct investment and economic growth in the context of European Union. Economic growth of the European Union bloc of countries was found to have been directly or indirectly enhanced by foreign direct investment inflows. Employing time series data analysis in the context of South Africa, Tshepo (2014) explored the foreign direct investment-growth-employment nexus using data ranging from 1990 to 2013. Both economic growth and employment was found to have been positively influenced by foreign direct investment in the short and long run. Using a multi-regression analysis, Chaudhury *et al.* (2020) examined the impact of foreign direct investment on the growth of the economy in South Asian countries. The foreign direct investment sectoral composition had a huge influence on the way economic growth was affected by foreign direct investment.

Ayenew (2022) examined the influence of foreign direct investment on economic growth using the ARDL approach with data ranging from 1988 to 2019 in Sub-Saharan African nations. The short run shows that economic growth was insignificantly enhanced by foreign direct investment whilst the long run produced results which indicates that foreign direct investment had a significant enhancement effect on economic growth in Sub-Saharan Africa. Gui-Diby (2014) examined the linkage between economic growth and foreign direct investment in Africa using panel data (1980-2009) analysis, the system GMM methodology. A significant positive relationship from foreign direct investment towards economic growth was observed in the context of Africa. Bekere and Bersisa (2018) also examined a similar topic in East Africa using the dynamic GMM with panel data spanning from 1996 to 2015. A significant enhancing influence of foreign direct investment on economic growth was noted in this study.

Using Vietnam's time series annual data from 1997 to 2018, Nguyen (2020) examined the nexus between foreign direct investment, exports, aid and economic growth. The study revealed that foreign direct investment, exports and aid individually had a positive influence on the growth of Vietnam's economy. Using Middle East countries as a unit of analysis, Mehdi (2011) examined the influence of foreign direct investment on economic growth using panel data (1980-2008) analysis. Economic growth was observed to have been indirectly and directly affected by foreign direct investment. Forte and Moura (2013) examined the nexus between economic growth and foreign direct investment using literature analysis approach. Their study noted that economic growth was enhanced by foreign direct investment.

Gochero and Boopen (2020) investigated the influence of mining foreign direct investment on the growth of the Zimbabwe economy using the ARDL approach with annual time series data spanning from 1988 to 2018. The study noted that in the long run, economic growth was significantly enhanced by mining foreign direct investment. Non-mining foreign direct investment had a lower economic growth impact on the economic growth of Zimbabwe during the period under study. Zain (2019) examined the economic growth influence of foreign direct investment on the economic growth of Pakistan using multi-regression analysis with annual time series data spanning from 2000 to 2016. Economic growth of Pakistan was enhanced by foreign direct investment during the period under study. Employing the multi-regression model with time series data (1981-2010), Gudaro *et al.* (2012) studied the impact of foreign direct investment on Pakistan's economic growth trajectory. Foreign direct investment's impact on Pakistan's economy was observed to be significantly positive.

Secondly, is the foreign direct investment inspired negative economic growth views which was supported by Dinh *et al.* (2019). Using the fully modified ordinary least squares (FMOLS) and vector error correction model with data ranging from 2000 to 2014, Dinh *et al.* (2019) examined the role of foreign direct investment in influencing economic growth in developing countries. Foreign direct investment had a stimulating impact on economic growth in the long run whilst the short run produced results which shows that foreign direct investment had a deleterious effect on economic growth in developing countries.

Thirdly, is the bi-directional view between foreign direct investment and economic growth and this was supported by Makhoba and Zungu (2021), among others. The relationship between economic growth and foreign direct investment was also investigated by Makhoba and Zungu (2021) in the context of South Africa using the vector autoregressive approach with annual time series data spanning from 1960 to 2019. Their study revealed that foreign direct investment and economic growth influenced one another in the context of South Africa.

Fourthly, is the view that certain absorption capacities should exist in the host country before foreign direct investment significantly affect economic growth. The view was supported by Kulu *et al.* (2021), Mahembe and Odhiambo (2014), Baiashvili and Gattini (2020), Mamingi and Martin (2018), Borensztein *et al.* (1998), Koojaroenprasit (2012) and Mboko Ibara (2020), among others. Kulu *et al.* (2021) investigated the influence of institutions in the foreign direct investment-growth nexus in Ghana using the autoregressive distributive lag (ARDL) using secondary data (annual time series) ranging from 1995 to 2019. The complementarity between foreign direct investment and quality institutions had a better positive impact on economic growth compared to their individual influence in both the short and long run. Mahembe and Odhiambo (2014) investigated the economic growth influence of foreign direct investment using a theoretical framework analysis. Their study noted that foreign direct investment enhances economic growth through the technology and knowledge transfer channels. Baiashvili and Gattini (2020) used the GMM approach to find out the influence of foreign direct investment on economic growth in both developing and developed countries. Their study noted that the influence of foreign direct investment on economic growth is in the form of a U-shape. The influence of foreign direct investment on economic growth becomes more pronounced from low to middle-income nations.

Employing the GMM methodology with panel data spanning from 1988 to 2013, Mamingi and Martin (2018) studied the nexus between economic growth and foreign direct investment in the Organisation of Eastern Caribbean States (OECS). Foreign direct investment's positive influence on economic growth was quite minimal in the OECS group of nations. However, the complementarity between infrastructural development and foreign direct investment had a significant positive effect on the growth of the economy in the OECS countries.

In a study of 69 developing nations, Borensztein *et al.* (1998) noted that foreign direct investment enhances economic growth through technology transfer channel. The study also observed that the positive influence of foreign direct investment on economic growth was more pronounced at higher threshold levels of human capital development. Sufficient availability of advanced technology in the host country was also found to be another precondition before economic growth is significantly enhanced by foreign direct investment.

Koojaroenprasit (2012) studied the foreign direct investment's growth effects in South Korea using multiple regression analysis with annual time series data spanning from 1980 to 2009. Foreign direct investment had a strong enhancing effect on the economy of South Korea. On the other hand, the interactions between (1) human capital development and foreign direct investment and (2) exports and foreign direct investment enhanced economic growth in South Korea in a negative manner. The system GMM approach with annual panel data (1970-2019) was used by Mboko Ibara (2020) to examine the economic growth effects of foreign direct investment in the Central African Economic and Monetary Community (CEMAC) region. The study noted that foreign direct investment had a direct influence on economic growth of the CEMAC region. On the other hand, human capital development was found to have enhanced the economic growth influence of foreign direct investment in CEMAC region.

These mixed, divergent, diverse and conflicting findings from related empirical literature provides evidence that the nexus between foreign direct investment and economic growth is not yet decided and is still unsettled in the field of finance and economics. Further empirical research can still help to dissect and conclude on the influence of foreign direct investment on economic growth in BRICS. This study used BRICS as a focal point unlike

existing empirical studies which totally ignored the growth-foreign direct investment nexus in such an emerging and important emerging economic grouping.

3. EXPLANATORY VARIABLES

Table no. 1 – Economic growth function – Explanatory variables

Variable (s)	Measure used	Explanation	Expected impact on growth
Financial development (FIN)	Domestic credit to private sector (% of GDP)	The financial sector help in transferring the financial resources from the surplus sector to the deficit sector of the economy (Schumpeter, 1911). McKinnon (1973) and Shaw (1973) also argued that efficient allocation of financial resources in the economy is performed better by a developed financial sector.	+
Human capital development (HCD)	Human capital development index	Highly skilled, educated and healthy workforce is more productive and contributes more towards technological diffusion and innovation in the economy (Pelinescu, 2015).	+
Infrastructural development (INFR)	Individuals using internet (% of population)	Denisia (2010) argued that infrastructural development is one of the locational advantages of foreign direct investment, thereby indirectly enhancing economic growth. One of the ingredients which is necessary for economic growth to take place is the availability of developed infrastructure (Fedderke & Garlick, 2008).	+
Trade openness (OPEN)	Total of exports and imports (% of GDP)	Coe and Helpman (1995) argued that when the level of trade openness of a country is very high, local firms can easily acquire cheaper and efficient inputs and raw materials for their own manufacturing processes from wherever there are. International trade brings in a substantial amount of foreign currency into the country (Hart, 1983). The local industry can be badly affected because its products might not be preferred as compared to foreign products (Baltagi *et al.*, 2009).	+/-
Savings (SAV)	Gross domestic savings (% of GDP)	Increased quantity of savings in the economy enhances the general level of investment and economic growth (Romer, 1986; Singh, 2010).	+
Population growth (POP)	Population growth (% annual)	Increased population growth enhances technological progress and economies of scale, which are the ingredients for economic growth (Peter & Bakari, 2018). Population growth negatively affects economic growth because increased number of people contributes to a faster depletion of natural resources, argued Sachs (2008).	+/-
Personal remittances (REMIT)	Personal remittances received (% of GDP)	According to Adarkwa (2015), personal remittances brings in foreign currency into the labour sending country, reduces liquidity constraints in the economy and enables children in remittance receiving households to attend school and acquire skills. Remittances creates overreliance on the support from relatives working outside the country therefore creating laziness among the people who remained behind. Such laziness deletes the positive effects remittances might have been able to bring into the labour sending country's economy, consistent with (Meyer & Shera, 2017).	+/-

Source: author

Net FDI inflows is a measure of foreign direct investment used whilst real gross domestic product (GDP) per capita is the proxy of economic growth employed in this study, consistent with empirical studies done by Gui-Diby (2014), Bekere and Bersisa (2018), Nguyen (2020), Mehdi (2011), Koojaroenprasit (2012), Gochero and Boopen (2020), Forte and Moura (2013), Dinh *et al.* (2019), Zain (2019), Gudaro *et al.* (2012), Pandya and Sisombat (2017) and Mboko Ibara (2020), among others. Alongside data availability considerations, the same empirical studies influenced the selection of proxies used for these variables (dependent and explanatory variables).

4. RESEARCH METHODOLOGY

4.1 Data

Panel data ranging from 1991 to 2019 for BRICS countries was employed in this study. World Development Indicators is the major database that was made use in this study.

4.2 Model descriptions

The general model specification is as follows:

$$GROWTH=f\ (FDI, FIN, HCD, REMIT, INFR, OPEN, SAV) \quad (1)$$

Empirical research which informed the use of explanatory variables in equation (1) includes but are not limited to Kulu *et al.* (2021), Awolusi and Adeyeye (2016), Moudatsou (2003), Tshepo (2014), Mahembe and Odhiambo (2014), Baiashvili and Gattini (2020), Chaudhury *et al.* (2020), Ayenew (2022), Makhoba and Zungu (2021), Mamingi and Martin (2018) and Borensztein *et al.* (1998).

Econometrically, equation (2) represents the dependent variable (economic growth), independent variable (foreign direct investment) and explanatory variables (financial development, human capital development, personal remittances, infrastructural development, trade openness, savings).

$$\begin{aligned} GROWTH_{it} &= \beta_0 + \beta_1 FDI_{it} + \beta_2 FIN_{it} + \beta_3 (FDI_{it}.FIN_{it}) + \\ &\beta_4 HCD_{it} + \beta_5 REMIT_{it} + \beta_6 INFR_{it} + \beta_7 OPEN_{it} + \beta_8 SAV_{it} + \mu + \varepsilon \end{aligned} \quad (2)$$

Table no. 2 – Decomposition of equation 2 components

t	Time
β_0	Intercept
$GROWTH_{it}$	Economic growth in country i at time t
FDI_{it}	Foreign direct investment in country i at time t
FIN_{it}	Financial development in country i at time t
HCD_{it}	Human capital development in country i at time t
$REMIT_{it}$	Personal remittances in country i at time t

β_1 to β_8	Explanatory variables' co-efficients
$INFR_{it}$	Infrastructural development in country i at time t
$OPEN_{it}$	Trade openness in country i at time t
ε	Error
SAV_{it}	Savings in country i at time t
i	Country
μ	Time invariant and unobserved country specific effect

Source: author

Equation (2) also included the complementary variable β_3(FDIit.FINit). This information was used to examine if financial development is a channel through which foreign direct investment enhances economic growth in BRICS. It's also used to investigate the influence of the combination of foreign direct investment and financial development on economic growth in BRICS. This is consistent with earlier research work (Adams, 2009; Baharumshah & Almasaied, 2009; Shahbaz & Rahman, 2010; Zhang *et al.*, 2010; Fu *et al.*, 2011; Tanggapan *et al.*, 2011) which argued certain absorption capacities (human capital development, financial development) are necessary in the host country to enable foreign direct investment to have a significant positive impact on economic growth. Dynamic ordinary least squares (DOLS), fixed effects and fully modified ordinary least squares (FMOLS).

5. MAIN DATA ANALYSIS

Stationarity tests, co-integration tests and main data analysis constitutes this section. Table no. 8 (annex section) shows the existence of a multi-collinearity problem between infrastructural development and economic growth, consistent with Stead (2007) argument. Table no. 9 (annex section) also indicates that there are outliers in the economic growth and financial development data set (range and standard deviation indicators) and that the data for all the variables used is not normally distributed (Jarque-Bera criteria's probabilities)-see Tsaurai and Ngcobo (2018). Consistent with Aye and Edoja (2017) and to address these issues, all the data used had to be converted into natural logarithms before use.

5.1 Panel stationarity investigation

Table no. 3 – Panel stationarity results –Individual intercept

	Levin *et al.* (2002) tests	Im *et al.* (2003) tests	ADF Fisher Chi Square tests	PP Fisher Chi Square tests
Level				
GROWTH	-1.04	0.95	5.26	3.14
FDI	-2.22**	-2.39***	22.29**	35.98***
FIN	-0.53	0.17	8.54	11.15
HCD	-3.45***	-3.03***	27.17***	33.86***
REMIT	-3.46***	-2.86***	25.74***	20.17**
INFR	-6.51***	-4.32***	38.90***	49.19***
OPEN	-1.49**	-1.50*	17.88*	30.58***
SAV	-1.30*	-1.94**	23.03**	12.15

	Levin *et al.* (2002) tests	Im *et al.* (2003) tests	ADF Fisher Chi Square tests	PP Fisher Chi Square tests
First difference				
GROWTH	-5.27***	-4.10***	35.17***	43.19***
FDI	-6.61***	-8.14***	74.78***	112.38***
FIN	-2.39***	-4.74***	43.24***	59.17***
HCD	-9.94***	-9.83***	91.48***	122.92***
REMIT	-6.47***	-6.82***	61.38***	99.06***
INFR	-2.16**	-2.20**	20.09**	23.53***
OPEN	-3.91***	-5.73***	51.46***	90.42***
SAV	-4.02***	-4.50***	40.56***	64.53***

Source: E-Views

The data for all the variables were integrated of order 1 (stationary at first difference) - see Table no. 3. These results are an indication that all the data set were stable and stationary at first difference.

5.2 Panel co-integration tests

Table no. 4 – Johansen Fisher Panel Co-integration test

Hypothesised No. of CE(s)	Fisher Statistic (from max-eigen test)	Probability	Fisher Statistic (from trace test)	Probability
None	599.8	0.0000	164.7	0.0000
At most 1	255.3	0.0000	212.1	0.0000
At most 2	227.8	0.0000	110.6	0.0000
At most 3	124.7	0.0000	54.81	0.0000
At most 4	79.57	0.0000	37.67	0.0000
At most 5	49.63	0.0000	28.75	0.0014
At most 6	31.94	0.0004	26.06	0.0037
At most 7	23.14	0.0102	23.14	0.0102

Source: author's compilation from E-Views

According to Table no. 4 results, at most 7 co-integrating relationships were established. The results support the view that the variables used in this study have got a long run relationship, consistent with Tsaurai and Ngcobo (2018).

5.3 Main data analysis

Fixed effects and FMOLS shows that foreign direct investment had a significant negative influence on economic growth across all the three models (model 1, 2 and 3). DOLS produced results which indicates a non-significant negative relationship running from foreign direct investment towards economic growth in model 1 and 3 whilst model 2 shows the economic growth was negatively affected by foreign direct investment in a significant manner in BRICS. These results show that foreign direct investment has a deleterious influence on economic growth in BRICS, consistent with the dependency theory which argued that an economy which is not controlled by its own local citizens cannot organically growth and is fragile and prone to instability (Amin, 1974).

Table no. 5 – FDI and growth in BRICS –Fixed Effects

	Economic growth		
	(1)	**(2)**	**(3)**
FDI	-0.13***	-0.87***	-0.17*
FIN	0.42***	0.44***	0.41***
HCD	0.56	1.10**	0.47
REMIT	-0.09	-0.09*	-0.09
INFR	0.24***	0.25***	0.24***
OPEN	-0.65***	-0.62***	-0.67***
SAV	1.47***	1.43***	1.45***
FDI*FIN		0.18***	
FDI*HCD			-0.09
Number of countries	5	5	5
Adjusted R-squared	0.89	0.86	0.90
F-statistic	115	121	105
Prob(F-statistic)	0.00	0.00	0.00

Note: ***/**/* indicate 1%, 5% and 10% significance levels respectively
Source: E-Views

FMOLS and fixed effects shows a significant positive correlation running from foreign direct investment towards economic growth across all the models, results which also agrees with DOLS, model 2 and 3 in BRICS. Model 1 under DOLS shows that foreign direct investment had an insignificant positive effect on economic growth in BRICS. These results indicate that financial development enhanced economic growth in BRICS, consistent with McKinnon (1973) and (Shaw, 1973) whose studies noted that a developed financial sector enhances the efficient allocation of financial resources in the economy.

An insignificant positive influence of foreign direct investment on economic growth in BRICS was observed under the fixed effects (model 1 and 3), FMOLS (model 1, 2 and 3) and DOLS (model 2 and 3) whilst model 2 under fixed effects shows that economic growth was enhanced by foreign direct investment in a significant manner in BRICS. The results indicate that human capital development in BRICS is of paramount importance in as far as economic growth is concerned, in line with Pelinescu (2015) whose study argued that highly skilled, educated and healthy workforce is more productive and contributes more towards technological diffusion and innovation in the economy. Contrary to the available literature, model 1 under the DOLS approach noted that negative foreign direct investment's effect on economic growth was non-significant in BRICS.

Table no. 6 – FDI and growth in BRICS –Fully Modified Ordinary Least Squares (FMOLS)

	Economic growth		
	(1)	**(2)**	**(3)**
FDI	-0.16***	-0.82***	-0.21*
FIN	0.32**	0.35***	0.31**
HCD	0.35	0.98	0.46
REMIT	-0.08	-0.07	-0.08
INFR	0.27***	0.26***	0.27***
OPEN	-0.88***	-0.85***	-0.88***
SAV	1.86***	1.84***	1.84***
FDI*FIN		0.16**	

FDI*HCD			-0.16
Number of countries	5	5	5
Adjusted R-squared	0.89	0.91	0.89
Prob(F-statistic)	0.00	0.00	0.00

Note: ***/**/* indicate 1%, 5% and 10% significance levels respectively
Source: E-Views

Table no. 7 – FDI and growth in BRICS –Dynamic Ordinary Least Squares (DOLS)

	Economic growth		
	(1)	**(2)**	**(3)**
FDI	-0.16	-0.87***	-0.17
FIN	0.32	0.44***	0.41**
HCD	-0.33	1.10	0.47
REMIT	-0.75**	-0.09	-0.09
INFR	0.33***	0.25***	0.24***
OPEN	-0.24	-0.62**	-0.67**
SAV	1.49*	1.43***	1.45***
FDI*FIN		0.18**	
FDI*HCD			-0.09
Number of countries	5	5	5
Adjusted R-squared	0.96	0.91	0.90
Prob(F-statistic)	0.00	0.00	0.00

Note: ***/**/* indicate 1%, 5% and 10% significance levels respectively
Source: E-Views

Across all the three econometric estimation methods, the complementarity between foreign direct investment and financial development significantly enhanced economic growth in BRICS, consistent with Fu *et al.* (2011), Shahbaz and Rahman (2010) and Zhang *et al.* (2010) whose studies noted that absorption capacities such as human capital and financial development facilitates better influence of foreign direct investment on economic growth. A non-significant negative influence of foreign direct investment on economic growth in BRICS was observed under the fixed effects, DOLS and FMOLS. Although the overall impact of the complementarity variable is negative, it is however clear across all the three econometric methods that human capital development managed to reduce the size of the negative influence of foreign direct investment on the growth of BRICS countries. Such a result also resonates with Shahbaz and Rahman (2010), Fu *et al.* (2011) and Zhang *et al.* (2010) whose studies observed that absorption capacities are a necessary ingredient which improves the economic growth influence of foreign direct investment.

To a greater extent, it is observed that infrastructural development and savings' positive impact on economic growth in BRICS was significant. The results agree with the available literature (see Table no. 1). Trade openness had a significant negative effect on economic growth whereas economic growth was negatively affected by personal remittances in an insignificant manner in BRICS. The results generally are supported by existing literature, for example Baltagi *et al.* (2009) on trade openness-growth relationship and Meyer and Shera (2017) with regards to personal remittances-growth nexus.

6. CONCLUSION

This study added to the growing list of recent empirical researchers that produced results on the influence of foreign direct investment on the economy. Foreign direct investment negatively affected economic growth of BRICS countries during the period under study. The results are supported by the dependency theory explained by Amin (1974). Financial development was found to have significantly improved foreign direct investment's positive effect on economic growth in BRICS. In a non-significant manner, human capital development enhanced foreign direct investment's influence on the BRICS' economic fortunes. Further research investigating the minimum threshold levels of financial sector and human capital development that enhances significant positive effects of foreign direct investment on economic growth needs to be undertaken.

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ANNEX

Table no. 8 – Correlation analysis

	GROWTH	FDI	FIN	HCD	REMIT	INFR	OPEN	SAV
GROWTH	1.00							
FDI	0.17**	1.00						
FIN	0.25***	-0.02	1.00					
HCD	0.52***	0.19**	-0.03	1.00				
REMIT	-0.43***	-0.22***	-0.30***	-0.63***	1.00			
INFR	0.84***	0.16*	0.24***	0.39***	-0.24***	1.00		
OPEN	0.05	-0.02	0.12	0.18**	-0.05	0.10	1.00	
SAV	-0.18**	0.28***	-0.20**	0.03	0.06	-0.02	0.38***	1.00

Note: ***/**/* indicate 1%, 5% and 10% significance levels respectively

Source: E-Views

Table no. 9 – Descriptive statistics

	GROWTH	FDI	FIN	HCD	REMIT	INFR	OPEN	SAV
Mean	4 670	2.09	61.54	0.70	0.74	20.62	41.26	28.17
Median	3 480	1.81	51.89	0.72	0.24	8.07	42.30	25.76
Maximum	15 975	6.19	142.42	0.83	4.17	82.64	110.58	51.09
Minimum	301.16	0.01	11.76	0.44	0.03	0.01	15.64	15.09
Standard. deviation	3 827	1.48	35.30	0.09	1.08	24.49	14.96	10.15
Skewness	0.87	0.58	0.64	-0.90	1.77	0.97	0.54	0.60
Kurtosis	2.94	2.51	2.27	3.33	4.58	2.53	4.66	2.28
Jarque-Bera	18.21	9.67	13.28	20.21	90.78	24.13	23.74	11.82
Probability	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Observations	145	145	145	145	145	145	145	145

Source: E-Views

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Linear and Nonlinear Relationship Between Real Exchange Rate, Real Interest Rate and Consumer Price Index: An Empirical Application for Countries with Different Levels of Development

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Abstract: The research population of this study consists of Australia, Azerbaijan, Egypt, Brazil, Chile, Canada, Hungary, Pakistan, India, Ukraine and the United Kingdom. For these countries; T, the relationship between Exchange Rate Index (exc), Real Interest Rate (int) and Consumer Price Index (cpi) variables were examined. Data from 2000Q1 to 2021Q3 were used in the study. The data are taken from the IMF's data bank. Analysis was done in R-Studio. Wo Seasonality Test, Augmented Dickey-Fuller Test, Linear Granger Causality Analysis and Nonlinear Granger Causality Analysis were used to investigate the relationship between variables. The theory claims that there is causality in both directions between exchange rate, interest rate and inflation. In the study, the relationship between these variables was investigated with linear and nonlinear causality tests. It is thought that the empirical results that contradict the theory are caused by the development levels of the countries, their macroeconomic structures, the applied fiscal and monetary policy instruments, the conjuncture and the analysis methods. The study aims to investigate these claims. For this reason, the development levels, sociocultural and socioeconomic structures of the selected countries were requested to be different. In addition, two different test methods, linear and non-linear, were preferred for the causality relationship. It was observed that the selected analysis methods significantly affected the results. Linear causality analysis results are closer to theoretical implications. However, the level of development of the countries does not have a significant effect on the relationship between the variables.

Keywords: linear and nonlinear Granger causality test; development levels of countries; time series analysis.

JEL classification: P33; P34; F37; F42.

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1. INTRODUCTION

Price inflation refers to the change in the prices of goods and services between two periods. In the literature, the variables that cause inflation are defined with different approaches. However, it is seen that the most influential variables are the exchange rate and interest rate (Turna & Özcan, 2021). On the other hand, in countries that implement a free exchange rate system, the nominal interest rate is very effective in the formation of the exchange rate.

The relationship between exchange rate, interest rate and price inflation is theoretically discussed with three different models.

The traditional model discusses the relationship between the interest rate and the exchange rate. According to the model, it says that in a market where deposits are given high-interest rates, the investor turns to the financial system. The theory argues that the expectation of profit due to higher interest rates will increase the value of the local currency and the value of the exchange rate will decrease. This situation continues until the interest rate reaches equilibrium (Sağlam & Yıldırım, 2007). The Interest Rate Parity Approach considers the interest rate as the dependent variable. The two-country model claims that the difference in domestic interest rates is due to spot and forward exchange rates (Keynes, 1923). The exchange rate difference between countries is balanced by the change in interest rates. The investor makes an investment decision in the direction of the country where the balance is disturbed. This trend continues until the exchange rate stabilizes in the spot market. In this way, both the exchange rate and the nominal interest rate are automatically balanced in a completely free market. If the interest rate in a country is above the market equilibrium, the investor invests in the local currency. In the opposite case, it invests in foreign currency. In the first case, the value of the domestic currency increases, in the second case the value of the domestic currency decreases (Sünbül, 2022).

The second model discusses the additional financing costs that businesses incur due to high-interest rates. High-interest rates negatively affect operating profitability and cash flow slows down. At the same time, high-interest rates increase the risk of bad credit. For this reason, the balance sheet balance of financial institutions may deteriorate. When a lower interest rate is applied, the exchange rate rises and the value of the local currency falls.

The third model discusses the impact of changes in exchange rates and interest rates on the prices of goods and services. It also examines the effects on the public debt stock. It is claimed that exchange rates and interest rates will increase the public debt stock and disrupt macroeconomic balances with high inflation. Therefore, high inflation and increased risk perception decrease the value of the local currency and increase the risk premium (Sağlam & Yıldırım, 2007).

As a result, the Interest Rate Parity Approach claims that there is an inverse relationship between the interest rate and the exchange rate (Keynes, 1923), and the Capital Market Approach (Frenkel, 1976; Bilson, 1978) claims that there is a relationship in the same direction between the interest rate and the exchange rate. The Money Supply Demand Equilibrium Approach; on the other hand, states that domestic prices must increase in order for the relationship between domestic goods and services prices and exchange rates to be in the same direction (Frenkel, 1976; Bilson, 1978).

Theoretical implications are self-consistent. However, empirical studies may differ according to theory. Sünbül (2021) attributes the differences between theory and empirical

studies to the development levels of countries, their macroeconomic structures, the applied fiscal and monetary policy instruments, the conjuncture and the differences in analysis methods.

The aim of the study is to test the claim of Sünbül (2021). In this context, it was requested that the development levels, macroeconomic structures, cyclical structures, fiscal and monetary policy instruments of the countries in the study universe be different. In addition, two different research methods, linear and non-linear, were used to reveal the measurement differences arising from the methodology. As a result, the sample of the study consists of Exchange rate, Interest Rate and Inflation variables of Australia, Azerbaijan, Egypt, Brazil, Chile, Canada, Hungary, Pakistan, India, Ukraine and the United Kingdom, between 2000Q1 and 2021Q3.

Data were obtained from the IMF's website. Time series analysis methods were used to examine the relationships between variables. The "wo" Seasonality Test (Ollech & Webel, 2020) was used to analyze the seasonality of the data. Augmented Dickey-Fuller Test (Fuller, 1996) was conducted for stationarity research. Linear Granger Analysis (Granger, 1980) and Nonlinear Granger Causality Analysis (Baek & Brock, 1992; Hiemstra & Jones, 1994) were used to analyze the relationship between variables. Functions for seasonality analysis are available in the R-Studio “stats” and “seats” library. Functions for stationarity testing, linear causality analysis, and nonlinear causality analysis are in the “NlinTS” library.

2. LITERATURE REVIEW

Empirical studies have shown that the exchange rate expectation is more effective than the interest rate in investor decisions (Coleman, 2010; Vasilyev *et al.*, 2017). In addition, some studies have proven that the risk premiums and financial structures of countries are also effective in investor decisions (Bhatti, 2014). Vasilyev *et al.* (2017) attribute investment decisions to risk premiums. Bhatti (2014) found that the most effective investment decision factor in Commonwealth of Independent States member countries is arbitrage expectation.

Parveen *et al.* (2012) used the Least Squares Method (OLS) and Simple Linear Regression models in their study examining the factors affecting the exchange rate change with the annual data of Pakistan for the 1975-2010 period. They found that the most important variable affecting the exchange rate is inflation. Based on the results of the study, they suggested that first of all, fiscal policies should be aligned with monetary policy, and then both policies should be effectively associated with trade policy. Leigh and Rossi (2002) examined the permeability between price inflation and the exchange rate and found that the transition from the exchange rate to the price inflation takes 4 to 12 months. Kara and Ogunc (2005) saw a unidirectional causality between the variables in the floating exchange rate system, but they could not find any relationship in the fixed exchange rate system. Kayhan *et al.* (2013) examined the nonlinear relationship between real exchange rate and real interest rate in BRIC-T countries. They have not found a relationship between variables for China and India, but they have found a relationship between variables for Brazil and Russia. Öner (2018) investigated the effects of Consumer and Producer Price Indices on exchange rates using Granger Causality Analysis. He could not find a relationship between the variables. Yalcinkaya and Tunalı (2019) examined the causality between the USD/TL index and SWAP rates in the London market between 2017 and 2018 interest rates and USD/TL rate. They saw that the change in TL SWAP rate caused a bidirectional change in both the policy rate and the USD/TL rate. Cevher (2016) examined the relationship between deposit interest rate and

exchange rate with the data of the 2010M8-2015M12 period. He found that there is Partial and Conditional Granger Causality in the same direction from exchange rate to deposit interest. Agenor *et al.* (1997) found that the real exchange rate has a significant effect on interest rates. Sekmen and Revanoğlı (2017) investigated the relationship between interest rate and exchange rate using Kazakhstan's data for the period 2005M05-2017M06. In the study, Johansen Cointegration Analysis was performed. They could not find any relationship between the variables. When they extended the analysis with VAR Causality and Unlimited VAR methods, they found a bidirectional causality relationship between the variables.

3. RESEARCH METHODOLOGY AND APPLICATION

In this study, R-Studio program was used for time series analysis. Seasonality and stationarity analyses of the series were performed for preliminary preparation. Then, linear and non-linear causality relationships between the variables providing the assumptions were examined.

There are 11 different countries in the study universe. It was requested that the economic development levels, socioeconomic and sociocultural structures of the countries within the scope of the application be different. These countries are Australia, Azerbaijan, Egypt, Brazil, Chile, Canada, Hungary, Pakistan, India, Ukraine and the United Kingdom.

Selected country datasets cover the period 2000Q1 to 2021Q3. The data were taken from the IMF data bank. Data used; Exchange Rates (Local Currency Per Dollar, End of Period, Exchange Rate), Interest Rate (Interest Rates, Lending Rate, Annual Percent), Inflation (Prices, Consumer Price Index, All Items, Index).

For the analysis of seasonality has been used “wo” tests (Ollech & Webel, 2020). For the analysis of stability investigation, Augmented Dickey-Fuller Test has been used (Fuller, 1996). And, for the analyses of causality Linear Granger Analysis (Granger, 1969) and Nonlinear Granger Analysis have been used (Baek & Brock, 1992; Hiemstra & Jones, 1994).

Functions for seasonality analysis are available in the R-Studio “stats” and “seats” library. Functions for stationarity analysis are “urca” library. And, function for linear causality analysis, and for nonlinear causality analysis are in the “NlinTS” library.

3.1 Data Review

Seasonality checks and seasonal decompositions were made for the preliminary evaluation of the time series. In addition, stationarity checks and difference-taking operations were performed.

3.1.1 Seasonality analysis

It is expected that the averages of non-seasonal time series will be close to 1. Seasonality is determined for periods deviating from the mean. In this study, the "wo" function in R-Studio was used for seasonality control (Ollech & Webel, 2020). Statistical results for seasonality analysis are presented in Table no. 1.

Table no. 1- Statistical results on seasonal analysis

WO Seasonality Analysis				
Country	**Variable**	**P-value**	**Test Statistic**	**Result**
Egypt	exc	1/ 1/ 0.6450	0	
	int	1/ 1/ 0.6450		
	cpi	3.1656/ 1/ 0.0868	0	
Azerbaijan	exc	1/ 1/ 0.8508	0	
	int	1/ 1/ 0.3328	0	
	cpi	2.2637/ 2.3422/ 2.1752	1	Seasonal
Brazil	exc	1/ 1/ 0.3807	0	
	int	1/ 1/ 0.0646	0	
	cpi	0.0319/ 0.2655/ 0.0009	1	Seasonal
Hungary	exc	1/ 1/ 0.5016	0	
	int	1/ 1/ 0.1093	0	
	cpi	1.2663/ 0.0001/ 2.6261	1	Seasonal
India	exc	1/ 1/ 0.1595	0	
	int	1/ 1/ 0.8368	0	
	cpi	9.8809/ 2.6068/ 4.8872	1	Seasonal
Ukraine	exc	0.0225/ 0.0216/ 0.0234	0	
	int	1/ 1/ 0.0823	0	
	cpi	0.0020/ 0.1907/ 5.3475	1	Seasonal
Australia	exc	1/ 1/ 0.5821	0	
	int	1/ 1/ 0.8255	0	
	cpi	0.7223/ 0.7146/ 0.1207	0	
Chile	exc	0.7973/ 0.6495/ 0.2770	0	
	int	1/ 1/ 0.5790	0	
	cpi	0.4849/ 0.1561/ 0.0024	0	
Canada	exc	1/ 1/ 0.3457	0	
	int	1/ 1/ 0.3420	0	
	cpi	0.0001/ 0.0027/ 9.7909	1	Seasonal
United Kingdom	ex	1/ 1/ 0.2951	0	
	in	1/ 1/ 0.9989	0	
	cp	5.4163/ 5.8193/ 5.3670	1	Seasonal
Pakistan	exc	1/ 1/ 0.4763	0	
	int	1/ 1/ 0.7311	0	
	cpi	0.0036/ 0.0071/ 0.0092	1	Seasonal

When Table no. 1 is examined, seasonality was determined in 8 out of 33 variables. Seasonal decomposition was made in these variables.

3.1.2 Stability analysis

Many tests have been developed to test stationarity in time series. ADF Test was preferred for this study. For the ADF Test, the command "ur.df" in the R-Studio "urca" library was used (Hamilton, 1994).

The equations used to test the stationarity are presented in: 3.1, 3.2, 3.3 (Fuller, 1996).

$$\Delta Yt = \gamma Yt\text{-}1 + \varepsilon t \text{ (for model without constant term and without trend)} \quad (3.1)$$

$$\Delta Yt = \beta 1 + \gamma Yt\text{-}1 + \varepsilon t \text{ (for constant term model)} \quad (3.2)$$

$$\Delta Yt = \beta 1 + \beta 2t + \gamma Yt\text{-}1 + \varepsilon t \text{ (for model with constant term and trend)} \quad (3.3)$$

For the test, first of all, unit root tests at I (0) level were performed. Stationarity tests were repeated first according to Equation 3.3, then according to Equation 3.2 and finally according to Equation 3.1. For the model that provides the stationarity assumptions, the stationarity of the series has been decided. Tests were repeated in I (1) for non-stationary series in I (0). The Akaike Information Criterion (AIC) was used to determine the lag length.

• The null hypothesis for unit root research (for ADF) is presented below;
H0= Series is not stationary, (F-p value <0.01, 0.05, 0.1 significance level),
• The null hypothesis for the validity of the model is presented below;
H0= Model significant, (Test statistic <significance levels).
Statistical results for stationarity control are presented in Table no. 2.

Table no 2 – Statistical results for stability control

Augmented Dickey-Fuller Test Unit Root Test				
Country	**Variable**	**Indicator**	**Statistic**	**Result**
Egypt	exc	Coefficients: Pr	0.0000 ***	I (1) None
		F- p-value:	0.000	
		Test-statistic:	-6.205	
			tau1 -2.6 -1.95 -1.61	
	cpi	Coefficients: Pr	0.01 *	I (1) Trend
		F- p-value:	0.0000	
		Test-statistic:	-4.68	
			tau3 -4.04 -3.45 -3.15	
	int	Coefficients: Pr	0.0000 ***	I (1) None
		F- p-value:	0.000	
		Test-statistic:	-6.205	
			tau1 -2.6 -1.95 -1.61	
Azerbaijan	exc	Coefficients: Pr	0.0000 ***	I (1) None
		F- p-value:	0.000	
		Test-statistic:	-6.434	
			tau1 -2.6 -1.95 -1.61	
	cpi	Coefficients: Pr	0.0019 **	I (1) Drift
		F- p-value:	0.000	
		Test-statistic:	-4.952	
			tau2 -3.51 -2.89 -2.58	
	int	Coefficients: Pr	0.0000 ***	I (1) None
		F- p-value:	<0.000	
		Test-statistic:	-8.022	
			tau1 -2.6 -1.95 -1.61	
Brazil	exc	Coefficients: Pr	0.0000 ***	I (1) None
		F- p-value:	0.000	
		Test-statistic:	-5.708	
			tau1 -2.6 -1.95 -1.61	
	cpi	Coefficients: Pr	0.039 *	I (1) Drift
		F- p-value:	0.0001	
		Test-statistic:	-4.706	
			tau3 -4.04 -3.45 -3.15	
	int	Coefficients: Pr	0.0150 *	I (0) Trend

Augmented Dickey-Fuller Test Unit Root Test				
Country	**Variable**	**Indicator**	**Statistic**	**Result**
		F- p-value:	0.0000	
		Test-statistic:	-3.205	
			tau3 -4.04 -3.45 -3.15	
Hungary	exc	Coefficients: Pr	0.0000 ***	I (1) None
		F- p-value:	0.000	
		Test-statistic:	-6.367	
			tau1 -2.6 -1.95 -1.61	
	cpi	Coefficients: Pr	0.0001 ***	I (1) Drift
		F- p-value:	0.0000	
		Test-statistic:	-4.901	
			tau2 -3.51 -2.89 -2.58	
	int	Coefficients: Pr	0.0047 **	I (0) Trend
		F- p-value:	0.0000	
		Test-statistic:	-3.213	
			tau3 -4.04 -3.45 -3.15	
India	exc	Coefficients: Pr	0.0000 ***	I (1) None
		F- p-value:	0.000	
		Test-statistic:	-5.538	
			tau1 -2.6 -1.95 -1.61	
	cpi	Coefficients: Pr	0.0075 **	I (1) Trend
		F- p-value:	0.000	
		Test-statistic:	-5.123	
			tau3 -4.04 -3.45 -3.15	
	int	Coefficients: Pr	0.0000 ***	I (1) None
		F- p-value:	0.000	
		Test-statistic:	-6.944	
			tau1 -2.6 -1.95 -1.61	
Ukraine	exc	Coefficients: Pr	0.052	I (1) Drift
		F- p-value:	0.000	
		Test-statistic:	-6.854	
			tau2 -3.51 -2.89 -2.58	
	cpi	Coefficients: Pr	0.032 *	I (1) Trend
		F- p-value:	0.0000	
		Test-statistic:	-4.85	
			tau3 -4.04 -3.45 -3.15	
	int	Coefficients: Pr	0.0033 **	I (0) Drift
		F- p-value:	0.0010	
		Test-statistic:	-3.559	
			tau2 -3.51 -2.89 -2.58	
Australia	exc	Coefficients: Pr	0.0000 ***	I (1) None
		F- p-value:	0.000	
		Test-statistic:	-5.46	
			tau1 -2.6 -1.95 -1.61	
	cpi	Coefficients: Pr	0.0000 ***	I (1) Drift
		F- p-value:	0.000	
		Test-statistic:	-6.795	
			tau2 -3.51 -2.89 -2.58	
	int	Coefficients: Pr	0.0274 *	I (0) Trend
		F- p-value:	0.000	
		Test-statistic:	-3.623	
			tau3 -4.04 -3.45 -3.15	

Augmented Dickey-Fuller Test Unit Root Test				
Country	**Variable**	**Indicator**	**Statistic**	**Result**
Chile	exc	Coefficients: Pr	0.0000 ***	I (1) None
		F- p-value:	0.000	
		Test-statistic:	-5.949	
			tau1 -2.6 -1.95 -1.61	
	cpi	Coefficients: Pr	0.0000 ***	I (0) Drift
		F- p-value:	0.0000	
		Test-statistic:	-5.659	
			tau2 -3.51 -2.89 -2.58	
	int	Coefficients: Pr	0.0194 *	I (0) Drift
		F- p-value:	0.0172	
		Test-statistic:	-2.877	
			tau2 -3.51 -2.89 -2.58	
Canada	exc	Coefficients: Pr	0.0000 ***	I (1) None
		F- p-value:	0.000	
		Test-statistic:	-6.041	
			tau1 -2.6 -1.95 -1.61	
	cpi	Coefficients: Pr	0.0007 ***	I (0) Trend
		F- p-value:	0.0039	
		Test-statistic:	-3.615	
			tau3 -4.04 -3.45 -3.15	
	int	Coefficients: Pr	0.0440 *	I (0) Trend
		F- p-value:	0.0000	
		Test-statistic:	-3.603	
			tau3 -4.04 -3.45 -3.15	
United Kingdom	exc	Coefficients: Pr	0.0000 ***	I (1) None
		F- p-value:	0.0000	
		Test-statistic:	-6.428	
			tau1 -2.6 -1.95 -1.61	
	cpi	Coefficients: Pr	0.0008 ***	I (1) Drift
		F- p-value:	0.0001	
		Test-statistic:	-4.06	
			tau2 -3.51 -2.89 -2.58	
	int	Coefficients: Pr	0.081 .	I (0) None
		F- p-value:	0.0000	
		Test-statistic:	-1.777	
			tau1 -2.6 -1.95 -1.61	
Pakistan	exc	Coefficients: Pr	0.076 .	I (1) Drift
		F- p-value:	0.0000	
		Test-statistic:	-4.355	
			tau2 -3.51 -2.89 -2.58	
	cpi	Coefficients: Pr	0.089 .	I (1) Trend
		F- p-value:	0.0000	
		Test-statistic:	-5.606	
			tau3 -4.04 -3.45 -3.15	
	int	Coefficients: Pr	0.0945 .	I (0) Trend
		F- p-value:	0.000	
		Test-statistic:	-3.275	
			tau3 -4.04 -3.45 -3.15	

When Table no. 2 is examined, it can be seen that the 10 series is stationary at the I (0) level, and the 23 series is stationary at the I (1) difference. Both linear and nonlinear causality research was conducted with stationary series.

3.2 Causality Analysis

In the literature, Granger Causality Analysis is mostly preferred in examining the relationship between time series. Granger (1980) uses the Least Squares estimator to analyze causality in time series and calculates the Minimum Mean Squares Estimated Error criterion to evaluate predictive power (Granger & Newbold, 1986). The prerequisite for the analysis is that the variables are stationary (Granger, 1980).

Granger Causality Analysis gives successful results both for I (0) stationary series and for series with I (1) level difference (Sünbül & Benli, 2021). However, Granger Causality Analyses developed for linear analysis are not suitable for detecting the presence of nonlinear causality (Brock, 1991).

Baek and Brock (1992) proposed a nonlinear statistical causality model. This proposed model is a different version of the Granger Causality model. Hiemstra and Jones (1994) and made new contributions to Baek and Brock's model.

Diks and Panchenko (2005, 2006) claimed that the model proposed by Hiemstra and Jones (1994) is not compatible with the Granger model. Therefore, they developed a new test that eliminated the problem. Bell *et al.* (1996), Su and White (2008, 2014) are other examples of nonlinear causality tests in the literature.

In this study, the model proposed by Granger (1980) for linear causality analysis and Hiemstra and Jones (1994) for nonlinear causality research was used.

In the Granger's Causality test, the result is obtained with the equality (X, Y).

$$Y = \sum_{i=1}^{m} \partial_i Y(t-i) + \sum_{j=1}^{m} \varphi_j X(t-j) + u(2t) \tag{3.4}$$

$$X = \sum_{i=1}^{m} \alpha_i Y(t-i) + \sum_{j=1}^{m} \beta_j X(t-j) + u(1t) \tag{3.5}$$

While the error terms u(1t) and u(2t) are considered independent of each other in the equations, m represents the lag length. Equation (3.4) investigates X to Y and Equation (3.5) Y to X causality. In Equation (3.4), the dependent variable is included in the model with the appropriate number of lags. Then the other variable is included in the model. Then the F statistic developed by Wald is calculated.

$$F_{(m,n-2m)} = \frac{ESSr - ESSur}{ESSur \,/\, (n-2m)} \tag{3.6}$$

Equation (3.6) is used to calculate the F statistic. In the equation;

- ESS: Error sum of squares,
- ur: Unlimited models
- r: Indicates the restricted model.

If the F statistic (m;n-2m) calculated at the α-result level in degrees of freedom is large, the null assumption is rejected (Granger, 1980).

Architecture for nonlinear causation (Artificial Neural Networks); The delay coefficient was determined as 2, the number of neurons in the first hidden layer was 2, the number of neurons in the second hidden layer was 4, the learning iteration was 50, the p-value was 0.05, and the learning algorithm was “stochastic gradient descent”. The "NlinTS package" library in R-Studio was used for the non-linear Granger Test.

The null hypothesis of Granger Causality Analysis;

H0= Independent variable is not the cause of the dependent variable. (Data 2 does not cause data 1).

The causality test statistics are presented in Table no. 3.

Table no 3 – Linear and nonlinear causality test statistics

Granger Causality Test					
Country	**Relationship**	**Linear Causality F-test. P-val.**	**None-linear Causality F-test. P-val.**	**Result**	
				Lineer	**None-lineer**
Egypt	from cpi to exc	0.7010	0.9520	H0 Accept	H0 Accept
	from int to exc	0.7217	0.9999	H0 Accept	H0 Accept
	from exc to cpi	0.0007	0.9999	H0 Red	H0 Accept
	from int to cpi	0.0007	1	H0 Red	H0 Accept
	from exc to int	0.8716	0.7919	H0 Accept	H0 Accept
	from cpi to int	0.7010	0.0223	H0 Accept	H0 Red
Azerbaijan	from cpi to exc	0.6257	0.5898	H0 Accept	H0 Accept
	from int to exc	0.3580	5,2534	H0 Accept	H0 Accept
	from exc to cpi	0,0989	0.9999	H0 Red	H0 Accept
	from int to cpi	0.0108	1	H0 Red	H0 Accept
	from exc to int	0.6606	1	H0 Accept	H0 Accept
	from cpi to int	0.7088	1	H0 Accept	H0 Accept
Brazil	from cpi to exc	0.8359	0.8896	H0 Accept	H0 Accept
	from int to exc	0.3421	1	H0 Accept	H0 Accept
	from exc to cpi	0.6546	1	H0 Accept	H0 Accept
	from int to cpi	0.0149	1	H0 Red	H0 Accept
	from exc to int	0.1911	1	H0 Accept	H0 Accept
	from cpi to int	0.1311	1	H0 Accept	H0 Accept
Hungary	from cpi to exc	0.9911	1	H0 Accept	H0 Accept
	from int to exc	0.4364	0.9999	H0 Accept	H0 Accept
	from exc to cpi	0.2750	1	H0 Accept	H0 Accept
	from int to cpi	0.0496	1	H0 Red	H0 Accept
	from exc to int	0.0332	1	H0 Red	H0 Accept
	from cpi to int	0.4851	0.9996	H0 Accept	H0 Accept
India	from cpi to exc	0.7528	1	H0 Accept	H0 Accept
	from int to exc	0.7493	0.9999	H0 Accept	H0 Accept
	from exc to cpi	0.6252	1	H0 Accept	H0 Accept
	from int to cpi	0.4820	1	H0 Accept	H0 Accept
	from exc to int	0.6640	1	H0 Accept	H0 Accept
	from cpi to int	0.4073	1	H0 Accept	H0 Accept
Ukraine	from cpi to exc	0.0982	1	H0 Red	H0 Accept
	from int to exc	0.5779	0.2892	H0 Accept	H0 Accept
	from exc to cpi	5,5664	0.0322	H0 Accept	H0 Red
	from int to cpi	0.3681	0.0983	H0 Accept	H0 Accept
	from exc to int	0.0163	0.9999	H0 Red	H0 Accept
	from cpi to int	0.6411	0.9999	H0 Accept	H0 Accept

Granger Causality Test					
Country	**Relationship**	**Linear Causality F-test. P-val.**	**None-linear Causality F-test. P-val.**	**Result**	
				Lineer	**None-lineer**
Australia	from cpi to exc	0.0025	1	H0 Red	H0 Accept
	from int to exc	0.3580	1	H0 Accept	H0 Accept
	from exc to cpi	0,0989	0.9953	H0 Red	H0 Accept
	from int to cpi	0.0108	0.3953	H0 Red	H0 Accept
	from exc to int	0.6606	1	H0 Accept	H0 Accept
	from cpi to int	0.7088	1	H0 Accept	H0 Accept
Chile	from cpi to exc	0.1128	0.9999	H0 Accept	H0 Accept
	from int to exc	0.2070	1	H0 Accept	H0 Accept
	from exc to cpi	0.0916	0.9999	H0 Red	H0 Accept
	from int to cpi	0.0409	1	H0 Red	H0 Accept
	from exc to int	0.1157	1	H0 Accept	H0 Accept
	from cpi to int	0,0580	1	H0 Red	H0 Accept
Canada	from cpi to exc	0.0409	1	H0 Red	H0 Accept
	from int to exc	0.9999	1	H0 Accept	H0 Accept
	from exc to cpi	0.0711	1	H0 Red	H0 Accept
	from int to cpi	0.7129	1	H0 Accept	H0 Accept
	from exc to int	0.0003	1	H0 Red	H0 Accept
	from cpi to int	0.0396	1	H0 Red	H0 Accept
United Kingdom	from cpi to exc	0.0416	1	H0 Red	H0 Accept
	from int to exc	0.8716	1	H0 Accept	H0 Accept
	from exc to cpi	0.1276	0.9947	H0 Accept	H0 Accept
	from int to cpi	0.9605	1	H0 Accept	H0 Accept
	from exc to int	0,0005	1	H0 Red	H0 Accept
	from cpi to int	0.0003	1	H0 Red	H0 Accept
Pakistan	from cpi to exc	0.6703	0.9999	H0 Accept	H0 Accept
	from int to exc	0.0667	0.9475	H0 Red	H0 Accept
	from exc to cpi	0.0090	0.9999	H0 Red	H0 Accept
	from int to cpi	0.7815	0.9999	H0 Accept	H0 Accept
	from exc to int	0.3885	1	H0 Accept	H0 Accept
	from cpi to int	0.0007	1	H0 Red	H0 Accept

Table no. 3 shows the causality statistics between three different variables of 11 different countries. In the study, linear and nonlinear 66 + 66 tests of "exc ⇒ cpi", "exc ⇒ int", "cpi ⇒ int", "cpi ⇒ exc", "int ⇒ exc" and "int ⇒ cpi" tests were performed. According to linear causality statistics; There was a causality between the variables in 44 of the 66 tests. According to non-linear causality statistics; There was a causality between the variables in 2 of the 66 tests.

4. CONCLUSION

Theoretically, no causality is predicted between inflation to interest rate "cpi ⇒ int" and inflation to exchange rate "cpi ⇒ exc". In the study, the causality between all these variables was investigated with linear and non-linear causality tests. The theory assumes causality in both directions between exchange rate, interest rate and inflation "exc ⇒ cpi, exc ⇒ int, int ⇒ exc, int ⇒ cpi, cpi ⇒ exc and, cpi ⇒ int".

In this context, when the results of the analysis are examined in detail; There was causality between variables in 44 of 66 linear causality tests. These; For Egypt, cpi to cpi and int to cpi, cpi to cpi and int to cpi, for Azerbaijan, int to cpi, for Brazil, int to cpi, for Hungary, int to cpi and exc to int, for Ukraine, cpi to exc and exc to int, for Australia, cpi to exc, exc to cpi and int to cpi, for Chile, cpi to cpi, int to cpi and cpi to int, for Canada, cpi to exc, exc to cpi, exc to int and cpi to int, for UK, cpi to exc, exc to int and cpi to int and for Pakistan, int to exc, exc to cpi and cpi to int. Nonlinear causality was not found for India.

Two of the 66 nonlinear causality tests showed causality between variables. These; For Ukraine, exc to cpi and for Egypt, cpi to int. Except for these two, nonlinear causality was not found.

When the results of the study are compared with the literature; While there is no causal relationship from inflation to exchange rate for Pakistan, Parveen *et al.* (2012) have come to a different conclusion. While there is no causal relationship between real exchange rate and real interest rates for India, Kayhan *et al.* (2013) have reached different results for India and similar results for Brazil in their nonlinear causality analysis. From exchange rate to inflation, linear causality was found in six countries and non-linear causality in 10 countries. These results are similar to those of Leigh and Rossi (2002). Linear causality relationship between inflation and exchange rate was determined in seven countries and non-linear causality relationship was determined in 11 countries. These results are consistent with Öner (2018) study. Linear causality running from exchange rates to interest rates have found in four countries. These results are Cevher (2016), Agenor *et al.* (1997) is compatible with the study. However, the majority of the results obtained from the study are different from this study in the literature.

It can be said that linear causality tests are more successful when the theoretical inferences are assumed to be correct. In addition, no significant relationship was found between the factors such as the development levels, socioeconomic and sociocultural differences of the countries, and the causality relations of the variables.

Suggestions of researchers; Sünbül (2021) attributes the differences between theory and empirical studies to the development levels of countries, their macroeconomic structures, the applied fiscal and monetary policy instruments, the conjuncture, and the differences in analysis methods. This claim has been tested in research. In this context, it was requested that the development levels, macroeconomic structures, cyclical structures, and fiscal and monetary policy instruments of the countries in the study universe be different. In addition, two different research methods, linear and non-linear, were used to reveal the measurement differences arising from the methodology. Therefore, it is recommended that these differences be taken into account in future comparative analyzes and that the results be viewed critically.

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How to Analyze the Association between Two Categorical Variables Based on Census Data with a High Level of Nonresponse

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Abstract: Statistical surveys are often used in shaping managerial policy and practice. In this paper we study, how to analyze the association between two categorical variables based on census data with a high level of nonresponse. The purpose is to discuss the suggested approach to the investigation. We used the census data from the survey executed at one Slovak University for testing the new process. The proposed process offers the methods of analysis of the association between two categorical variables based on pseudo-population estimated from the census data with a high level of nonresponse. We recommend using the process in the surveys in which the costs of survey execution by the census are practically not different from sample survey costs, and the connections to all units of the population are available.

Keywords: census data; nonresponse; association between two categorical variables; residuals; odds ratio.

JEL classification: C18.

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1. INTRODUCTION

Statistical surveys are often used in forming managerial policy and practice. In this paper we study, how to analyze the association between two categorical variables based on census data, with a high level of nonresponse.

In the academic year 2020/2021, a second questionnaire survey was planned at the University of Economics in Bratislava (the first one was realized in the academic year 2019/2020). As in the first stage, the objective of the project was to work up an interactive and multimedia framework for teaching The Principles of Economics 1 (ET1) and The Principles of Economics 2 (ET2), the core courses of the study programs at the undergraduate level and, also to study some issues related to the subjective well-being of the students. The sample survey and census were available. The high level of nonresponse, quite common in current surveys, can significantly impair the quality and explanatory power of the survey results (see Cochran, 1977; Tillé, 2001; Särndal & Lundström, 2005; Levy & Lemeshow, 2008; Chaudhuri, 2014; Lohr, 2019; Terek, 2020; Tillé, 2020). If the same response rate in census and sample survey is supposed, then the number of responses is higher in the census. If the connection to all population units is available and the costs of survey execution by the census are practically no different from sample survey costs, then the census should be preferred. Therefore, a census was chosen in the survey at the University of Economics in Bratislava.

Many studies focus on analyzing the association between two categorical variables based on sample survey data (Agresti, 2010, 2013; Agresti & Finlay, 2014; Terek, 2016, 2017; Agresti, 2018; Terek, 2019a). The purpose of this study is to suggest the approach to the analysis of the association between two categorical variables based on census data with a high level of nonresponse. We propose a new procedure of the analysis of association between two categorical variables if the data from census collected in a questionnaire survey with a high level of nonresponse are available. We recommend using of the approach in all surveys in which the costs of the survey by census practically do not differ from the sample survey costs and the connections to all population units are available.

We realize the research in two steps. Firstly, the estimation of the population frequency distribution based on weights modified by compensation for nonresponse is studied. The result is obtaining the frequency distribution of pseudo-population. In the second step, we suggest the methods of the analysis of the association between two categorical variables on the obtained pseudo-population. We verify the proposed approach on census data from the mentioned survey realized at the University of Economics in Bratislava in 2020/2021.

2. MATERIAL AND METHODS

If the data from the sample survey with a high nonresponse rate are available, it is possible to estimate the frequency distribution with compensation for nonresponse, using the modified sampling weights. In without-replacement sampling, the sampling weight w_{Bi} for observation i is always the reciprocal of the probability π_i that the observation i is included in the sample. If the considering of nonresponse is needed, the adjustment factor to the base weight is used. The final weight for the i^{th} observation is then

$$w_i = w_{Bi} \cdot w_{NRi}$$

where w_{NRi} is the nonresponse adjustment factor (for more details, see Terek *et al.*, 2021). The probability that a unit selected for the sample will respond φ_i (unknown but assumed

positive) is called the response propensity for the i^{th} unit. If responding of unit *i* is independent of the indicator variable for presence in the selected sample, then the probability that unit *i* will be selected in the sample and responds is equal to $\pi_i \varphi_i$.

In Lohr (2019) the methods of estimation the response propensity φ_i are presented. One of them is based on poststratification using weights (see Terek *et al.*, 2021, for more details on this method and other possibilities of estimating the response propensity). After taking a simple random sample, units are grouped into *H* different poststrata (for more on poststratification, see Lohr (2019); Levy and Lemeshow (2008); Terek *et al.* (2021)). The population has N_h units in h^{th} poststratum; of these, n_h were selected for the sample, and n_{hR} responded. The response propensity for every respondent *i* in poststratum *h* is estimated by

$$RR_{w_h} = \frac{\sum_{i=1}^{n_{hR}} w_{Bi}}{N_h} \tag{1}$$

and nonresponse adjustment factor is

$$w_{NRi} = \frac{1}{RR_{w_h}} \tag{2}$$

In Eltinge and Yansaneh (1997); Gelman and Carlin (2001); Little and Vartivarian (2003); Vartivarian and Little (2003); Terek *et al.* (2021) is stated when the collapsing of poststrata is needed. The weights w_i can be used to construct the estimators of population quantities.

If the decision to apply the poststratification using weights is taken, the decision on which poststratification variables should be used in poststratification must be solved. It is known that the bias of estimators caused by nonresponse can be minimized by finding poststratification variables that are strongly correlated with the response propensity. In Terek *et al.* (2021) is advised the use of correlation ratio $\eta_{(Z|X)}$ for measuring that correlation.

In Terek *et al.* (2021), the problem of estimation with compensation for nonresponse in statistical analyses of census data is studied and discussed. The suggested approach is based on the idea that the census in which all population units are selected can be understood as a without-replacement sampling of size *N* with the only difference that the last unit is selected non-randomly. Then the poststratification using weights can be used (if MAR data[1] are assumed).

The final weight w_i for unit *i* is then

$$w_i = \frac{1}{RR_{w_h}} = \frac{N_h}{N_{hR}} \tag{3}$$

where N_h is the number of units in poststratum *h;* of these, N_{hR} responded.

If a sample is non-self-weighting, i. e., all final weights are not equal, the use of weights in constructing estimators of population quantities is needed. The estimate of the frequency of class *j* is then (Terek, 2019b).

$$n_j = \sum_{i \in S} w_i u_{i,j} \tag{4}$$

where $u_{i,j}$ = 1 if observation *i* is in class *j* and 0 otherwise, and *S* denotes the selected sample. The frequencies n_j define the pseudo-population (Terek & Muchova, 2017; Lohr, 2019) and, further, are called the frequencies of pseudo-population.

If certain values of one variable tend to go with certain values of the other, there is an association between two variables (Agresti & Finlay, 2014). The data of the analysis of categorical variables are displayed in contingency tables. When the data in the contingency table are analyzed, the corresponding joint, marginal and conditional distributions can be determined (Freund, 1992; Agresti & Finlay, 2014; Miller & Miller, 2014). Two categorical variables are statistically independent if the population conditional distributions on one of them are identical at each category of the other. The variables are statistically dependent if the conditional distributions are not identical (Agresti & Finlay, 2014).

Suppose the contingency table contains the data from a random sample. The questions usually addressed in the analysis of a contingency table are as follows (Agresti & Finlay, 2014):

- Do an association exist? The chi-squared test of homogeneity or independence answers this question (in the case of ordinal variables, also other possibilities exist – see Agresti (2010); Agresti (2013); Agresti and Finlay (2014); Agresti (2018).
- How do the data differ from what is expected under independence? The standardized residuals identify the cells that are different from what the independence predicts.
- What is the strength of association? The difference of proportions and odds ratio are strongly advised for measuring it.

If the data from the whole population (or pseudo-population) are accessible, the statistical independence can be found directly by comparing conditional distributions.

2.1 Pseudo-population and analysis of association between two categorical variables

If the census takes the form of the questionnaire survey, a high level of nonresponse must be expected, which means that the obtained population data are not complete. Imagine the response rate is 20 %. Is it possible to consider such data set as the studied population and to compare conditional distributions? Certainly not.

If we understand a census of the population of the size N be random sampling without replacement of size N, can we use the chi-square test and other well-known steps of the analysis of association? We cannot because it supposes that the observations are statistically independent and equally distributed, which can be considered fulfilled if the sample size n is small compared to the size N of the population ($\frac{n}{N} \leq 0{,}05$). But, in a census, all units of the population are selected. The corrections for the chi-squared test are needed (see Lohr, 2019). However, the nonresponse is not considered.

We propose the following approach. If we have the data from a sample survey with a high nonresponse rate, we can estimate the frequency distribution with compensation for nonresponse. Then we can analyze the association between two categorical variables on the obtained pseudo-population. If the census is understood as without-replacement random sampling, the same approach is also possible for a census.

After compensating for nonresponse, the final weights are not equal for all observation units. That means that a sample is non-self-weighting. Then the use of sampling weights in estimating the population frequency distribution is needed. The estimate of the frequency of class ij is:

$$n_{ij} = \sum_{k \in S} w_k u_{k,ij} \tag{5}$$

where $u_{k,ij}$ = 1 if observation k is in the class ij and 0 otherwise. The frequencies n_{ij} are the frequencies of pseudo-population.

If the contingency table contains the data on the population (or pseudo-population), the conditional distributions can be directly compared. The comparison of conditional distributions can only provide evidence of the association's existence but not on its structure. We propose to analyze the association structure by residuals $d_{ij} = (n_{ij} - o_{ij})$, where n_{ij} are the frequencies of pseudo-population and $o_{ij} = \frac{n_{i\cdot} \cdot n_{\cdot j}}{n}$ are expected frequencies of pseudo-population. The cells different from the situation supposed by the independence of variables can be recognized by residuals. The positive sign of residual indicates that the combination *ij* is more frequent than expected under independence, and the negative sign indicates that the combination *ij* is less frequent than expected under independence.

The strength of association in any sub-table 2 x 2 of the contingency table can be measured by the odds ratio. For a binary response variable, success denotes the outcome of interest and failure the other outcome. The odds of success are defined as follows.

$$\text{Odds} = \frac{Probability\ of\ success}{Probability\ of\ failure}$$

Suppose the data from a random sample are available. The estimated odds for a binary response variable equal the number of successes divided by the number of failures. If the data of finite population (or pseudo-population) are available, the word estimated in the term estimated odds is omitted. The odds ratio measures the association for any 2 x 2 contingency table. It equals the odds in row 1 divided by the odds in row 2. The odds ratio can equal any nonnegative number, and its values farther from 1 in a given direction represent a stronger association (Agresti & Finlay, 2014).

3. ANALYSES OF ASSOCIATION IN THE REALIZED CENSUS

We carried out the census mentioned above in the framework of the project "Learn Economics" at the end of the academic year 2020/2021. We included in the survey six Faculties of the University of Economics in Bratislava − Faculty of National Economy (FNE), Faculty of Business Informatics (FBI), Faculty of Commerce (FC), Faculty of Business Management (FBM), Faculty of International Relations (FIR), and Faculty of Applied Languages (FAL).

The questionnaire consisted of two parts. The first part (questions 1 – 24) concerns the teaching of the courses. The Principles of Economics 1 (ET1), and The Principles of Economics 2 (ET2), the second part of the questionnaire (questions 27 – 38), focus on subjective well-being. We used Google forms software for the execution of the survey and Microsoft Excel in analysis of contingency tables. A total of 1,336 students at the University of Economics completed at least one of the mentioned courses in the academic year in question. We approached the students via the Academic Information System at their e-mail addresses. We contacted only those students who took part in the exam of the courses ET1 and/or ET2 during the academic year 2020/2021. We delivered the questionnaire to each of them. The questions of the first part referred to the content, methodology, format of lectures, and seminars. The questions asked for the assessment of online teaching, preferable way of teaching, identification of most complicated topics in the syllabus, ideas for improving the lectures and seminars, personal experience with the online platform used for education, and others. The second part of the questionnaire was focused on subjective well-being and quality of life. It included 13 questions dealing with life satisfaction, health, family background,

university study, daily activities. 258 students returned the completed questionnaire, total response rate achieving 238/1336 = 0.1781, i. e., 17.81%.

The study department at the University of Economics provided some auxiliary information about the population of 1,336 students. The frequency distribution by Faculty and Gender is presented in Table no. 1 (with corresponding numbers of responding students in parentheses). Then, we calculated the correlation ratio $\eta_{(Z|X)}$ between the response propensity and variables (for the calculation details, see Terek *et al*., 2021). The results are presented in Table no. 2. Table no. 2 shows that the Faculty – Gender reaches maximum correlation ratio, and thus, these will serve as poststratification variables. We define the poststrata by combinations of categories of Faculty and Gender. There are 2 x 6 = 12 poststrata.

Table no. 1 −The distribution of students accomplishing at least one of the courses in the academic year in question by Faculty and Gender

	FNE	FBI	FC	FBM	FIR	FAL	Total
Males	153 (26)	138 (17)	109 (9)	135 (12)	42 (6)	5 (0)	582 (70)
Females	186 (39)	136 (38)	164 (42)	159 (25)	78 (18)	31(6)	754 (168)
Total	339 (65)	274 (55)	273 (51)	294 (37)	120 (24)	36 (6)	1 336 (238)

Table no. 2 – The values of the correlation ratio

	$\eta_{(Z\|X)}$
Faculty	0,075
Gender	0,133
Faculty – Gender	0,169

Next, the association between the Faculty of the students studies and the answers to the No. 31 question of the questionnaire: "How satisfied are you with the studies at the University of Economics?" will be analyzed. The listed answers to the question include – "completely unsatisfied", "unsatisfied", "I can't decide", "satisfied", "completely satisfied". 233 students answered the question. Based on the requirement to gain at least 20 responding units in each poststratum, we collapsed some columns. The second condition – $w_{NRi} \leq 2$, advised in Lohr (2019), cannot be met, so we must be reckoned with less stability of weights. After collapsing there are 2 x 3 = 6 poststrata. Table no. 3 shows the resulting structure of poststrata (the number of addressed and responding students, in parentheses).

Table no. 3 – The structures of poststrata after collapsing with the number of responding students in parentheses

	FNE	FC, FBM	FBI, FIR, FAL	Total
Males	153 (25)	244 (21)	185 (22)	582 (68)
Females	186 (38)	323 (65)	245 (62)	754 (165)
Total	339 (63)	567 (86)	430 (84)	1336 (233)

The final weights calculated from Table no. 3, following relation (3), are presented in Table no. 4.

Table no. 4 −Final weights

	FNE	FC, FBM	FBI, FIR, FAL
Males	6.120	11.619	8.406
Females	4.895	4.969	3.952

The frequencies of responding students linked to poststrata are in Table no. 5. After weighing the frequencies by final weights in Table no. 4 and after joining males and females, the final frequency distribution n_{ij} of the pseudo-population is acquired as presented in Table no. 6 (n_{ij} are calculated following the relation (5)).

Table no. 5 −Frequencies linked to poststrata

		FNE	FC, FBM	FBI, FIR, FAL	Total
Completely unsatisfied	Males	1	0	0	1
	Females	0	2	0	2
Unsatisfied	Males	1	0	0	1
	Females	2	6	3	11
I can't decide	Males	0	8	2	10
	Females	5	8	6	19
Satisfied	Males	18	10	18	36
	Females	23	44	38	105
Completely satisfied	Males	5	3	2	10
	Females	8	5	15	28
Total		63	86	84	233

Table no. 6 −The final frequency distribution of pseudo-population

	FNE	FC, FBM	FBI, FIR, FAL	Total
Completely unsatisfied	6.12	9.938	0	16.058
Unsatisfied	15.91	29.814	11.856	57.58
I can't decide	24.475	132.704	40.524	197.703
Satisfied	222.745	334.826	301.484	859.055
Completely satisfied	69.76	59.702	76.092	205.554
Total	339	567	430	1336

For identifying if there is an association between responses to No. 31 question and faculties, the conditional distributions of answers to No. 31 question on faculties are calculated (dividing each frequency in the referring column in Table no. 6 by its column total) and presented in Table no. 7. The conditional distributions in the columns of Table no. 7 are not identical. Thus, there is an association between faculties and answers to the No. 31 question.

Table no. 7 − The conditional distributions of answers to No. 31 question on faculties

	FNE	FC, FBM	FBI, FIR, FAL
Completely unsatisfied	0.018	0.018	0
Unsatisfied	0.047	0.053	0.028
I can't decide	0.072	0.234	0.094
Satisfied	0.657	0.591	0.701
Completely satisfied	0.206	0.105	0.177
Total	1	1	1

We analyze the structure of the association by residuals. Firstly, we calculated the expected frequencies $o_{ij} = \frac{n_{i\cdot} \cdot n_{\cdot j}}{n}$ (in Table no. 8) and then the residuals $d_{ij} = (n_{ij} - o_{ij})$ in Table no. 9. For expected frequencies in Table no. 8, all conditional distributions of answers to No. 31 question on faculties are identical (it means that the variables "Faculty" and "Answers to No. 31 question" are independent).

Table no. 8 − Expected frequencies o_{ij}

	FNE	FC, FBM	FBI, FIR, FAL	Total
Completely unsatisfied	4.075	6.815	5.168	16.058
Unsatisfied	14.610	24.437	18.532	57.58
I can't decide	50.166	83.905	63.632	197.703
Satisfied	217.979	364.584	276.492	859.055
Completely satisfied	52.158	87.237	66.159	205.554
Total	339	567	430	1336

Table no. 9 − Residuals d_{ij}

	FNE	FC, FBM	FBI, FIR, FAL	Total
Completely unsatisfied	2.045	3.123	− 5.168	0
Unsatisfied	1.300	5.377	− 6.676	0
I can't decide	− 25.691	48.799	− 23.108	0
Satisfied	4.766	− 29.758	24.992	0
Completely satisfied	17.602	− 27.535	9.933	0
Total	0	0	0	0

The interpretation of the residuals in Table no. 9 leads to exciting outcomes. The positive sign of a residual indicates that the combination *ij* is more frequent than expected under independence. The negative sign indicates that the combination *ij* is less frequent than expected under independence. Thus, Table no. 9 shows that, for example, the answers "satisfied" and "completely satisfied" of the students of the Faculty of Commerce and Faculty of Business Management are less frequent than expected under independence, and the answers "completely unsatisfied," "unsatisfied," and "I can't decide" of the students at these faculties are more frequent than expected under independence. A different situation is, for example, at the Faculty of Business Informatics, Faculty of International Relations, and Faculty of Applied Languages. The answers "completely unsatisfied," "unsatisfied," and "I can't decide" are less frequent than expected under independence, and the answers "satisfied" and "completely satisfied" are more frequent than expected under independence. At the Faculty of National Economy, the answers "completely unsatisfied," "unsatisfied," "satisfied," and "completely satisfied" are more frequent, and the answers "I can't decide" are less frequent than expected under independence.

Table no. 10 − Sub-table of Table no. 6

	Unsatisfied	Satisfied	Total
FBI, FIR, FAL	11.865	301.484	313.34
FC, FBM	29.814	334.826	364.64

The strength of association can be measured in any sub-table 2 x 2 of the contingency table by odds ratio. The answers "unsatisfied" and "satisfied" at Faculties of Business Informatics, International Relations, and Applied Languages and at Faculties of Commerce

and Business Management will be compared, for illustration. Table no. 10 is the corresponding sub-table of Table no. 6.

We treat the answer to the No. 31 question as to the response variable. If we use the answer "satisfied" as success and "unsatisfied" as a failure, the odds for "satisfied" at the Faculties of Business Informatics, International Relations, and Applied Languages is

$$\frac{301.484}{11.856} = 25.429$$

It means that at the Faculties of Business Informatics, International Relations, and Applied Languages, there were 25.429 satisfied students for every unsatisfied student. The odds for "satisfied" at the Faculties of Commerce and Business Management is

$$\frac{334.826}{29.814} = 11.231$$

It means that at the Faculties of Commerce and Business Management, there were 11.231 satisfied students for every unsatisfied student. The odds ratio is

$$\frac{25.429}{11.231} = 2.264$$

The result can be interpreted, for example, as follows: Suppose one student is randomly selected from the population. If he is from Faculties of Business Informatics, International Relations, and Applied Languages, there are approximately 2.3 times greater odds that he is satisfied at the University of Economics, as if he is from the Faculties of Commerce and Business Management. All possible sub-tables of Table no. 6 can be analyzed accordingly.

4. CONCLUSIONS, LIMITATIONS AND DIRECTIONS FOR FUTURE RESEARCH

The purpose of the paper is to propose a procedure of analysis of the association between two categorical variables based on the data collected from a census with a high level of nonresponse. We used the method of estimation with compensation for nonresponse applicable in censuses (proposed in Terek *et al.*, 2021) to estimate the frequency distribution of the population. Then we propose the procedure analyzing the association between two categorical variables on the obtained pseudo-population. The resulting pseudo-population allows the determination of the independence of variables by comparing conditional distributions. If the variables are dependent, we recommend the analysis of the association structure by residuals. Finally, the strength of association for any 2 x 2 sub-table of a contingency table can be measured by odds ratio.

The proposed procedure is designed for the cases in which the costs of survey execution by the census are practically no different from sample survey costs, and some applicable auxiliary information on the population units is available. The procedure also considers nonresponse quite common in current surveys. In the presented study, the response rate was only 17.81%. Therefore, such a data set cannot be regarded as the studied population, and compensation for nonresponse is needed. The interpretation of the analysis results leads to exciting information. The residuals allow identifying if the combination *ij* is more or less frequent than expected under independence. The interpretations of odds and odds ratio are exciting too.

In practice, there are a lot of situations similar to the situation in the presented study. For example, in a large company, they want to analyze employees' attitudes towards various methods of stimulating work, namely whether these attitudes vary depending on gender,

employee age category, and the like. Or it may be interesting to determine the attitude and preferences of employees to different forms of further education. Here too, it may be interesting to examine whether these attitudes vary, for example, depending on the employee's age category. These problems came to the forefront during the period of the Covid Pandemic 19 when it was necessary to prefer distance education. At present, it may be interesting to find out whether employees would prefer this form of communication even today when it is no longer necessary or prefer to return to traditional forms of communication. There is no point in similar situations to realize random sampling of respondents because the company has contact with each employee and the cost of sample survey and census is virtually the same. Of course, in similar surveys, it is necessary to count on a large degree of nonresponse, similar to the presented survey. In addition, the company also owns a wealth of information about its employees, which can serve as auxiliary information in finding suitable poststratification variables. The presented procedure can therefore be used only at the level of a company or other organization. In these objects the conditions of the same cost per census and sample survey are practically always met, contact for each unit is known and the suitable auxiliary information should be in disposition.

In the subsequent similar study, in the academic year 2021/22, the original research related to the teaching of the course Basics of Economics and well-being has been extended to investigate the value orientation of students. Based on the obtained new data, the authors plan to use the procedure presented in this paper to the analysis of the association between the type of high school that the student has completed and his satisfaction with the study at the University of Economics. This can be useful to improve the focus of marketing activities aimed at acquiring students to study at that University.

We would like to focus further research on investigating the possibilities of census data analysis with a high level of nonresponse with the use of regression analysis. The procedure will be based on obtaining the frequency distribution of pseudo-population with aid of the procedure presented in this paper. One possibility is then the selection of an ordinal variable as a dependent variable. When we assign a score to each of its values, we can treat it as a quantitative continuous variable and a dependent variable in regression analysis. The parameters of the regression equation can be calculated by the least squares method (for more details, see Lohr, 2019, pp. 436-437). This equation should summarize useful information about the relationship between the dependent variable y and one or more independent variables in the finite population. If we consider the finite population, the population correlation coefficient of x and y, which measures the intensity of the linear relationship between two variables is known (see Lohr, 2019, p. 118). The coefficient of determination in simple linear regression and the multiple correlation coefficient and multiple coefficient of determination in multiple regression can be also calculated and interpreted.

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Notes

[1] More about MAR, MCAR and NMAR data, see Lohr (2019).

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Effects of International Financial Integration on Economic Growth in Developing Countries: Heterogeneous Panel Evidence from Seven West African Countries

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Abstract: From the existing literature, there is no consensus on the effects of financial integration on economic growth. The studies have mostly focused on country samples without taking into account country heterogeneity, or have been limited to a causality study. This paper examines the effects of international financial integration on economic growth in seven West African Economic and Monetary Union's countries (WAEMU)[1], over the period 1980 - 2019. Methodologically, the study applies heterogeneous panel techniques taking into account inter-individual dependence (MG, CCEMG and AMG). The results show that the stock of external debt and the opening of the capital account negatively affect long-term economic growth in the WAEMU region. The country analysis confirms the panel results for Benin, Burkina Faso and Mali. Sectoral misallocation of external capital could be a plausible explanation. The economies of WAEMU countries are mostly dominated by the service sector, which contributes more to their GDP than the productive sectors, i.e. agriculture and industry. While the agricultural sector, which employs a large part of the active population, is still traditional and does not benefit from capital inflows, the industrial sector is still embryonic.

Keywords: international financial integration; economic growth; heterogeneous panel; WAEMU.

JEL classification: F36; F38; F62.

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1. INTRODUCTION

Restricted access to capital has long been presented as one of the main obstacles to the development in the least developed countries. In the early 1970s, there was a renewal of liberal economic theory, which advocated a total liberalisation of financial systems. Authors such as McKinnon (1973) and Shaw (1973) believe that differences in the quantity and quality of services offered by financial systems can partly explain the differences in growth between countries. In particular, they point to distortions in the financial markets, linked to government intervention in the achievement of equilibrium, and take a neoclassical view. Kaminsky and Schmukler (2008) define financial liberalisation as deregulation at three levels, namely the domestic financial sector, the capital account and the stock market : (i) a fully liberalised domestic financial sector is characterised by the absence of controls on lending and borrowing rates, and the absence of credit controls; (ii) liberalisation of the capital account allows firms or banks to borrow freely from abroad; even if the authorities have to be kept informed, authorisations are delivered almost automatically; (iii) a fully liberalised stock market allows foreign investors to acquire domestic securities without restrictions.

In addition, capital account liberalisation has played an important role in international financial integration. International financial integration refers to the links of a given country with international capital markets, and can be assessed *de jure* through the degree of restrictions on cross-border capital movements, or *de facto* through the flows or stocks of such capital. Through the creation of larger financial spaces, international financial integration should improve the regional and global allocation of savings and credit to the most productive investments. In the early 1980s, the WAEMU countries, like other developing countries, adopted strategies to liberalise their economies. This liberalisation concerned both the real sector, through, among other things, the privatisation of state-owned enterprises, and the financial sector, the aim of which was to respond more effectively to the growing need for financing. The financial reforms aimed in particular to clean up the failing domestic banking sector and to attract large international banks and investors.

Statistically, there has been a relative improvement in indicators between 1980 and 2019. Gross stocks of external liabilities and assets, a *de facto* measure of international financial integration, rose from an average of 78.6% of GDP over the period 1980-1989 to around 115% over the period 2010-2019. However, over the same period, the *de jure* index of capital account opening, in average, deteriorated from 0.34 to 0.16 (on a scale of 0 to 1). This situation can be explained by the strengthening of controls on capital flows, which aims to reduce illicit capital flows and the financing of terrorism. These provisions are set out in Article 17 of Regulation N°09/2010/CM-UEMOA on the external financial relations of the West African Economic and Monetary Union (WAEMU) Member States. Article 97 of the WAEMU Treaty of 10 January 1994 had already provided for provisions allowing Member States to impose measures on foreign capital flows for reasons of public security.

Nevertheless, the major challenge for the literature, both theoretical and empirical, is to establish a causal relationship between the degree of international financial integration and the macroeconomic performance of a country. Neoclassical theory states that international financial integration should reduce the cost of capital in initially less endowed developing countries and initiate a process of investment and per capita product growth. Fischer (1998) points out that the free movement of capital facilitates an efficient global allocation of savings

and helps channel resources to their most productive uses, thereby increasing economic growth and prosperity.

In addition, capital mobility expands opportunities to hedge against certain risks, through international portfolio diversification. For Krugman *et al.* (2009), the motive of diversifying the overall portfolio risk is an important factor behind the international exchange of financial assets. To reduce portfolio risk, it is preferable to diversify one's investments rather than invest all one's wealth in a single asset. We owe this principle to the portfolio choice theory of Markovitz (1952) and later to the analysis of Tobin (1958). A country's openness to international capital flows thus gives it more opportunities for international diversification, which allows investors to reduce their overall portfolio risk.

Barro *et al.* (1995) demonstrate, however, the non-instantaneous transmission of the effects of the opening of the capital account to the real sector, starting from a Cobb-Douglas type production function. They consider that capital mobility is present in two effects; first, in capital convergence, through the total amount of foreign capital entering the country (foreign debt and foreign direct investment), and second, in the case of technological catch-up, through the composition of foreign capital. While it is true that the speed of convergence (to the steady state) of an open economy under foreign credit constraints is higher compared to that of a closed economy, this speed is likely to be limited and does not deviate greatly from that of a closed economy. Theoretical criticisms, on the other hand, centre around the Lucas (1990) paradox, which points to a greater movement of capital from poor to developed countries in the 1980s. Another criticism is that of the imperfection of financial markets (Stiglitz & Weiss, 1981), which, due to informational asymmetries, do not always lead to an optimal allocation.

Empirically, the relationship between international financial integration and economic growth has been the subject of several analyses in developing countries, providing equally controversial results. Indeed, most empirical studies have failed to find positive effects of financial openness on economic growth. One of the first studies to find a positive link between financial integration and economic growth is that of Quinn (1997). His work was original in that he developed a new index for assessing financial openness (Quinn Intensity Index). Empirical estimates for 64 countries indicate that capital account liberalisation has a positive and significant effect on GDP per capita growth. This study was extended to 94 countries by Quinn and Toyoda (2008), confirming the results of the previous study. Nevertheless, criticism is often levelled at *de jure* measures of financial integration, as a country can liberalise its capital account without benefiting from the capital flows characteristic of financial integration. Prasad *et al.* (2003) use capital stocks as a percentage of GDP as an indicator of financial globalisation, which is considered more stable than flow variables and preferred to *de jure* measures.

Furthermore, with a sample of 76 countries, they are unable to draw a clear conclusion about the macroeconomic impact of financial globalisation. Mougani (2011), in the context of African countries, uses as measures of financial integration, the net capital flows/GDP ratio and the FDI/GDP ratio. The results show that the impact of external capital flows on growth remains mixed, and the author stresses that the contribution of financial integration would depend mainly on the initial conditions and policies implemented in each country. Ray (2012), in the context of India, shows instead that there is a causal relationship from economic growth to international financial integration. Misati *et al.* (2015) analyse the relationship in two African regions (COMESA and SADC) and find mixed and regionally varying results. While

two of the indicators of financial integration are significant in the COMESA region, only one indicator is significant for SADC. The *de jure* financial openness index has a significant negative effect on growth in the COMESA region, while FDI and portfolio investment flows have a positive effect. In SADC, only FDI flows have a significant positive effect. Finally, Saafi *et al.* (2016) take a sample of 19 emerging and developing countries and perform a country-by-country analysis. They find that international financial integration is a cause of economic growth in 06 countries and a reverse causality in 09 countries, with 04 countries showing a neutral result.

The research finds its interest in the controversial results of studies undertaken in developing countries, and recent theoretical developments whose application to WAEMU countries would add to the literature. Moreover, integration through capital markets is a major development policy issue for the countries of the zone, with the adoption of the new regulation of financial relations introduced in 2010. The latter intend to take advantage of the wave of international financial integration, and this study will help identify avenues for new economic policy directions. To this end, and in contrast to several studies on the subject, a range of indicators of international financial integration is used, to take account of the specificity of their effects on economic growth. The study also takes into account the heterogeneity of the countries in the panel, and provides insights into country-specific factors that may influence the relationship between international financial integration and economic growth.

The rest of the article is structured around three points. The 2nd Section presents the methodological approach for analysing the long-run relationship between international financial integration and economic growth, based on heterogeneous panel techniques. The 3rd Section presents the results and comments, and the 4th Section concludes.

2. METHODOLOGICAL APPROACH

This part is devoted to the presentation of the data and the models for analysing the long-term relationship between the different panel variables.

2.1 Data and sources

The analysis covers seven WAEMU countries over the period 1980-2019, Guinea-Bissau being excluded for lack of data. The data are extracted from several sources for the construction of the database. Thus, the data relating to international financial integration are extracted from the Lane and Milesi-Ferreti (2017) database, updated in 2021, for the *de facto* measures, and from the updated KAOPEN database of Chinn and Hiro (2008) for the *de jure* measure. Starting from the *de facto* measures, we construct the global index of international financial integration by summing the stocks of foreign assets and liabilities in relation to GDP; we also include in the analysis the stocks of external debt and foreign direct investment.

The *de jure* measure takes into account the existence or not of regulatory restrictions on international capital movements, but also the intensity with which these are implemented; the normalised index varies from 0 to 1, with the highest value symbolising perfect financial integration. We use the IMF's multidimensional index (Sahay *et al.*, 2015) to capture the level of domestic financial development. This indicator takes into account the development of financial markets on the one hand, and financial institutions on the other; it also has the advantage of incorporating the dimensions of access, efficiency and depth of financial

systems. The variables as human capital, gross fixed capital formation (as % of GDP) and public consumption (as % of GDP) are taken from the Penn World Table (PWT). The other variables, real GDP per capita growth, inflation and trade openness are taken from the World Bank's World Development Indicators database.

2.2 Heterogeneous panel model

We have long series to analyse the long-term relationships between the different variables. We estimate an econometric model of economic growth as follows:

$$g_{it} = a_0 + IFI_{it}\beta + +X_{it}\alpha + \varepsilon_{it} \quad (1)$$

where g_{it}, IFI_{it} and X_{it} represent, respectively, economic growth, a vector of international financial integration variables and a vector of control variables of country i in period t ; ε_{it} represents the error term. For the estimations, the techniques of analysis of long term relations on heterogeneous panel data are retained by taking into account the cross-sectional dependence. The MG (Mean Group) estimators of Pesaran and Smith (1995), the CCEMG (Common Correlated Effects Mean Group) of Pesaran (2006) and the AMG (Augmented Mean Group) of Eberhardt and Teal (2010) offer interesting perspectives for the analysis of cointegration relationships on panels of countries with relative heterogeneity and cross-sectional dependence. The AMG estimator of Eberhardt and Teal (2010) provides unbiased estimates in cases of cross-sectional dependence, and is presented by the authors as an alternative to the CCEMG estimator of Pesaran (2006). The AMG estimator takes into account non-stationary variables and multifactor error terms. Moreover, unlike the CCEMG approach, it treats common unobservable variables as a common dynamic process. This common dynamic process can be presented as follows:

$$y_{it} = \beta_i x_{it} + \mu_{it} \quad (2)$$

with $\mu_{it} = \alpha_{1i} + \lambda_i f_t + \varepsilon_{it}$ et $x_{it} = \alpha_{2i} + \lambda_i f_t + \gamma_i g_t + e_{it}$; the x_{it} and y_{it} are observable variables; β_i is the country-specific slope for the observable regressors; the μ_{it} represents the unobservable regressors ; ε_{it} and e_{it} are error terms (white noise type); $\alpha_{.i}$ represent group fixed effects, i.e. time-invariant heterogeneous characteristics; f_t and g_t are unobserved common factors that may exhibit non-linearity and non-stationarity; and λ_i represent factors that exhibit time-varying heterogeneity and cross-sectional dependence. The model is estimated in two steps:

- First step (i):

$$\Delta y_{it} = b'\Delta x_{it} + \sum_{t=2}^{T} c_t \Delta D_t + e_{it} \text{ with } \hat{c}_t = \hat{\mu}_t^{\bullet} \quad (3)$$

- Second step (ii):

$$y_{it} = a_i + b_i' x_{it} + c_i t + d_i \hat{\mu}_t^{\bullet} + e_{it} \quad \text{with } \hat{b}_{AMG} = N^{-1} \sum_i \hat{b}_i \quad (4)$$

The first step (i) represents a standard OLS regression with T - 1 dummy years in first differences, from which the dummy year coefficients (renamed $\hat{\mu}_t^{\bullet}$) are collected. In the second step (ii), $\hat{\mu}_t^{\bullet}$ is included in each of the N standard country regressions which also include a linear trend term to capture omitted idiosyncratic processes evolving linearly over time; the

estimates are averaged across countries using the MG approach of Pesaran and Smith (1995). As for the CCEMG estimators, they focus on the estimation of $\hat{b}$ The CCEMG estimators focus on the estimation of the coherence and not on the nature of the unobserved common factors or their factor loadings; they do not provide an explicit estimate for the unobservable factors f_t. In addition to the panel analyses, the MG, CCEMG and AMG estimators provide us with country specific results allowing for a specific analysis. In the presence of individual panel dependence, heterogeneity, non-stationary variables and multifactor error terms, the power of the AMG estimator outweighs the other two estimators (MG and CCEMG).

3. MAIN RESULTS

3.1 Descriptive analysis

The results for the descriptive statistics (mean, standard deviation, minimum and maximum) are presented in the following Table no. 1.

Table no. 1 – Descriptive statistics of the data

Variables	N	mean	sd	min	max	skewness	kurtosis
Economic growth (%)	280	0.665	4.225	-19.18	18.18	-0.551	6.468
De facto financial integration (% of GDP)	280	91.28	39.49	18.23	270.8	1.334	6.057
Foreign direct investment (% of GDP)	280	10.89	9.890	0.468	61.02	1.882	8.242
External debt (% of GDP)	280	57.23	25.95	13.85	207.9	1.280	7.027
KAOPEN *de jure* index (0 - 1)	272	0.238	0.114	0.164	0.477	0.936	1.894
Financial development (0 - 1)	280	0.109	0.0261	0.0489	0.195	0.548	2.967
Trade (% of GDP)	280	42.62	14.30	15.79	99.29	0.884	4.157
Human capital index (value)	280	1.307	0.230	1.014	1.919	0.737	2.449
Gross Fixed Capital Formation (% of GDP)	280	0.143	0.0651	0.0120	0.464	0.521	4.619
Public consumption (% of GDP)	280	0.172	0.0727	0.0698	0.577	1.938	8.407
Inflation (%)	280	4.693	8.916	-24.41	56.28	2.747	13.83

Source: authors' calculations

It can be noted that over the study period (1980 – 2019), the average growth rate of per capita GDP is 0.66%, with a minimum of -19.18% and a maximum of 18.16%, recorded respectively in Niger in 1984 and Mali in 1985. As regards international financial integration indicators, the WAEMU countries have an average debt stock of 57.23% of GDP, compared to an average stock of foreign direct investment of 10.89% over the period. The overall *de facto* financial integration indicator (IFI) averages 91.28%, with the highest level of 270.8% reached in 2015 by Burkina Faso, and the lowest of 18.23% also achieved in 1980 by Burkina Faso. The KAOPEN capital account opening index remained on average low at 0.238. We also note a high variability of the different observations, both in time and space between countries. Table no. 2 below shows the average evolution of key indicators over five decades. We note a positive and continuous evolution of per capita growth from the 1980/1989 decade to the 2010/2019 decade. The global index of international financial integration took a breather in the decade 2000, before a sharp recovery in the last decade. While the stock of foreign direct investment has experienced a positive and sustained trend over the period, the stock of foreign debt has declined. This could be due to the decline in public debt in the early 2000s, following the Heavily Indebted Poor

Countries initiative. Finally, controls on international capital movements have tightened over time, resulting in a decline in the KAOPEN index from one decade to the next.

Table no. 2 – Average change in key indicators

Period	1980-1989	1990-1999	2000-2009	2010-2019
Economic growth	-1,007847	0,4247002	0,5589242	2,439049
International financial integration	78,61563	91,54873	85,01645	115,2906
Foreign direct investment	6,970055	6,011747	9,473416	21,75817
External debt	62,21257	69,12112	52,83534	49,22747
KAOPEN Index	0,3476307	0,2876769	0,1643452	0,1643452

Source: authors' calculations

3.2 Results of preliminary tests

In this section, we present the cross-sectional independence, unit root and cointegration tests.

The results of the preliminary tests are presented in Tables no. 3 to no. 6 below. The Pesaran (2004) cross-sectional dependency test results are presented in Tables no. 3. The results at the variable level do not allow us to accept the null hypothesis of independency between the individuals in the panel (the probabilities associated with the tests are all lower than 0.05). We conclude that there is a strong cross-sectional dependency in the evolution of the respective variables.

Table no. 3 – Results of the Pesaran cross-sectional dependency test

Variable	Test CD	p-value
Economic growth	5.69	0.000
Financial integration	10.35	0.000
Foreign direct investment	19.27	0.000
External debt	11.10	0.000
Financial development	4.57	0.000
Human capital	27.61	0.000
Domestic investment	6.19	0.000
Public consumption	11.12	0.000
Commercial opening	6.40	0.000
Inflation	13.81	0.000

Note: Null hypothesis: cross-sectional independency

Source: author's construction

The results of the cross-sectional independency test guide the choice of the unit root test. When there is cross-sectional dependency, as presented in Tables no. 3, second generation tests are preferred to first generation tests[2]. The unit root test of Pesaran (2003) was therefore chosen for this analysis and the results are presented in Table no. 4. All international financial integration variables are stationary in first difference. The other variables are stationary at level, with the exception of the human capital variable, which is stationary at second difference. However, this stationarity of different orders does not represent a problem for cointegration studies and the variables can be combined to analyse their long-term evolution.

Table no. 4 – Results of Pesaran panel unit root test (2003)

Variables	Level		First difference		Decision
	Constant	Constant + trend	Constant	Constant + trend	
Economic growth	-4.321 (0.000)	-4.231 (0.000)	-	-	I(0)
De facto financial integration	-1.953 (0.314)	-2.636 (0.187)	-3.940 (0.000)	-3.989 (0.000)	I(1)
De jure financial integration	1.865 (0.969)	3.194 (0.999)	-2.890 (0.002)	-2.297 (0.011)	I(1)
Foreign direct investment	-2.011 (0.258)	-2.852 (0.062)	-4.216 (0.000)	-4.239 (0.000)	I(1)
External debt	-2.102 (0.182)	-3.023 (0.020)	-4.107 (0.000)	-4.051 (0.000)	I(1)
Financial development	-1.862 (0.408)	-2.432 (0.391)	-4.465 (0.000)	-4.382 (0.000)	I(1)
Human capital	-1.274 (0.923)	-0.659 (1.000)	-0.732 (0.998)	-2.367 (0.467)	I(2)
Domestic investment	-1.815 (0.460)	-2.223 (0.638)	-4.885 (0.000)	-4.913 (0.000)	I(1)
Public consumption	-2.499 (0.022)	-3.358 (0.001)	-	-	I(0)
Commercial opening	-1.637 (0.657)	-2.299 (0.548)	-5.057 (0.000)	-5.057 (0.000)	I(1)
Inflation	-4.674 (0.000)	-4.658 (0.000)	-	-	I(0)

Note: Probabilities in parentheses. Null hypothesis: Presence of a unit root.

Source: author's construction

The second generation cointegration test (Westerlund, 2008) is used following the unit root tests. results are presented in Tables no. 3. We use the international financial integration variables in different equations. The test provides four statistics: the Ga and Gt statistics or *Mean Group tests* consider, under the null hypothesis of non-cointegration for at least one individual, that the parameters of the error correction term may be different between the individuals in the panel; the Pa and Pt statistics or *Panel tests* which are based on the hypothesis that the error correction term is identical for all the individuals, the rejection of the null hypothesis implying that the series are cointegrated for all individuals in the panel. The results make it possible to reject the null hypothesis of the absence of cointegration, both at the level of the group of countries and at the panel level.

Table no. 5 – Results of the Westerlund (2008) cointegration test

	(IFI)	(KAOPEN)	(IDE)	(DEBT)
Gt	-3.959***	-3.940***	-3.886***	-4.186***
	(0.003)	(0.000)	(0.000)	(0.000)
Ga	-26.414**	-23.955***	-24.963***	-27.532***
	(0.020)	(0.002)	(0.001)	(0.000)
Pt	-9.710***	-9.251***	-9.509***	-9.895***
	(0.009)	(0.003)	(0.001)	(0.000)
Pa	-22.009**	-22.300***	-23.015***	-24.064***
	(0.032)	(0.000)	(0.000)	(0.000)

Note: Probabilities in parentheses. Null hypothesis: No cointegration.

Source: author's construction

Finally, in Table no. 6 we present the results of the slope homogeneity test of Pesaran and Yamagata (2008). These results reveal a problem of heterogeneity. In the specification of the models, the cross-sectional dependence and heterogeneity of the coefficients must be taken into account to avoid estimation bias.

Table no. 6 – Pesaran and Yamagata (2008) slope homogeneity test

Model 1 (*de facto* integration)		**Model 2 (*de jure* integration)**	
Statistics	P-value	Statistics	P-value
$\tilde{\Delta}$ 2.455	0.014	$\tilde{\Delta}$ 1.849	0.064
$\tilde{\Delta}_{adj}$ 2.789	0.005	$\tilde{\Delta}_{adj}$ 2.109	0.035
Model 3 (IDE)		**Model 4 (DEBT)**	
Statistics	P-value	Statistics	P-value
$\tilde{\Delta}$ 1.970	0.049	$\tilde{\Delta}$ 2.516	0.012
$\tilde{\Delta}_{adj}$ 2.238	0.025	$\tilde{\Delta}_{adj}$ 2.858	0.004

Null hypothesis: homogeneity of the slope

Source: author's construction

These different tests have allowed the choice of estimators adapted to long-term relationships on heterogeneous panels. The individual dependence, the no stationarity of several variables and the strong heterogeneity of the countries lead us to favour the results of the AMG estimators in the analyses.

3.3 Econometric results

The main results are presented in Table no. 7. The overall trend is that international financial integration negatively and adversely affects economic growth. Thus, in the long run, capital account openness and the stock of foreign capital negatively affect real GDP per capita growth; the effect is of greater magnitude for the *de jure* capital account openness index. These results do not confirm those found by Quinn (1997) and Quinn and Toyoda (2008) who find positive effects of *de jure* financial integration on economic growth. However, Quinn's (1997) de jure index has been much criticised in the literature and we prefer Chinn and Hiro (2008) index. Following the critique of Lucas (1990), capital account opening has not produced the expected results in developing countries, and has most often resulted in capital flight from the latter. Sectoral misallocation of external capital could also be a plausible explanation. The economies of WAEMU countries are mostly dominated by the service sector, which contributes more to their GDP than the productive sectors, i.e., agriculture and industry. While the agricultural sector, which employs a large part of the active population, is still traditional and does not benefit from capital inflows, the industrial sector is still embryonic.

Table no. 8 summarises the results of estimations with the external debt and the stock of foreign direct investment (FDI), which constitute the bulk of international capital movements in the zone. The previous conclusions, i.e. the negative and significant effect is verified for the external debt stock variable. FDI stocks have a negative but insignificant effect. The external liabilities of WAEMU countries are concentrated in debt (with a high participation of governments) valued on average at 57.23% of GDP, while the stock of FDI is worth only 10.89% on average over the period 1980 - 2019. Debt remains a burden for states and is often

seen as a key determinant of structural deficits. On an unsustainable path, the debt burden can divert governments' efforts to promote the productive sectors of their economies. The evolution of the stock of external debt (see Table no. 2) is also indicative of its weight for countries that benefited from debt relief following the HIPC (Heavily Indebted Poor Countries) initiative in the early 2000s. Indeed, the stock of external debt fell from around 69% in the 1990-1999 decade to around 52% and then 49% respectively in the 2000-2009 and 2010-2019 decades. Thus, while the structural adjustment programmes (SAPs) advocated private initiatives with minimal state involvement in the economy and incentives for foreign capital inflows, the HIPC initiative aimed to relieve states of the burden of debt servicing and allow them to accompany the private sector.

Table no. 7 – International financial integration and economic growth

Dependent variable: ***Real GDP per capita growth***						
Variables/Methods	**MG**		**CCEMG**		**AMG**	
De facto financial integration	0.0129		-0.0591*		-0.0324***	
	(0.0144)		(0.0316)		(0.0118)	
De jure financial integration		-3.990		-11.96		-9.928***
		(3.567)		(15.93)		(2.896)
Financial development	26.06	16.88	10.87	14.94	33.73**	26.94
	(21.54)	(24.73)	(14.81)	(18.79)	(14.64)	(16.98)
Human capital	0.598	-4.108	31.91	31.74	-5.227	0.0294
	(2.284)	(3.127)	(69.18)	(51.38)	(4.984)	(2.777)
Domestic investment	23.84***	19.73**	32.82***	25.26***	18.65**	26.13***
	(6.273)	(8.383)	(12.12)	(6.847)	(7.387)	(8.276)
Government consumption	-21.29	-13.78	-8.299	-5.893	-5.490	-2.629
	(20.14)	(16.67)	(20.79)	(17.77)	(14.43)	(14.23)
Trade openness	0.0840	0.0690	0.0203	0.0271	0.0988**	0.0523
	(0.0534)	(0.0485)	(0.0756)	(0.0797)	(0.0427)	(0.0411)
Inflation	-0.0539	-0.0414	-0.0995***	-0.0552*	-0.0386	-0.0384
	(0.0351)	(0.0388)	(0.0338)	(0.0300)	(0.0251)	(0.0262)
Constant	-8.687*	-0.157	27.32	-2.100	-6.998	-10.88**
	(4.865)	(4.933)	(22.48)	(18.38)	(5.600)	(4.507)
Observations	280	272	280	272	280	272
Number of countries	7	7	7	7	7	7
CD-test	2.82	2.58	-3.01	-2.88	-3.59	-3.44
P-value	0.005	0.010	0.003	0.004	0.000	0.001

Note: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Source: author's construction

Other variables appear relevant for the explanation of economic growth in the WAEMU area. The domestic investment variable positively and significantly affects economic growth, the result being robust for all equations and estimators. Policies should therefore be more directed towards domestic capital accumulation which is the main source of growth. Financial development also has a significant and positive effect on economic growth.

Table no. 8 – Effects of FDI stocks and debt stocks on economic growth

Dependent variable: ***Real GDP per capita growth***						
Variables/Methods	**MG**		**CCEMG**		**AMG**	
Foreign Direct Investment	-0.0957		-0.157		-0.0617	
	(0.0809)		(0.118)		(0.0733)	
External debt		0.00771		-0.128*		-0.0581***
		(0.0204)		(0.0757)		(0.0172)
Financial development	20.66	30.43	-0.936	7.739	40.38***	35.61**
	(20.22)	(22.09)	(12.02)	(16.91)	(13.70)	(17.42)
Human capital	7.073	3.393	63.02	144.0*	7.922	-2.487
	(5.076)	(2.812)	(92.75)	(83.57)	(6.204)	(4.252)
Domestic investment	19.38***	26.01***	21.17*	35.21**	20.25***	16.19*
	(7.145)	(6.997)	(10.83)	(14.34)	(7.205)	(9.088)
Government consumption	-20.59	-18.20	-7.176	-1.308	-0.0997	-2.372
	(18.70)	(20.09)	(18.56)	(21.41)	(14.28)	(14.36)
Trade openness	0.0966*	0.0895*	0.0124	0.0116	0.0857**	0.104***
	(0.0578)	(0.0514)	(0.0667)	(0.0803)	(0.0367)	(0.0391)
Inflation	-0.0599	-0.0473	-0.0817***	-0.116**	-0.0294	-0.0342
	(0.0376)	(0.0386)	(0.0249)	(0.0520)	(0.0229)	(0.0284)
Constant	-13.87**	-12.71*	-11.67	-14.24	-24.10***	-10.08*
	(6.371)	(6.647)	(23.55)	(42.00)	(8.086)	(5.894)
Observations	280	280	280	280	280	280
Number of countries	7	7	7	7	7	7
CD-test	3.27	2.90	-3.03	-2.77	-3.33	-3.55
P-value	0.001	0.004	0.002	0.006	0.001	0.000

Note: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Source: author's construction

The panel results provide interesting evidence of the perverse effects of international financial integration on the growth of WAEMU countries. To take into account the heterogeneity of the effects, we propose a country analysis. Table no. 9 provides the results of the regressions by country. The analysis is done for each indicator of international financial integration retained above. Significant and negative effects are found in three countries (Benin, Burkina Faso and Mali). The rest of the countries show negative but non-significant coefficients. These results are more significant for external debt than for FDI stocks and the de jure capital account opening index. External debt stocks therefore have perverse effects on the economic growth of these countries. Factors not taken into account in the analysis may provide some justification for this heterogeneity of results across countries. These factors could include institutional quality, governance, absorptive capacity and other structural factors.

Table no. 9 – Country level results of the effects of international financial integration.

Ctry	Variables	(MG)	(CCEMG)	(AMG)	Ctry	Variables	(MG)	(CCEMG)	(AMG)
	IFI	-0.0411	-0.211*	-0.071		IFI	0.015	0.020	-0.053
		(0.042)	(0.111)	(0.046)			(0.038)	(0.100)	(0.039)
	KAOPEN	-2.669	-94.43*	-1.353		KAOPEN	12.953	-7.36	-9.145
		(8.233)	(57.25)	(8.345)			(9.355)	(21.12)	(11.717)
BEN	FDI	0.109	0.278	0.161	**NER**	IDE	-0.078	0.038	-.119
		(0.189)	(0.276)	(0.193)			(0.084)	(0.191)	(0.073)
	DEBT	-0.075	-0.549***	-0.128**		DETTE	0.053	0.011	-.033
		(0.051)	(0.123)	(0.056)			(0.051)	(0.106)	(0.054)
	IFI	-0.025	-0.019	-0.042**		IFI	0.025	-0.067	0.007
		(0.018)	(0.024)	(0.017)			(0.053)	(0.083)	(0.050)
	KAOPEN	-16.279	-30.61	-22.21**		KAOPEN	-11.201	-2.373	-12.49
		(10.573)	(70.65)	(8.883)			(11.017)	(49.10)	(10.67)
BFA	FDI	-0.217	-.442	-0.379	**SEN**	IDE	-0.331	-0.405	-.238
		(0.260)	(0.319)	(0.241)			(0.361)	(0.417)	(0.346)
	DEBT	-0.033	-0.054	-0.095**		DETTE	0.036	-0.188	-0.0009
		(0.035)	(0.051)	(0.036)			(0.062)	(0.116)	(0.060)
	IFI	0.007	0.021	-0.017		IFI	0.033	-0.122*	0.006
		(0.029)	(0.042)	(0.024)			(0.035)	(0.062)	(0.034)
	KAOPEN	-1.991	10.60	-9.683		KAOPEN	0	0	0
		(9.707)	(12.97)	(8.622)			(.)	(.)	(.)
CIV	FDI	-0.372	0.182	0.057	**TGO**	IDE	0.126	-0.398	0.086
		(0.332)	(0.341)	(0.292)			(0.121)	(0.261)	(0.114)
	DEBT	0.015	0.029	-0.019		DETTE	-0.022	-0.116	-0.046
		(0.025)	(0.041)	(0.022)			(0.057)	(0.072)	(0.052)
	IFI	0.073**	-0.035	-0.055					
		(0.031)	(0.070)	(0.034)					
	KAOPEN	-8.743	40.46	-14.60					
		(13.253)	(63.28)	(9.526)					
MLI	FDI	0.094	-0.353	0.001					
		(0.292)	(0.363)	(0.209)					
	DEBT	0.079**	-0.027	-0.082**					
		(0.034)	(0.104)	(0.040)					

Note: Standard errors are in parentheses; *** p<0.01. ** p<0.05. * p<0.1. BEN: Benin. BFA: Burkina Faso. CIV: Ivory Coast. MLI: Mali. NER: Niger. SEN: Senegal. TGO: Togo.

4. CONCLUSION

This paper is devoted to the analysis of the long-term effects of international financial integration on economic growth in the WAEMU countries. With observations covering the period 1980-2019, we adopted the methodology of heterogeneous panel analysis in a multivariate system. The results of the Westerlund (2008) cointegration test confirm the existence of a long-term relationship formed by all the variables selected for the study. The main findings are that the external debt stock and the opening of the capital account have significantly negative effects on economic growth in the WAEMU. However, these results are sensitive to country-specific factors; in three out of seven countries, the panel results are confirmed. As a way forward, further investigation into possible transmission channels from international financial integration to economic growth could better explain the contradictions between theoretical predictions and empirical studies. These extensions should also take into account endogenous factors, such as governance and institutional quality, which may present threshold conditions, in order to better account for the effects of international financial integration on economic growth.

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Notes

[1] Benin, Burkina Faso, Côte d'Ivoire, Guinea-Bissau, Mali, Niger, Senegal and Togo. In this study, we have removed Guinea-Bissau due to lack of data over a large part of the period.

[2] A third generation of tests takes into account structural breaks and outliers (Carrion-i-Silvestre et al, 2005).

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Modelling the Non-Linear Dependencies between Government Expenditures and Shadow Economy Using Data-Driven Approaches

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Abstract: This article aims to model the relationship between the size of the shadow economy and the most important government expenditures respectively social protection, health, and education, using nonlinear approaches. We applied four different Machine Learning models, namely Support Vector Regression, Neural Networks, Random Forest, and XGBoost on a cross-sectional dataset of 28 EU states between 1995 and 2020. Our goal is to calibrate an algorithm that can explain the variance of shadow economy size better than a linear model. Moreover, the most performant model has been used to predict the shadow economy size for over 30,000 simulated combinations of expenses in order to outline some possible inflection points after which government expenditures become counterproductive. Our findings suggest that ML algorithms outperform linear regression in terms of R-squared and root mean squared error and that social protection spending is the most important determinant of shadow economy size. Further to our analysis for the 28 EU states, between 1995 and 2020, the results suggest that the lowest size of shadow economy occurs when social protection expenses are greater than 20% of GDP, health expenses are greater than 6% of GDP, and education expenses range between 6% and 8% of GDP. To the best of the authors' knowledge, this is the first paper that used ML to model shadow economy and its determinants (i.e., government expenditures). We propose an easy-to-replicate methodology that can be developed in future research.

Keywords: machine learning; shadow economy; government spending.

JEL classification: C63; H50; E26.

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1. INTRODUCTION

Market transactions that are not deliberately declared to the competent authorities of the state represent a high proportion of the GDP of that state. These, along with other informal activities (e.g., criminal activities, domestic activities) constitute the phenomenon of underground economy (hereinafter referred to also as *informal economy* or *shadow economy*). Shadow economy, within a society that prioritizes the co-existence and the well-being of the society, is equivalent to non-assumption and evading responsibility.

The negative repercussions of informal economies are the major damages to government revenue size and the infringement of tax regulations. As such, policy makers conduct strategies to fight the increase of the shadow economy, using all the measures at their disposal. As governments allocate resources collected from society towards different priorities (*e.g.*, education, health, social protection), it is vital to have a better understanding of how their decisions regarding this distribution influence shadow economy.

Just as in an individual's life structuring spending in a way that brings the best results, in a society, there is a need for proper management of tax revenues so that sectors that are vulnerable and of interest can be funded. In economic terms, better financial management of a state will be reflected, among others, in a reduced dent in the underground economy. Corroborating the above two statements, we can say that an efficient distribution of tax revenues should also be reflected in a lower level of the underground economy. Regarding the efficiency of government spending, indicators have also been developed by the World Economic Forum Global Competitiveness Index, placing countries in a range between 1-7. It is in this direction that the present study aims to be developed, to see what the premises are for which we can consider the spending of a state as efficient or not, considering the level of the underground economy.

The laws of worldwide states differ according to each state approach to their public economic strategy and history. As far as EU member states are concerned, the legislative and economic elements are largely homogeneous, based on broadly the same future development prospects. Focusing on the latter category of states will allow us to formulate relevant conclusions that can be generally applicable to them. Moreover, the data on the underground economy are difficult to find from a reliable source, but as concerns the EU member states, we have identified databases that were previously analyzed in the specialized literature and that are considered relevant and reliable, as will be described in this paper.

There is a rich empirical literature that studies the relationship between shadow economy and different casual variables. Various categories of expenditures were also studied in relation to the evolution of the informal economy, in different forms and through different methods. Although well documented, most of the empirical studies use a linear model in order to explain the sensitivity of the shadow economy to different variables. However, the interactions between financial and economic variables are very complex and, in most cases, highly nonlinear.

This paper aims to model the dependencies between three main public expenditures (*i.e.*, social protection expenditure, education expenditure, health expenditure) and shadow economy size using data-driven approaches. To the best of the authors' knowledge, this is the first article to use machine learning to model the informal economy and government expenditures as determinants. Our goal is to calibrate an algorithm that can explain the variation of shadow economy better than a linear model in a real word setting. We are also trying to find out if there are some inflection points after which government expenditures become counterproductive in

decreasing the size of shadow economy, thus finding an optimal level of public spending based on the cross-sectional data of 28 EU states between 1995 and 2020.

Our input to the literature is two-fold: i) empirical, by considering a range of government expenditures describing the economic strategy of the governments, as well as an innovative method to study the link between the underground economy and government spending, namely machine learning; ii) practical, through a series of recommendations.

The sections in this paper are organized as follows: Section 2 presents part of the significant proceedings in our research; Section 3 briefly describes the machine learning algorithms used in this study; Section 4 presents the methodology and Section 5 the results of a linear analysis; Section 6 presents the results of the nonlinear analysis. Conclusions and further research are presented in Section 7.

2. LITERATURE REVIEW

Many determinants of the shadow economy have been analysed over time in the scientific literature. From the most common determinants of tax burden, social security contributions, tax complexity, and uncertainty (Alm *et al.*, 1992; Schneider & Enste, 2002; Smuga *et al.*, 2005; Schneider & Williams, 2013 and others) to perceptual determinants such as quality of public institutions, public services, level of development, regulations, moral tax (Schneider & Enste, 2000; Aruoba, 2010; Schneider *et al.*, 2010 and others) have been intensively analysed by the authors both in relaxing economic contexts and in periods when states have been forced to proceed with certain economic measures that have been controversial in the eyes of society.

If, in terms of fiscal policy, its relationship with the informal economy has often been demonstrated in the literature by authors such as Cebula (1997) or Duncan and Peter (2014), the same is applicable with regard to other government policies. For example, budgetary policy, which is closely related to fiscal policy, has not been addressed as often. In the following, we will set out some of the views that have been expressed on the latter policy.

Other authors have considered that governments can control the willingness of individuals to evade the formal area of the economy. Malaczewska (2013) studies a pattern of the shadow economy and the idea of beneficial government spending, using the sensitivity analysis of Nash equilibrium. The findings also emphasize that if the probability of detecting activities specific to the underground economy increases, then the government can be expected to increase the level of the amounts spent on control institutions (such as the *Agencies for Fiscal Administration*). The author concludes that households encouraged by useful government expenditure will give up underground activities and will migrate to the formal sector.

In the same direction, another view of the relationship between government policy and informal activities is captured by Aruoba (2010). The level of government spending is responsible for the variance in fiscal rates. The government implements strategies to finance the balanced number of expenditures for each sector using revenues collected from imposed taxes.

Government spending was also investigated by Igor and Schneider (2017). The authors show that there is a positive link between government (military) expenditures and the shadow economy in the Baltic states. In the same study, for government expenditures (health), the results indicate a negative relationship in connection with the shadow economy. So military expenditures, being a less transparent category and less visible to the general public, do not

provide (*e.g.*, contrasting with the health expenditures) so many tangible benefits in lowering the agents' inclination to divulge their incomes.

Social protection is a variable that has been considered when it comes to the informal economy. In this sense, the European Union funded a project led by ARS Progetti S.P.A. et al. (2017), the project's purpose being to develop valuable approaches to strengthen social protection among people in the informal economy. Weaker public services negatively influence social perception regarding government policy Kelmanson *et al.* (2019). Mara (2021) argues that in the long run a possible solution to reduce the size of the shadow economy is to increase social protection expenditures, but points out that this solution needs to be accompanied by other important policies, such as reducing corruption, securing property rights, and maintaining a reasonable tax burden.

Surprisingly, with regard to the impact of education on the shadow economy, the results in the literature are contradictory. There are authors who find a positive correlation between education and the size of the shadow economy. Stulhofer (1997) and Hanousek and Palda (2004) have studied the cases of two countries in transition, respectively, Croatia and the Czech and Slovak Republic. Their findings reveal that a higher level of education has an increasing effect on tax evasion, as a component of the informal economy. Furthermore, Torgler *et al.* (2010) reveal in their paperwork a positive correlation between education expenditures and the informal economy. The authors conclude that as the amount of education increases, more opportunities are developing in the shadow economy. This connection is also found by Pang *et al.* (2021), across the provinces of China.

On the other hand, there are authors that observe a negative impact between shadow economy and education expenditures. Some of the important explanations by which such a discrepancy could be revealed are (i) the form in which *education* is quantified in these studies, (ii) the models through which they were studied, and the related factors involved in those models. We note that, as a general rule, for studies on education in terms of cognitive skills, forming values (such as tax morality), or school attendance (Hastie *et al.*, 2009; Gerxhani & van de Werfhorst, 2013), and in studies that also consider factors related to the environment of weak public services, the quality of institutions, and the perception of the people on government efficiency (Buehn & Farzanegan, 2013; Berrittella, 2015), higher levels of education have resulted in decreasing the size of the shadow economy. These mixed results may suggest that other factors, such as other government expenditures, may be important in understanding the final effect of education on the shadow economy.

Tax evasion and informal economy data are limited and hard to quantify because of the choices made by citizens according to their own values and because individuals engaging in informal economic activities often remain undetected. Using the causes and indicators of the informal economy, using the widely known MIMIC method, authors such as Slemrod (2007; 2012), Dell'Anno (2007), Schneider *et al.* (2010), Alm and Embaye (2013), and Medina and Schneider (2018) have managed to quantify the size of the shadow economy. The data collection published by these authors will be used to improve the study here, as will be made clear in the following sections.

Regarding the non-linear relationship between the data, Wu and Schneider (2019) show that there is a U-shaped relationship between the shadow economy and the level of development using a quadratic regression equation. However, they noted a limitation in their study by suggesting the possibility of an asymmetric relationship between variables. In our study we are modelling the nonlinear relationship using nonparametric models. In addition,

we analyze the simultaneous impact of three variables, respectively, social protection, education, and health expenditures.

3. MACHINE LEARNING MODELS

The interactions between financial and economic variables are very complex and, in most cases, highly non-linear. Although many scholars use a linear analysis in their studies to explain the behaviour of provided data in a real-word setting, more performant models are required. Machine learning algorithms are very handy in capturing non-linear dependencies. In this paper, 4 different models have been used, namely *Support Vector Regression*, *Random Forest*, *XGBoost,* and *Neural Networks*. All models have impressive results in financial and economic applications, as in Medeiros et al. (2021), for inflation forecasting, Aziz and Dowling (2019) for risk management, or Ivașcu (2021) for option pricing.

3.1 Support Vector Regression

The first model to which we refer is the Support Vector Regression (SVR). The Support Vector Machine algorithm, with the extension of SVR, has been developed by authors such as Boser *et al.* (1992); Guyon *et al.* (1993); Vapnik (1995); Vapnik *et al.* (1997).

The idea of SVR is based on the computation of a linear regression function in a high-dimensional feature space where the input data are mapped via a non-linear function (kernel). In contrast to OLS, the objective function of SVR is to minimize the coefficients, not the squared error. Instead, the error term is handled within the constraints, where we set the absolute error less than or equal to a specified margin, called the maximum error, ϵ. In practice, these constraints are very restrictive and often fail to account for prediction errors. Two new variables, namely ξ_i, ξ_i^*, were introduced, in order to relax the optimization conditions. Therefore, we will arrive at the formulation presented in Vapnik (1995):

$$\begin{aligned} &minimize\ \frac{1}{2}\|\omega\|^2 + C\sum_{i=1}^{l}(\xi_i + \xi_i^*) \\ &subject\ to\ \begin{cases} y_i - \langle\omega, x_i\rangle - b \le \epsilon + \xi_i \\ \langle\omega, x_i\rangle + b - y_i \le \epsilon + \xi_i^* \\ \xi_i, \xi_i^* \quad\quad \ge 0 \end{cases} \end{aligned} \tag{1}$$

Here, $\{(x_1, y_1), \dots, (x_l, y_l)\} \subset \mathcal{X} \times \mathbb{R}$ represent the training data and $\mathcal{X}$ represents the multidimensional space determined by the input parameters. The coefficient denoted by ω and b is the constant of linear regression. $C > 0$ represents the trade-off between the reduced slope of the function and the magnitude of the deviation above that will be tolerated. To ensure nonlinearity, a kernel function will be applied. One of the most common kernels is the radial basis function (RBF), respectively $k(x_i, x) = \exp(-\gamma\|x_i - x\|^2)$. An interested reader can check the full derivation in Smola and Schölkopf (2004).

3.2 Random Forest

The Random Forest model is a model that has been introduced by Breiman (2001), and it is one of the most efficient algorithms for both classification and regression tasks. The model is based on bagging principle (Breiman, 1996), an aggregation scheme that (i) generates multiple sets of data by bootstrapping from the original input set, (ii) makes a prediction for each set using the CART model (Breiman *et al.*, 1984) and (iii) aggregates the predictions in a single result.

The CART-split criterion is used in the construction of a single tree to find the best *cut* perpendicular to the axes. At each node in each tree, the best *cut* is selected by optimizing this informative criterion based on the Gini impurity (on classifications) or the square errors of prediction (on regressions).

3.3 Extreme Gradient Boosting (XGBoost)

The XGBoost model developed by Chen and Guestrin (2016) is an efficient and scalable implementation of the Gradient Boosting Machine. Its popularity in the Machine Learning competitions is due to numerous optimizations like (i) the addition of a regularization term that improves the generalization ability, (ii) the multithreading parallel computing, which increases the speed over 10 times according to Chen and Guestrin (2016), and (iii) the efficiency of dealing with missing data.

To train the model, the following optimization function must be minimized:

$$\mathcal{L}(\phi) = \sum_i l(\hat{y}_i, y_i) + \sum_k \Omega(f_k) \tag{2}$$

where l is the cost differentiable function that measures the difference between the prediction $\hat{y}_i$ and the target value y_i and Ω, is a function of penalizing the complexity of the tree. Intuitively, the objective function will choose the model with the best prediction and the lowest complexity.

3.4 Deep Neural Network

A deep neural network is a set of interconnected processing nodes whose functionality is based on an animal's neural network. It was first introduced by McCulloch and Pitts (1943). The processing ability of the network is determined by the weights given to each node. Weights are obtained from a learning process (or adaptation) from a set of training data. According to Hornik *et al.* (1989), a neural network is a universal approximator, and any function can be modelled by using enough neurons.

Any neural network model presents three different types of layer: an input layer in which we have the explanatory variable, one or more hidden layers, and an output layer. Each layer contains many neurons. The functionality of an individual neuron is simple and direct. Each neuron sums all the signals sent to it, adds a bias term, and performs a non-linear transformation through an activation function. The activation (transfer) function is increasingly monotonic, most often a logistic, hyperbolic, or ReLu-type tangent. The signal transformed into a neuron is forwarded by a certain weight to another neuron in another layer, and the process is repeated. This step is called a follow-up step. The processing power of the network is determined by the weights given to each neuron, which are computed using the backpropagation method – for more details, see Rumelhart *et al.* (1986).

4. DATA DESCRIPTION

This research is based on a cross-section analysis of the 28 EU Member States, including the United Kingdom, for the period 1995-2020 that has been performed to determine the sensitivity of shadow economy size with respect to public expenditures. The general model specification is as follows:

$$SE = f(social\ protection, education, and\ health\ expenditures) \quad (3)$$

where f is a linear and nonlinear function, respectively.

Data on the size of the shadow economy are from the data set developed by Medina and Schneider (2019); that is, following the research undertaken by the authors, the largest existing data set on the size and trends of the shadow economy in 158 countries all over the world from 1995 to 2020. Medina and Schneider (2019) use the macroeconomic multiple indicators multiple causes model (MIMIC) and the currency demand approach (CDA) to estimate the size of the shadow economy. As the data provided by the mentioned authors is restricted to 2017, for years 2018, 2019 and 2020 the data were predicted using the ARIMA model, following the Box-Jenkins methodology. The indicator is expressed as a percentage of GDP, and, as also mentioned above, it represents the most comprehensive database of the underground economy, both from the perspective of the sample of states concerned and of the elements that are captured by it.

Data on social protection, education and health expenditures have been provided by the European Commission (*Eurostat database*) and variables are quantified as percentage of GDP. These variables reflect the attention given by the state to certain sectors. For the interpretation of the results, the perception of the citizens of budgetary policies is also important. The descriptive statistics of the variables are presented in Table no. 1.

Table no. 1 – Summary statistics for EU-28

	Observations	Mean	Std. Dev.	Minimum	Maximum
Shadow economy	700	18.43%	6.98%	6.40%	35.30%
Social protection	700	15.99%	4.06%	7.10%	25.50%
Education	700	5.14%	0.96%	2.80%	7.30%
Health	700	5.86%	1.43%	1.80%	8.90%

Source: own estimation

Furthermore, Figure no. 1 presented in the following represents a scatter plot matrix between the variables of interest. On the secondary diagonal, we show the distribution of each variable and above the diagonal the pairwise Pearson correlation. As it might be seen, all correlations are small or moderate (less than 0.7), with a negative direction between social protection and health, on the one hand, and the shadow economy, on the other. Education expenditures appear to be not correlated with any of the variables. The correlation implied a low level of multicollinearity. However, to confirm this, we applied a second method of multicollinearity test, VIF analysis. According to Nachane (2006), VIF values of not more than 10 are accepted as low levels of multicollinearity. The results presented in Table no. 2 confirm that this is applicable to the sample in question.

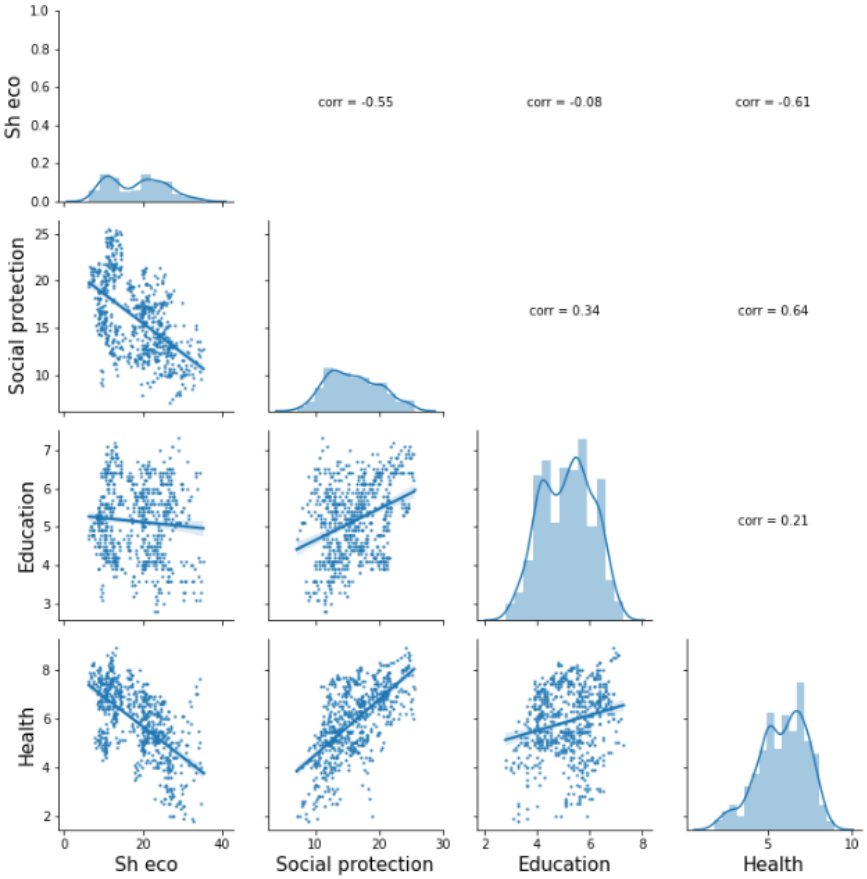

Figure no. 1 – Scatter plot matrix of the variables of interest
Source: own estimation

Table no. 2 – Results of the VIF analysis

Variable	Coefficient Variance	Uncentered VIF	Centred VIF
Social Protection	0.0026	1.9265	1.9322
Health	0.0148	1.7728	1.2151
Education	0.0397	2.2724	1.1248
C	2.1699	2.3709	

Source: own estimation

In order to check the causality relationship among variables, we conducted a panel Granger causality test. The results of Table no. 3 validate the causality between the shadow economy and the factors analyzed. It is worth noting the existence of the bidirectional relationship between shadow economy size and social protection and health expenditure. On this note, Mara (2021) obtained in a recent paper the same bidirectional relationship between shadow economy and public expenditure. Schneider (2006) argues that an increase of the

shadow economy can lead to reduced state revenues, which in turn reduce the quality and quantity of publicly provided goods and services, with the consequence of even stronger incentives to participate in the shadow economy.

Table no. 3 – Results of panel Granger causality test

Null Hypothesis:	F-Statistic	Result	Conclusion
Social Protection does not Granger Cause Shadow Economy	5.3837***	Yes	**SP → SE**
Shadow Economy does not Granger Cause Social Protection	11.7129***	Yes	SE → SP
Education does not Granger Cause Shadow Economy	13.8180***	Yes	**E → SE**
Shadow Economy does not Granger Cause Education	0.2496	No	
Health does not Granger Cause Shadow Economy	12.4888***	Yes	**H → SE**
Shadow Economy does not Granger Cause Health	7.0464***	Yes	SE → H
Education does not Granger Cause Social Protection	2.8823*	Yes	E → SP
Social Protection does not Granger Cause Education	1.4572	No	
Health does not Granger Cause Social Protection	1.8958	No	
Social Protection does not Granger Cause Health	1.8754	No	
Health does not Granger Cause Education	6.9022***	Yes	H → E
Education does not Granger Cause Health	2.1007	No	

Note: ***, ** and * indicate the significance at 1%, 5%, and 10% levels, respectively.
Source: own estimation

5. LINEAR ANALYSIS

As the linear analysis is widely used in shadow economy studies, we also conducted such analyses, in order to compare the results obtained herein with the ones to be obtained using a non-linear approach. In this regard, to analyze the effect of public expenditures on shadow economy, we apply the following methodology. Based on the direction in which our study is heading, namely, quantifying a possible link between certain types of government expenditure and the shadow economy, we outlined the following form of linear regression:

$$Shadow\ Economy_t = \beta_0 + \beta_1 * Social\ Protection_t + \beta_2 * Education_t + \beta_3 * Health_t + \epsilon_t \quad (4)$$

Given the panel set-up, a modelling concern is related to the heterogeneity across time and countries, that is the choice between a fixed-effects and random-effects specification, compared to a simple Pooled OLS specification. First, we start by conducting the Breusch-Pagan LM test to check if the variance components (period and cross-section) have significant effects. According to this test, only cross-sectional effects are statistically significant, suggesting that a random-effects specification is preferred to a pooled OLS model. Hence, we proceed by executing the Hausman test for selecting between fixed- and random-effects models. When testing the null hypothesis, the chi-square test is consistently zero, implying an estimation of negative variance. According to Psychoyios *et al.* (2021) this is not uncommon, provided that the Hausman statistic can be negative even asymptotically. The testing results support the use of the random-effects specification over fixed-effects, as we fail to reject the null hypothesis.

Table no. 4 – Random effects estimates
(dependent variable: size of the shadow economy, % of GDP)

Intercept	Social Protection Expenditure	Education Expenditure	Health Expenditure
15.1885***	-0.1249***	2.8899***	-1.6406 ***
(1.47)	(0.05)	(0.19)	(0.12)

Note: Std. Errors are displayed in parentheses under the coefficient estimates.
*** Statistically significant at the 1% level.
Source: own estimation

Table no. 4 reports the results of the Random Effects specification of the multiple regression model of Equation (3). All variables are statistically significant at the 1% level. At first glance, it is clear that social protection and health expenditures have a negative relationship with shadow economy size. An increase in social protection expenditure by 1 percentage point will decrease the size of the shadow economy by almost 0.12 percentage points, and an increase in health expenditure will decrease the shadow economy by more than 1.64 percentage points. These results agree with studies conducted by other authors who have confirmed the negative relationship between health expenditure and the shadow economy (Igor & Schneider, 2017; Kelmanson *et al.*, 2019 and others). Health and social protection services are directly related to the informal economy through the impact they have on citizens. According to our results, a state with a functioning social system that is also investing in health means a state with a declining level of the shadow economy.

On the other hand, there is a direct relationship between public expenditures on education and the informal economy: when public expenditures on education increase by 1 percentage point, the informal economy will also increase by almost 2.89 percentage points. The result is expected, given that factors that reflect the public perception on public institutions or on government efficiency, as well as socio-cultural factors, have been disregarded. Also, this positive correlation confirms the results of other authors such as Stulhofer (1997); Hanousek and Palda (2004); Torgler *et al.* (2010); Pang *et al.* (2021). One explanation for this result may be that in the case of countries that are either developed or developing, the level of education is already high, the citizens having internal values that come from both school and home (including self-education). If education expenditure increases (and thus it would have positively influenced the educational level of citizens), citizens will benefit from the education received in a satisfactory way. In the absence of perceptual indicators, they will not shy away from underground activities. In addition, a better education often comes with finding barely legal and resourceful approaches to tackle an activity that is part of the underground economy.

Figure no. 2 shows the scatter plot between the estimated values of the size of the shadow economy and the observed values. As might be seen, the errors of prediction are quite high, the differences between estimated points and estimated regression line being over 15 percentual points. Public spending on social protection, education, and health does explain only 42.35% of shadow economy variance. Naturally, this aspect is to be expected, as several other factors influence the shadow economy, especially perceptual factors, which have been studied by many authors in the literature (tax morality, fiscal policy, human development, the quality of public institutions, etc.). However, this could also suggest that there is not a linear relationship between public expenditures and shadow economy size, suggesting that previous results may be questioned. To check if this is the case, we applied the *Ramsey Regression Equation*

Specification Error Test (RESET) test to see whether non-linear combinations of the fitted values help explain the response variable. We obtain an F-statistic of 6.55 (p-value=0.0109) which indicates the possibility of a nonlinear relation. Therefore, a more advanced analysis is required.

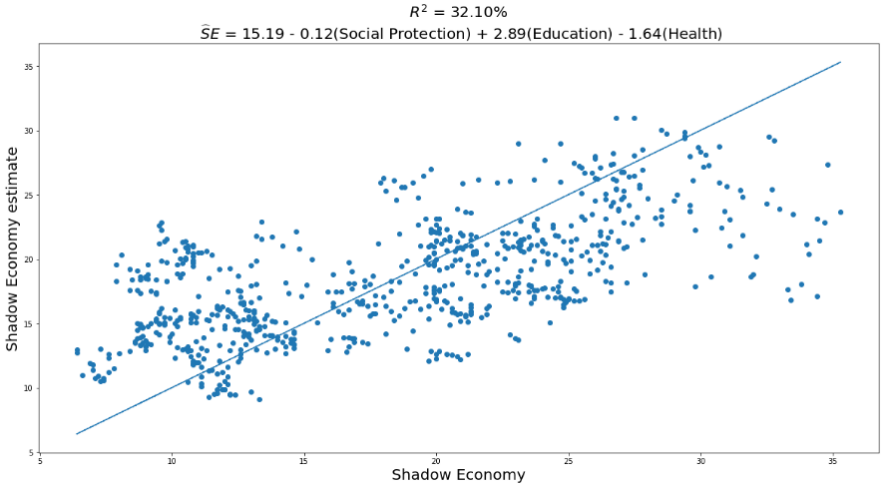

Figure no. 2 – Scatter plot of shadow economy estimates vs observed values
Source: own estimation

6. NONLINEAR ANALYSIS

To select the best heuristic method, the following methodology has been employed. The data set has been randomly divided into 2 different sets, respectively train set (in sample data) and test set (out of sample data), with 80% of the data in the train set and 20% in the test set. The models used in this analysis are presented in Section 3. Linear regression has been considered as a reference point. The neural network (NN) model has 3 hidden layers with 100, 70 and 30 neurons and the activation function is represented by ReLu. XGBoost (XGB) and Random Forest (RF) have a maximum depth in tree construction of 10 and Support Vector Regression (SVR) a tolerance of 10^{-6} and kernel represented by radial bias function.

Table no. 5 shows the root mean squared error (RMSE) and R-squared values for both the in-sample and the out-of-sample data for each model. All machine learning algorithms outperformed the dummy linear regression for both in-sample and out-of-sample data. Support Vector Regression has comparable results with a linear regression suggesting that the data could not be modelled in a linear way even in higher dimensions. Neural Networks model does not significantly reduce the error of prediction. However, a better architecture could increase the R-squared value. Decision tree algorithms, respectively, XGBoost and Random Forest clearly outperform the other methods, XGBoost being the best. Due to their mathematical formulation, the models fit almost perfectly the in-sample data. The out-of-sample RMSE is more than 2 times lower than the one from linear regression, suggesting that a heuristic approach could model better the dynamics between public spending and shadow economy size.

To determine the optimal public spending that can decrease the size of parallel economy, the most performant model, respectively, the XGBoost model has been selected. In order to

increase the accuracy of the algorithm, another training has been performed using all cross-sectional data sets. Figure no. 3 shows the most important variables (features) in tree construction (please see Hastie *et al.*, 2009, p. 367 for technical details). The model assigns the most relevance to social protection expenses, almost the same as combined education and health expenses. Therefore, a fiscal policy focused on social protection could further reduce the shadow economy. This can be explained by the fact that the social sector is, in essence, perhaps the closest to the people. A well-organized social sector, in which people are offered employment and vocational training opportunities, as well as help with the problems they face (unemployment, disability, old age), in which they are assured that they will not be discriminated and that they will receive equal treatment, will lead to a situation in which citizens will have neither time nor need to seek informal economy activities.

Table no. 5 – Root mean squared error and R-squared results for both train sets (in sample) and test sets (out of sample) sets for machine learning algorithms

	RMSE (%)		R-squared	
	In sample	**Out sample**	**In sample**	**Out sample**
Linear	5.28	5.98	32.17%	31.69%
NN	4.94	4.65	56.13%	55.34%
XGB	0.02	2.12	99.99%	83.12%
RF	1.16	2.93	92.62%	79.42%
SVR	5.18	4.69	43.40%	42.46%

Source: own estimation

In order to investigate the non-linear interactions between public expenses and shadow economy size, we simulate over 30,000 combinations of expenses rate (% of GDP) for the analysed variables: social protection, education, and health. Using XGBoost model trained on a full cross-sectional dataset, we have estimated the shadow economy size for each of the simulated combinations. On the basis of this heuristic, we can identify which combination of variables minimizes the size of the informal economy. Please note that estimated values are based on historical data of 28 EU countries for 25 years; therefore, some biases could occur due to sociocultural and economic differences between countries.

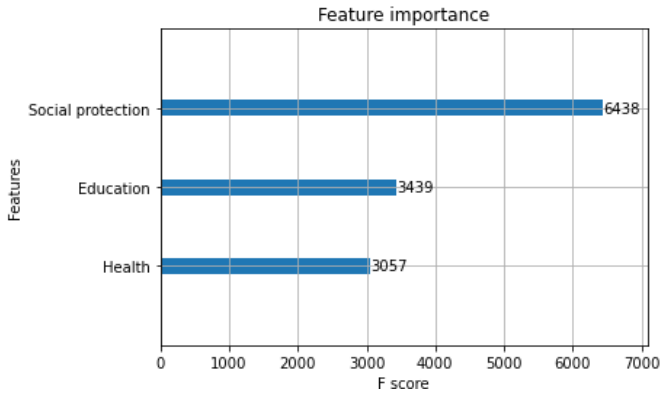

Figure no. 3 – Importance of Features for XGBoost in the Full Cross-sectional Data Set
Source: own estimation

Figure no. 4 shows the 3D scatter plot of the combinations of simulated expenses. The points have been colored on the basis of estimated values of shadow economy size. It is worth noting that health expenses less than 4% of GDP determine higher rates of informal economy and, in combination with a policy that does not favor social protection, a bigger parallel economy may develop. This was the case of Romania, Bulgaria and Cyprus in the 1990s and early 2000s, when shadow economy size represented over 30% of GDP. It seems that a higher level of social protection (over 15% of GDP) minimizes the informal economy, but this is not always true. For example, Ireland, Slovakia, or the Czech Republic report a small level of shadow economy even if public spending on social protection is relatively low. However, more than 5% of GDP must be allocated to health expenses.

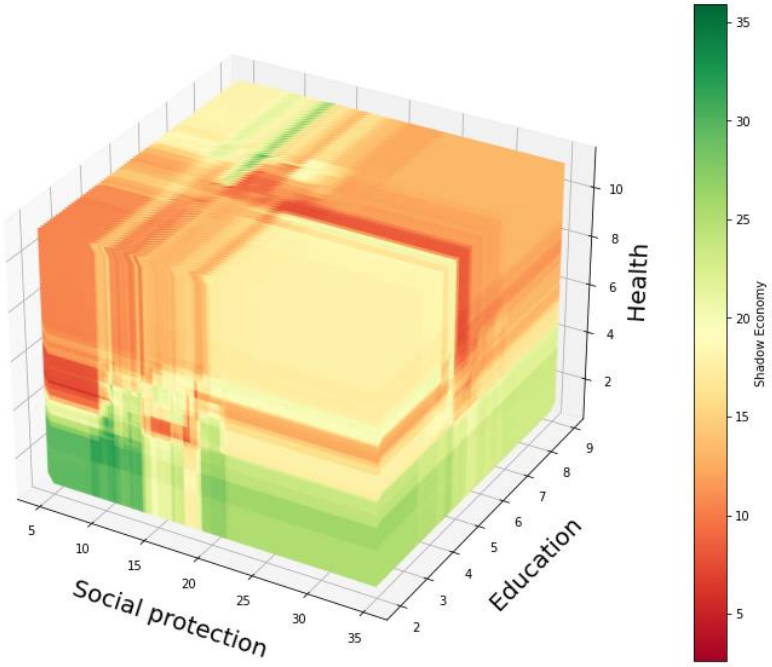

Figure no. 4 – Shadow economy size for over 30,000 simulations of combinations of expenses (% of GDP)

Source: own estimation

Regarding education, the results are debatable, depending on health and social protection policies. For example, high public spending on education reduces shadow economy only if social protection and health expenses are also high (for example, the cases of Sweden, Denmark, Finland, etc.). However, if social protection expenses are low, the shadow economy will increase. This is the case of Estonia in the 1990s, when an informal economy of more than 27% of GDP was reported, even if the government had allocated more than 7% of GDP to the education sector. On the other hand, an allocation smaller than 6% will negatively impact shadow economy size even if social protection is high, as in Italy or Greece.

The model suggests two scenarios in which the shadow economy registers the lowest values and is represented by red in our cube. The first minimum point of the underground economy is reached when education expenditures represent around 6-8% of GDP with high health and social protection expenditures. The second area in which the shadow economy reaches a low level is when education expenditures represent around 3-4% of GDP, with a low level of social spending between 10-15% and a level of health spending between 4-6%. In contrast, the highest levels of the underground economy occur at the lowest spending allocations in the three areas: social protection, education, and health.

This different approach on the relationship between shadow economy and government expenditures is welcomed in the literature because, especially in terms of education expenditures and shadow economy, the results show a contentious linear relationship. It is important to note that even in our research, the results regarding the influence of education expenditures are slightly dispersed, but useful directions can be outlined, most notably considering the other two categories of government expenditures, namely health and social protection expenditures.

To check the robustness of the methodology, the share of government expenditures quantified as percentage of GDP has been replaced by government expenditures quantified as euros per capita. Table no. 6 confirms the higher predictability performance of the ML algorithms compared to a linear regression in both the RMSE and the R-squared value. Again, decision tree-based models are the most performant with XGBoost having the lowest error and highest R-squared, which is more suited to model this nonlinearity. The same simulation methodology has been applied to see the relationship between variables.

Table no. 6 – Root mean squared error and R-squared results for both train sets (in sample) and test sets (out of sample) sets for machine learning algorithms (expenditures per capita)

	RMSE (%)		R-squared	
	In sample	**Out sample**	**In sample**	**Out sample**
Linear	4.22	4.36	56.35%	51.71%
NN	3.50	3.61	78.97%	71.33%
XGB	0.02	3.19	99.99%	82.29%
RF	1.54	3.21	94.88%	81.76%
SVR	4.02	4.10	70.27%	65.32%

Source: own estimation

Upon comparing the two scenarios, Figure no. 5 shows similar conclusions to Figure no. 4. In this second scenario, the lowest values of shadow economy are recorded when education expenditures are around 3000 € per capita (equivalent of the 6-8%% of GDP value in the first model), health expenditure above 2000 € (equivalent of the 6% of GDP value in the first model), and social protection over 10,000 € per capita (equivalent of the 20% of GDP value in the first model). Again, social protection expenses need to be understood in relation with the other variables, shadow economy levels being high regarding social protection costs whenever health expenses are less than 1000 € per capita.

All things considered, in terms of government policy, the way states manage budget expenditure influences taxpayers in their decision whether or not to comply with legal rules. From this perspective, the attention paid to them by governments, quantified by the level of budgetary expenditure distributed, will influence taxpayers' behavior. The main reason for this is that taxpayers are directly interested in how much of the taxes they pay go back to them, either through social benefits, better quality services, or a more innovative educational system.

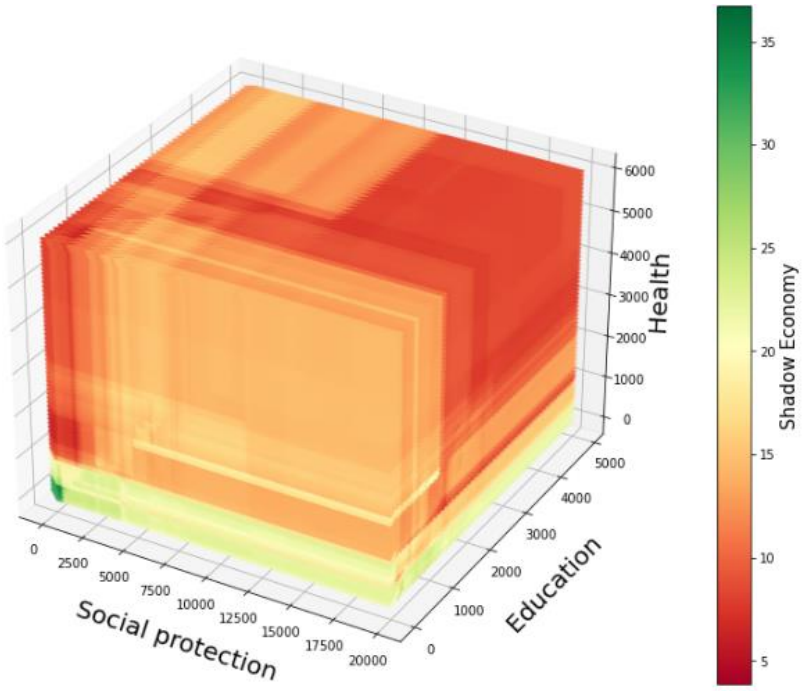

Figure no. 5 – Shadow economy size for over 30,000 simulations of combinations of expenses (€ per capita)
Source: own estimation

Thus, to reduce the level of the underground economy, states must consider an optimal distribution of budget expenditures. Our recommendation, following the analysis carried out in this paper, is that the government should not neglect the 3 important categories of expenditure, namely: education, health, and social protection. A government policy that focuses on social protection (around 20% of GDP), as this is the direction that is closest to the taxpayer and most easily perceived, but also maintains a moderate focus on education (6%-8% of GDP) and health (around 6% of GDP), will lead to a decrease in the informal economy. However, depending on certain unforeseen events that may occur, these efficiency points may fluctuate (such as the emergence of the coronavirus, which required increased attention and resources for the health sector). Moreover, for greater accuracy, the methodology presented by us in an improved and individualized version could be used by governments to generate their own analysis of the level of expenditure they should consider for a reduced level of the underground economy.

7. CONCLUSIONS

In summary, the general conclusion of our study is that government expenditures could influence the size of the shadow economy. We tried to model this influence using both linear models and data-driven approaches, and we showed that Machine Learning algorithms are suitable for this task and that they can explain much better the variation of shadow economy size than a linear model. Furthermore, we presented a methodology that can heuristically detect

optimal allocation of the public budget. Our findings suggest that social protection expenses greater than 20% of GDP, health expenses greater than 6%, and education expenses between 6% and 8% of GDP determine the lowest size of the shadow economy (for the EU member states).

The direction of our study is to confirm that the distribution of budget expenditures by states influences the level of the underground economy, on the one hand, and on the other hand, this paper intends to propose levels that can make the decrease of the underground economy more efficient. The key point of the work lies in the innovative method that we applied in studying the relationship between budget expenditures (social protection, health, and education) and the underground economy, a method that can be processed by states and could be used by them for analysis budget strategies to be implemented.

Ultimately, we also mention the directions in which our study can be further developed. An analysis with more countries considered or on a longer time frame should be enhanced so as to confirm or contradict our conclusions. Multiple variables can be added as control to increase the performance of machine learning models, such as sociocultural or economic indicators, or dummy variables that can isolate big events such as crises or EU policies. Also, different algorithms could be used in modelling, such as recurrent neural networks or memory models, to capture the dynamic of shadow economy.

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The 'Bad Behavior Index': A Composite Measure of the Development Hindering Behavior of Individuals and Institutions

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Abstract: Composite indices have become a popular tool for providing a quantitative, simplified, and visualized representation of complex phenomena. An example of such is the Human Development Index (HDI) which ranks countries by their level of development. The primary limitation of the HDI is its narrow scope, which hinders its effectiveness at explaining why some nations are more developed than others. The discussion as to why some nations are more developed than others goes back as far as the 14th century, where Ibn Khaldun developed a theory which aims to explain why civilizations rise and fall. Some of the hypotheses which seek to answer this question point to the importance of economic freedoms, absence of corruption, high investment in human capital, and the importance of institutions etc. to development. One hypothesis which has not been properly studied regards the culpability of individual and institutional behavior. The purpose of this study is to introduce a composite measure of the development hindering behavior of individuals and institutions, i.e., the Bad Behavior Index (BBI). The methodology of this study is influenced by the Mazziotta & Pareto framework for composite indices. The index weights have been computed by integrating expert opinion with the Fuzzy Analytic Hierarchy Process (FAHP). The findings of this study suggest that African countries engage in the highest level of bad behavior, which subsequently leads to their poor socio-economic development, whereas Northern countries engage in the least level of bad behavior. The study also finds that the most important drivers for socio-economic development are low levels of corruption, high levels of knowledge creation, strict application of the rule of law, high levels of social cohesion, and high levels of political stability.

Keywords: composite index; behavior; development; institutions; fuzzy AHP; expert opinion.

JEL classification: B5; C4; D01; D02; O1.

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1. INTRODUCTION

Like economic models, composite indices provide a simplification of reality. They provide a simplified, quantitative, and visual representation of phenomena that are complex and multidimensional in nature. Many composite indices have been developed to measure a country's level of development. The most popular of which is the UNDP's Human Development Index (HDI) (2019). The HDI draws influence from Sen's (1985) capability approach in its multi-dimensional nature, sharing the same ideological belief that the quality of life of individuals should not be measured merely by economic variables, but also include measures which are considered necessary for the individual to lead a decent life. The HDI was developed by economist Ul Haq (1995), who developed the index with the goal of enlarging people's choice – i.e., expanding their capabilities and functioning's.

The HDI and the capability framework is not the only approach which measures well-being. In the 1970's the focus was on economic well-being as an absolute measure of the development of societies, i.e., Neo-liberal approach (Jolly, 2003; Anto, 2011). This approach was soon replaced by the basic needs approach which focused on measures other than income. This approach focused on what individuals need in terms of resources to achieve long-term physical wellbeing. An example of such is focusing on needs such as food, shelter, access to education, and so on and so forth. The main objective of this approach is to provide more resources and better opportunities to those who are marginalized. The sustainable development approach soon replaced the basic needs approach, which shifted focus to addressing the harmful effects of human activities on the environments ability to provide sustainable resources. The sustainable development approach was later replaced by the human capability approach which focused more on the capability, opportunities, or freedoms available to individuals, rather than the goods or resources available to them. As aforementioned, this approach serves the theoretical basis for the HDI. The HDI ranks countries according to their level of development, as determined by three measures: 1) GNI per capita, which represents the measure of 'decent standard of living'; 2) life expectancy, which represents the measure of 'long and health life'; 3) expected years of schooling and mean years of schooling; which represents the measure of 'access to education'. The HDI assigns equal weights to the three dimensions, and fixed minimums and maximums are then utilized to transform the data. The results of the HDI are based on the average of the normalized dimensions.

The HDI is not without its limitations, as there is an extensive body of literature on its shortcomings (Kelley, 1991; McGillivray, 1991; Murray, 1991; Dasgupta & Weale, 1992; Lind, 1992; Srinivasan, 1994; Sagar & Najam, 1998; Todaro & Smith, 2006; Chhibber & Laajaj, 2007; Klugman *et al.*, 2011), among others. The primary criticism of the HDI pertains to its narrow definition of development, many scholars arguing that it provides "an oversimplified view of human development by relying on only a few indicators often derived from data of low quality" (Srinivasan, 1994). In short, the HDI was born from the failures of previous measures of development, as outlined in the preceding section.

Despite the plethora of literature addressing its limitations, the HDI is still widely used today as a measure of development. The primary reason for that is because of data availability, a lack of an alternative framework which properly defines development, and a historical emphasis on economic well-being as the primary measure of the socio-economic development of countries.

The reliability of the HDI as a measure of socio-economic well-being is a subject of debate. In terms of alternatives, there are numerous quantitative measures of development, but the HDI is often favored due to its simplicity, which considers only three dimensions, and data availability (Luque *et al.*, 2016). However, the HDI's simplistic nature and narrow economic focus has led to criticisms that it does not provide an accurate measure of development (Streeten, 2000). Moreover, the high correlation of the HDI with its variables (Ghislandi *et al.*, 2019), i.e., GNI per capita, life expectancy, mean years of schooling, and expected years of schooling, take away from the credibility of the HDI.

In addition to its narrow scope and simplified representation of reality, the HDI has limited capacity to elucidate the nature of development disparities across nations. While various hypotheses, such as the 'Resource Curse Thesis' of Auty (1995), the 'Endogenous Growth Theory' of Romer (1994), and 'Inclusive Institutions' of Robinson and Acemoglu (2012), offer potential explanations for such disparities, the HDI does not effectively address this issue.

This study contends that, while the previously stated hypotheses and others may have merit, the focus on external factors often overshadows the role of internal elements in explaining development disparities across countries. The culpability of individual and institutional behavior, for instance, is frequently overlooked. This study aims to explore an alternative hypothesis that focuses on such internal factors. Specifically, rather than attributing underdevelopment to poverty, corruption, political instability, and the like, this study posits that some countries are less developed than others due to bad behavior at the individual and institutional levels, which can serve as precursors to the aforementioned problems. This hypothesis, which emphasizes the importance of internal elements, has not been adequately investigated. The lack of a theoretical framework that clearly defines and identifies development-hindering behavior, also known as bad behavior, at the individual and institutional levels contributes to the absence of a quantitative measure for analyzing the impact of such behavior on development.

With that said, how can one develop such a quantitative measure of the development hindering behavior of individuals and institutions? What theories could be utilized to serve as the anchor for such a measure? What is the methodology behind constructing such a measure? How can one test the reliability and validity of the composite index outcomes? And what behaviors or variables are most important for development? These are some of the questions this study seeks to answer.

As such, the purpose of this paper is to introduce a composite measure of the development hindering behavior of individuals and institutions hereby referred to as the ‘Bad Behavior Index’ (BBI). This measure aims to be a more holistic and accurate measure of socio-economic development relative to the HDI. The index is based on a synthesized theoretical framework which will be discussed in the upcoming text and is based on proxies which are supported by theory and literature as culprits for poor development.

2. THEORETICAL FRAMEWORK

According to Mazziotta and Pareto (2017), the first step in constructing a composite index is to define the problem being measured, anchored by a theoretical basis for measuring such a phenomenon. With that said, the problem being studied is regarding the impact of individual and institutional behavior on the socio-economic development of countries. Does

engaging in *good* behavior contribute to the rise of nations? And does engaging in *bad* behavior lead to the fall of nations? How can one categorize behavior as either good, i.e., development promoting, or bad, i.e., development hindering? Is there any theoretical justification for measuring the behavior of individuals and institutions? The upcoming text will address some of these concerns.

2.1 Measuring the behavior of individuals

There is a lack of a theoretical justification for quantifying the behavior of individuals and institutions within the context of development. Nevertheless, various scholars have touched upon the culpability of behavior on the development of societies. For example, commenting on the fall of Muslim civilizations of the past, Al-Attas (1978) addresses individual culpability and how "it is important to stress the individual in seeking a just solution to our problem rather than the society and the state". According to Chapra (2008), commenting on Ibn Khaldun's theory of development, "the viability of the dynasty depends on the viability of the political authority". According to Ibn Khaldun (2004) himself, political authority hinges on the behavior of man, as evidenced by "the good qualities in man are appropriate to political and royal authority, since goodness is appropriate to political authority", as well as "The dynasty is an authority through which life is given to proper behavior. Proper behavior is a policy directed by the ruler" (Ibn Khaldūn, 1967). Smith (1759) discusses in the 'Theory of Moral Sentiments' the importance of behavior for achieving happiness, well-being, and the perfection of the world. To achieve this purpose, individuals must behave in accordance with general rules and guidelines which are the commands and laws of God. Those who follow these rule and guidelines are deemed men of honor, whilst those who do not follow those rules are deemed worthless fellows. Al Ghazaly (1937) expands upon Al Juwainy's (Kamali, 1999) framework of Islamic jurisprudence, i.e., Maqasid of Shariah (MS), to focus on the well-being or Maslaha dimension by elaborating upon the necessary behavior individuals must abide by to achieve well-being. Engaging in such behavior leads one to achieve societal well-being, i.e., Maslaha, whilst disobedience leads to societal harm, i.e., Mafsada. Weber (1958) argues that the Protestant Ethic led to an economically prosperous Calvinist society in Northern Europe relative to the Catholic South. Weber's thesis although at first sight centers on how religion can either positively or negatively impact economic well-being of society, deep down it centers on how behavior can have a positive role on development, as the Calvinists engaged in development promoting behavior such as a high work ethic, economic efficiency, thrift, and unobtrusive accumulation of wealth.

Various scholars have touched upon the pivotal role behavior plays in the development of societies, but the current literature has barely scratched at the surface of the hypothesis that individual and institutional behavior are culpable for the poor development of some societies. The rationale behind this is that what is deemed development promoting or development hindering behavior could be subjective, i.e., what is considered good behavior in one society could be perceived as bad behavior by another. As such, the first step in development a theoretical framework which facilitates for quantifying the behavior of individuals and institutions is to identify from theory and literature what is considered development hindering behavior and to properly define it. Once this objective it achieved, only then can a robust and empirical test capable theoretical framework can be developed.

Such a framework can be developed by synthesizing some of the theories discussed earlier, particularly the concept of Mafsada in the Maqasid of Shariah (Al Ghazaly, 1937) and

Adam Smith's worthless fellow (Smith, 1759), both of which serve as proxies for the behavior which leads to societal harm, behavior which only a worthless fellow would engage in.

The decision to prioritize Mafsada over Maslaha, in the Maqasid of Shariah, and measuring bad behavior over good behavior is due to the key principle widely accepted among Islamic scholars which is pushing away harm is prioritized over achieving Maslaha; assuming both are equal. Moreover, the reason for focusing on Adam Smiths' worthless fellow over the man of honor is because Smith viewed the act of disobedience to the rules and guidelines set by God as an aggressive form of bad behavior which goes against the plan of the deity and leads to the unhappiness of mankind. This is evidenced by the following passage in TMS: "By acting other ways, on the contrary, we seem to obstruct in some measure, the scheme which the Author of nature has established for the happiness and perfection of the world, and to declare ourselves, if I may say so, in some measure the enemies of God" (TMS III.5.7: 166; as cited by Berry *et al.*, 2013).

In summary, the lack of a theoretical framework which facilitates for quantifying the development hindering behavior of individuals means that it is essential to develop a framework which can provide theoretical justification for measuring such behavior. Various authors have discussed the pivotal impact behavior has on development, but not as far as to develop a robust framework which facilitates for empirical testing. In addition, some authors such as Sen (1987) have also discussed the impact of ethics on development, calling for a re-engagement between the two fields (Qizilbash, 2008). The idea that behavior, good, bad, ethical or otherwise, can impact development has long been discussed by scholars. However, there is a lack of a robust framework to study the relationship between these variables and development which can be attributed to the lack of consensus on what constitutes good or bad behavior within and across disciplines. This disagreement may arise from divergent epistemic orientations and worldviews, such as the Platonist view that human nature inherently encompasses knowledge, and the Aristotelian view that emphasizes experiential knowledge over innate knowledge. This epistemological divide resulted in the secularization of knowledge and disenchantment of nature, as well as the emergence of schools of thought that rejected established ethical norms, leading to more subjective behavior and a departure from established ethical frameworks like divine command theory (Al Fozaie, 2022).

In conclusion, this study acknowledges the theoretical limitations of the current literature. This study seeks to utilize the concepts of Mafsada in the Maqasid of Shariah, i.e., societal harm, and Adam Smiths' worthless fellow to serve as a justification for measuring the development hindering behavior of individuals and institutions, with particular emphasis on the concepts of adherence to rules and guidelines which if individuals engage in, they can achieve societal well-being, whilst not abiding by them leads to societal harm, under the assumption of an aggregated effect. The theories utilized in this study will influence the proxy selection process, as the proxies included in the BBI will represent behavior which a worthless fellow would engage in, i.e., Adam Smith's theory in TMS, which subsequently leads to societal harm, i.e., the concept of Mafsada in MS.

2.2 Measuring the behaviour of institutions

From a linguistic perspective, the terms *organization* and *institution* are often used interchangeably. From a theoretical perspective however, there are distinctions. According to Khalil (1995), organizations refer to a group of individuals or agents acting towards a common

goal, whereas institutions refer to formal and informal social structures. Ménard (1995) however states that some economists use the two terms interchangeably, especially those from the pre-neo-institutionalism era, referring to organizations as institutions or institutional arrangements (Davis & North, 1971; Jensen & Meckling, 1976), as well as variants of market activities (Alchian & Demsetz, 1972).

Despite the considerable scholarship on the topic, a clear definition of what constitutes an institution remains elusive (Alvesson & Spicer, 2019). Indeed, as DiMaggio and Powell (1991) contend, it is often easier to identify what institutions are not, rather than what they are. This study adopts a broad definition of institutions, which includes formal and informal structures such as public institutions, economic and political systems, and religious and cultural groups.

Elaborating upon formal and informal institutions, formal institutions are those developed by the political authority. They are defined as "the humanly devised constraints that structure political, economic, and social interaction" (North, 1991); the government, the legal system, the education system, and the healthy system are all examples of formal institutions. On the other hand, informal institutions are unwritten and socially shared rules, i.e., culture and norms (North, 1990; Kaufmann *et al.*, 2018).

The various theories discussed earlier were referring to the behavior of individuals or members of informal institutions, so how can one measure the behavior of the formal institutions? According to Voigt (2013), the common practice is to measure the outcome of the policies of these institutions. An alternative approach is to conduct identical experiments in different countries (Voigt, 2018). The limitation of such approaches is their narrow focus on the product or outcome of these institutions policies, and not on whether these institutions are holistically development hindering or development promoting. To elaborate, a particular policy could in fact lead to an outcome which creates more jobs in the local economy, but it also could lead to greater income inequality. As such, measuring the effectiveness of these institutions policies is an inefficient measure of whether these institutions are development promoting or development hindering institutions. This study adopts an alternative measure which seeks to provide justification for measuring the behavior if institutions by arguing that formal institutions are but the agglomeration of the members of a country's informal institutions. As such, formal institutions can be measured by aggregating the behavior of the members of the informal institutions working within the formal institution, and the aggregated behavior of these members is what deems whether an institution is development hindering or development promoting. This of course requires the construction of a framework which defines and identifies what is the behavior that is considered development hindering or development promoting as well as developing a protocol for measuring such behavior. An example of such behavior includes but is not limited to worker productivity, bribery, embezzlement, environmental footprint, among others. It must be made clear that not all institutions are identical, meaning that different institutions could have different units of measurements or proxies for what is considered development hindering or development promoting behavior. The idea itself however, aggregating the behavior of the members of the informal institution to reflect the behavior of the formal institution can be generalized and replicated for a country's various institutions.

In summary, due to a lack of a theoretical justification for measuring the behavior of formal institutions, this study adopts an alternative approach which aggregates the behavior of an institutions members so that it reflects the behavior of the institution itself. This is a novel approach which needs to be examined further and elaborated upon. However, this

approach is essential for the construction of the index this study proposes, since it justifies the use of some of the proxies being utilized in composite index – i.e., the Anti-Money Laundry proxy does not only reflect the development hindering behavior of a country's constituents, but also the behavior of the countries various institutions who have failed their duty of care in preventing such behavior.

2.3 Theoretical Framework Summary

The study builds on the concepts of Mafsada (Al Ghazaly, 1937) and worthless fellow (Smith, 1759) to quantify the development hindering behavior of individuals and institutions. Various measures of bad behavior are aggregated into the BBI, which seeks to represent actions that an honorable person would not engage in, while a worthless fellow would. The study highlights the need for a theoretical framework that can provide justification for measuring the bad behavior of individuals and institutions. While many authors have discussed the impact of behavior on development, no robust framework has been developed for empirical testing. The study recognizes the inadequacies of the existing literature in measuring institutional behavior and suggests an alternative method of aggregation, whereby the actions of an institution's members are used as a proxy for the behavior of the institution as a whole. This approach aims to validate the selection of certain proxies that reflect the conduct of both individuals and institutions.

3. METHODOLOGY

3.1 Composite Indices Framework

According to literature, the most popular framework for developing composite indices is the OECD and Joint Research Centre-European Commission (2008) framework. There are various other authors who develop a framework for constructing indices, including but not limited to Barrera-Roldán and Saldívar-Valdés (2002); Krajnc and Glavič (2005); Mazziotta and Pareto (2012); Armin Razmjoo *et al*. (2019); Dolge *et al.* (2020). It must be noted that no universal method exists for constructing composite indices (Mazziotta & Pareto, 2017), as such, best practice is to adopt the framework which has been extensively utilized in literature, as well as identifying highly influential and well-versed authors of this particular method. In this regard, this research adopts the framework of Mazziotta and Pareto (2017) which itself is influenced by the OECD and Joint Research Centre-European Commission (2008) framework. The reason for adopting this framework is due to the expertise of the authors at developing composite indices, as they have published several papers on this topic in the past couple of years (De Muro *et al*., 2011; Mazziotta & Pareto, 2012, 2013, 2014, 2016, 2017, 2022). This study adopts the Mazziotta and Pareto (2017) framework for constructing composite indices, and it can be summarized as follows:

1. Define the phenomenon to be measured.
2. Select a group of individual indicators.
3. Normalize the individual indicators.
4. Aggregate the normalized indicators.
5. Validate the composite index.

Expanding on the aforementioned, the *first step* is to define the concept being measured, and this includes defining the theoretical framework for the index, as according to the authors "the theoretical part is not separate from the statistical-methodological one" (Mazziotta & Pareto, 2017), which shows the great emphasis the authors place on the selection of a theoretical framework which best describes the purpose of the index.

The *second step* involves the selection of the various proxies of the index and their respective measures. The authors also emphasize the importance of this method, and how it should not be "independent from the choice of the aggregation method" (Mazziotta & Pareto, 2017).

The *third step* involves normalizing the selected indicators as, most likely, they will have different units of measure, as well as possibly having opposite impacts – i.e., GDP per capita and unemployment, for example, have opposite effects on the dependent variable. The most popular normalization methods according to the authors (Mazziotta & Pareto, 2017) are the 1) Standardization approach – i.e., "converting the indicators to a common scale of mean zero and standard deviation of one" (Mazziotta & Pareto, 2017); 2) Rescaling approach – i.e., a min-max approach which normalizes the indicators to a range of 0 to 1; 3) Ranking approach – i.e., ranking the countries, for example, based on their performance in this particular indicator; 4) Indicization approach – i.e., "this method takes the percentage ratio between original values and a reference for each indicator" (Mazziotta & Pareto, 2017).

The *fourth step* is the most important step according to the authors (Mazziotta & Pareto, 2017), and it involves combining, or aggregating, all the elements of the index to form the composite index. Aggregation has three sub-steps, *compensatory nature*, weighting, and aggregation method. Regarding the compensatory nature, the researcher must articulate whether the index being developed is 1) Compensatory – i.e., a deficiency in one proxy can be substitutable, or compensatory, by another proxy, one such example is how the '% of primary students enrolled in school' is compensatory with the '% of secondary students enrolled in school'; 2) Non-compensatory – i.e., the proxies are non-substitutable; or 3) Partially-compensatory – i.e., the proxies are substitutable to some degree. Regarding the *weighting* of the elements of the index, a weighting system must be adopted, i.e., equal weights, expert weighting, subjective weighting, or principal component analysis. Regarding the *aggregation method*, the most popular method according to the authors (Mazziotta & Pareto, 2017) are the arithmetic and geometric methods. The arithmetic mean is the most commonly used aggregation method among the most popular indicators (Mazziotta & Pareto, 2017), and it is usually adopted for compensatory indices. The geometric method on the other hand is commonly used for partially and non-compensatory composite indices. Instead of an additive approach, this method utilizes multiplicative functions (Mazziotta & Pareto, 2017). In summary, the first and most important step when aggregating the indicators is to identify the compensatory nature of the index being developed. After that, the researcher can then decide to whether utilize additive aggregation methods such as arithmetic mean and principal component analysis for his compensatory index, or the geometric mean or multi-criteria analysis if his index is partially or non-compensatory.

The *fifth step* involves assessing the *validity* and *robustness* of the index being developed, and this can be achieved by utilizing sensitivity analysis, i.e., "how much each individual source of uncertainty contributes to the output variance" (Mazziotta & Pareto, 2017), and uncertainty analysis, i.e., "how uncertainty in the input factors propagates through the structure of the composite index and affects the results" (Mazziotta & Pareto, 2017).

Like Mazziotta-Pareto Index (MPI) (2013), this study adopts a *non-compensatory* path (Figure no. 1) in the construction of the BBI, with the exception of the weighting method.

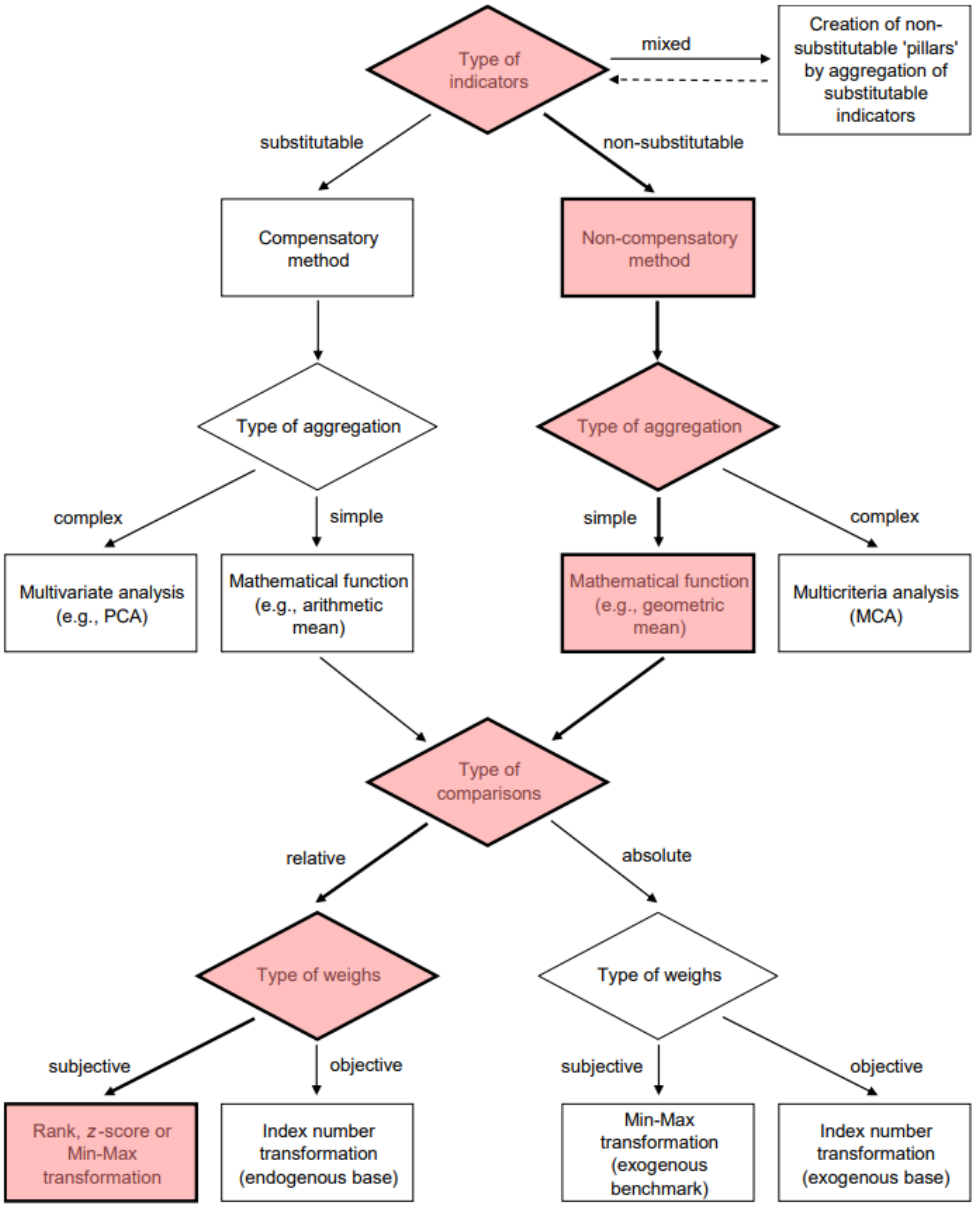

Figure no. 1 – The BBI follows a non-Compensatory, geometric, ranking based, and expert weighting approach (Based on MPI by Mazziotta and Pareto (2013), except for the weighting system)

Sources: Mazziotta and Pareto (2013)

3.2 Proxy Selection

What justification exists for selecting the proxies? As stated earlier, the BBI proxies represent the behavior a worthless fellow would engage in, which subsequently leads to societal harm. In addition to selecting proxies which align with the theories which form the basis of the BBI framework, the BBI proxies are also selected based on theory, supporting literature, and rational reasoning. To elaborate, proxies are selected to reflect prominent theories in academic literature, within the context of development, such as Alesina et al. (1996) seminal study on political instability, endogenous growth theory (Romer, 1994), resource curse theory (Auty, 1995) et al. Moreover, proxies were also selected based on evidence from academic literature such as Scully's (1992) views on economic freedoms, and how they lead to countries that are highly efficient at inputs into outputs; N'Zue's (2018) position on reducing pollution, and how it can support sustainable growth as well as improving societal welfare; and Wahyudi et al.'s (2021) who posit that lower levels of corruption lead to higher levels of development and quality of life. The theories and supporting literature which justify the selection of the BBI proxies due to their impact on the economic and social well-being of countries are presented as follows: 1) Economic Freedoms (Scully, 1992; Doucouliagos & Ulubasoglu, 2006; Williamson & Mathers, 2011; Piątek et al., 2013; Hussain & Haque, 2016; Brkić et al., 2020; Gezer, 2020); 2) Monopolistic Markets (Bae et al., 2021); 3) Resource Curse Thesis (Auty, 1995; Sachs & Warner, 2001); 4) Unemployment (Kukaj, 2018; Priambodo, 2021); 5) Savings (Krieckhaus, 2002; Misztal, 2011); 6) Inflation (Akinsola & Odhiambo, 2017; Yolanda, 2017); 7) Infrastructure (Kusharjanto & Kim, 2011; Palei, 2015; Mohanty et al., 2016; Apurv & Uzma, 2021); 8) Money Laundry (Argentiero et al., 2008; Kumar, 2012; Hetemi et al., 2018; Šikman & Grujić, 2021); 9) Corruption (Mo, 2001; Akçay, 2006; Popova & Podolyakina, 2014; Absalyamova et al., 2016; Wahyudi & Alfian, 2021); 10) Political instability (Alesina et al., 1996; Uddin et al., 2017; Yamarik & Redmon, 2017); 11) Rule of Law (Rodrik et al., 2004; Rigobon & Rodrik, 2005; Luong et al., 2020); 12) Social Dissension (Weber, 1958; Ibn Khaldūn, 1967; Fukuyama, 2001; Iyer et al., 2005); 13) Knowledge Creation (Romer, 1994; Solarin & Yen, 2016; Pinto & Teixeira, 2020); 14) Food Loss & Waste (Vilariño et al., 2017) 15) Access to Clean Water (Nawaz & Alvi, 2017; Kong et al., 2020); 16) Suicide Rates (Shepard et al., 2016; Kinchin & Doran, 2017); 17) Environmental Footprint (Azam et al., 2016; N'Zué, 2018). In summary, the 17 proxies which make up the BBI and pertain to 8 dimensions (Table no. 1), i.e., Economic, Corruption, Political, Governance, Social, Knowledge, Health, and Environmental dimensions, are anchored by the theories which make up the BBI framework and supported by literature which studies the impact of various variables on development.

Table no. 1 – BBI Proxies Summary

	Measure	Coun-tries	Vari-ables	Data Source
D1: Bad Economic Behavior				
1) Restricting Economic Freedoms (EF)	Economic Freedom Index	179	5	https://www.heritage.org/index
2) Monopolistic Markets (MM)	The Herfindahl-Hirschman Index	174	-	https://wits.worldbank.org
3) Rentierism (RENT)	Oil Rent as a % of GDP	187	-	https://data.worldbank.org
4) Unemployment (UR)	Unemployment Rate	187	-	https://data.worldbank.org

	Measure	Coun-tries	Vari-ables	Data Source
5) Inflation (INF)	Consumer price index (2010 = 100)	184	-	https://data.worldbank.org
6) Poor Savings (SAV)	Gross domestic savings (% of GDP)	177	-	https://data.worldbank.org
7) Poor Infrastructure (INFRA)	The Global Food Security Index	113	-	https://impact.economist.com
D2: Corruption				
8) Money Laundry (AML)	AML Index	140	17	https://index.baselgovernance.org
9) Public Sector Corruption (CPI)	Corruption Perception index	180	13	https://www.transparency.org/en
D3: Bad Political Behavior				
10) Political Instability (PI)	Fragile States Index	176	4	https://fragilestatesindex.org
D4: Poor Governance				
11) Poor Rule of Law (RL)	World Governance Indicators	154	8	https://data.worldbank.org
D5: Bad Societal Behavior				
12) Social Dissension (SD)	Prosperity Index Measure of "Social Capital"	167	17	https://www.prosperity.com
D6: Poor Knowledge Creation				
13) Poor Academic Influence (KC)	Research Output per capita	197	-	https://www.scimagojr.com/; https://data.worldbank.org/
D7: Preserving Health				
14) Food Loss & Waste (FLW)	The Global Food Security Index	113	-	https://impact.economist.com/
15) Poor Access to Clean Water (CLNW)	The Global Food Security Index	113	-	https://impact.economist.com/
16) Suicide Rates (SR)	Suicide Rate per 100K	183	-	https://who.int/
D8: High Environmental Footprint				
17) CO2 Emissions Per Capita (CO2E)	CO2 Emissions Per Capita	191	-	https://data.worldbank.org

In addition to being aligned with theory on the causes of poor development, the BBI proxies must also align with the purpose of this research, as well as with the study's theoretical framework. To elaborate, this research aims to develop a composite measure which is influenced by the holistic and multidimensional nature of Ibn Khaldun's 'Theory of Development', i.e., there are many elements which lead to the rise and fall of nations including but not limited to economic well-being, political authority, justice, behavior et al.

Given that the theoretical justification for measuring behavior is based on the concept of Mafsada in the Maqasid of Shariah and Adam Smith's worthless fellow in TMS, so are the proxies selected for the index. To elaborate, the corollaries of Mafsada, i.e., the behavior or outcomes which lead to societal harm, and the behavior which a worthless fellow would engage in, serve as drivers for the proxies selected. Regarding the former, the selected proxies must be the anti-thesis of the purpose of the 5 dimensions of the Maqasid, i.e., 1) preserving religion; 2) preserving wealth, including the sustainable use of earth's natural resource; 3) preserving the mind; 4) preserving the body, whilst gaining and utilizing knowledge for the betterment of mankind; and finally, 5) propagating earth to ensure the continuation of mankind. Regarding the latter, Smith's simple categorization of man as a man of honor or a

worthless fellow can facilitate the proxy selection process, as well as provide a theoretical basis for measuring the behavior of nations, i.e., the BBI can measure how 'honorable' or 'worthless' these countries are if they were to be judged as a man. In short, the proxies must be in accordance with theory and literature as to the behavior a worthless fellow would engage in and consequently cause societal harm, i.e., restricting economic freedoms, political instability, corruption etc. The justification for selecting the BBI proxies is presented in the Annex (Table no. A-1), whilst the proxies and their corresponding Maqasid are presented in Annex (Table no. A-2).

3.3 Proxy Adjustment

For some of the composite measures included, i.e., Economic Freedom Index, some of the variables which make up these measures were excluded to avoid double counting. To elaborate, there are 12 variables included in the measurement of the economic freedom index: Property Rights, Judicial Effectiveness, Government Integrity, Tax Burden, Government Spending, Fiscal Health, Business Freedom, Labor Freedom, Monetary Freedom, Trade Freedom, Investment Freedom, and Financial Freedom. Of those 12 variables 6 variables pertain to economic freedoms: Business Freedom, Labor Freedom, Monetary Freedom, Trade Freedom, Investment Freedom, and Financial Freedom. Of those variables 'Monetary Freedom' was excluded as it includes inflation as a proxy, which has been already included as a proxy under 'Inflation – Consumer Price Index'. As such, only 5 of the variables which make up the Economic Freedom Index are included in the construction of the BBI, whilst 7 variables were excluded. This exclusion procedure was repeated where necessary, and no other issues pertaining to double counting are present within the dataset to the best of the authors knowledge.

3.4 Data Sources & Limitations

The BBI proxies are composed of secondary data that has been collected from 'World Bank', 'Heritage Foundation', 'World Values Survey', 'The Fund for Peace', 'Transparency International', 'Basel Institute', 'Legatum Institute', 'UNESCO', 'SCIMAGO', 'The Economist Intelligence Unit', among others (Table no. 1).

Regarding the data limitations, the primary limitation of the data is its secondary nature, as it might not be a true reflection of the phenomena being measured. Given that this study seeks to quantify the development hindering behavior of individuals and institutions and given the lack of theoretical framework which facilitates such quantification, the study must resort to the use of secondary data which could be plagued by: 1) missing data for certain years or countries; lack of data pertaining to the issue the researcher is attempting to study; human error in the data collection process; lack of transparency in the data collection process; among others. Nonetheless, in the absence of primary data which could be of more relevance to the issues being studied, the use of secondary data is justified even if they are not a true reflection of the issues the researcher is attempting to study, as long as there are similarities (Chandola & Booker, 2022).

3.5 BBI selected Countries (N) & Year (t)

The present study aims to construct a composite index using data collected from over 150 countries. However, data is missing for the proxies of 'Food Waste' and 'Poor Access to Clean Water,' which reduces the number of countries included to 89. In addition, data is available for over 15 years for all proxies except 'Money Laundering,' 'Public Sector Corruption', 'Food Waste', and 'Poor Access to Clean Water'. As a result of limited data availability for recent years, the composite index presented in this study was constructed for the year 2019 with the aim of reducing data unavailability as the selected year produced the highest number of countries with the least amount of missing data without excessive interpolation and forecasting – less than 2%. Although data could have been forecasted for the proxies with missing data to include more countries in the BBI or select a more recent dataset, it was decided not to do so to limit data discrepancies. The list of countries included in the index are presented in Table no. 2 as follows:

Table no. 2 – Countries included in the BBI

Europe	Asia	Africa	NA	SA & CA	Oceania
Austria	Azerbaijan	Algeria	Canada	Bolivia	Australia
Belgium	Bahrain	Angola	Mexico	Brazil	New
Bulgaria	Cambodia	Benin	United	Chile	Zealand
Czech Republic	China	Botswana	States	Colombia	
Denmark	Egypt	Burkina Faso		Costa Rica	
Finland	India	Ghana		Dominican	
France	Indonesia	Ivory Coast		Republic	
Germany	Japan	Kenya		Ecuador	
Greece	Jordan	Morocco		El Salvador	
Hungary	Kazakhstan	Mozambique		Guatemala	
Ireland	Kuwait	Niger		Honduras	
Italy	Laos	Nigeria		Nicaragua	
Netherlands	Malaysia	Senegal		Panama	
Norway	Nepal	Sierra Leone		Paraguay	
Poland	Pakistan	South Africa		Peru	
Portugal	Philippines	Tanzania		Uruguay	
Romania	Qatar	Tunisia			
Russia	Saudi Arabia	Uganda			
Serbia	Singapore	Zambia			
Slovakia	South Korea				
Spain	Sri Lanka				
Sweden	Thailand				
Switzerland	United Arab				
Turkey	Emirates				
Ukraine	Vietnam				
United Kingdom					

3.6 Interpolation & Forecasting

Missing values for the entire dataset are *less than ~2%* after reducing t & N, and the missing data has been interpolated using the *moving-average* method which is an interpolation and forecasting technique which places higher weights for more recent values when calculating the missing data.

3.7 Data Normalization

Regarding the *normalization* method, this research utilizes the *ranking* approach. This approach ranks countries in each proxy, and its advantage over the other methods is that it is not affected by outliers (Mazziotta & Pareto, 2017). The ranking formula is presented as follows:

$$y_{ij} = rank(x_{ij})$$

where *'rank(x_{ij})'* is the rank of Country *'i'* for proxy *'j'*.

The ranking method is useful against outliers, variables with positive, negative, or zero values, and is applicable to both bounded and unbounded variables. However, its limitation is the assumption of equal intervals between the variables and is not suitable for ordinal data (Mazziotta & Pareto, 2017). Regarding the treatment of countries with equal scores for a particular proxy, i.e., share the same rank, the dataset will be subjected to the *soft-max* technique which transforms the vectors from numbers to probabilities. The formula for the soft-max function is as follows:

$$\sigma(x_j) = \frac{e^{x_j}}{\Sigma_i e^{x_i}}$$

3.8 Data Aggregation

Regarding the aggregation method, this research seeks to develop a non-compensatory index, which means the most appropriate method is the geometric or the multi-criteria analysis. Given the prominent use of the geometric mean in literature, this research will adopt this method of aggregation. Similar to Zhou et al.'s (2010) model, the BBI model with the application of the geomean method is presented as follows:

$$BBI_i^0 = \prod_{j=1}^{n} y_{ij}^{w_j} \qquad i = 1, 2 \ldots \text{m}$$

where…

- *'y_{ij}'* represents the '*BBI*' score for country *'i'* with respect to proxy *'j'*.
- *'n'* represents the number of proxies included in the BBI.
- *'m'* represents the number of country's included in the BBI.
- *'w_i'* represents the weight to be applied to proxy *'j'*.

It must be noted that the the BBI is a *negative index*, meaning that countries will be ranked in a descending order of highest to lowest engagement in development hindering behavior, i.e., highest to lowest levels of bad behavior.

3.9 Weighting Method

Regarding the *weighting* system adopted, the index will adopt an *expert weighting* system, which involves consulting a panel of experts and delegating them the task of assigning

the weights to the proxies via scale of relative importance. Although expert weights are more reliable than equal or arbitrary weights, they are troubled by subjectivity and inconsistency. To address this limitation, the expert weights are integrated with the *Fuzzy Analytic Hierarchy Process* (FAHP). This process subjects the proxies to a 1v1 comparison through a Fuzzy Pairwise Comparison Matrix (FPCM) which facilitates for identifying the most important proxies pertaining to the phenomenon being measured. The FAHP method is based on Zadeh's (1965) fuzzy sets theory, and Saaty's (2010) AHP method for Multi-Criteria Decision Making (MCDM).

The methodology behind integrating the expert weighting system and the FAHP method is based on Al Fozaie and Wahid (2022), and it involves 1) Developing a weighting scale based on a scale of relative importance; 2) Selecting a panel of experts and delegate the weighting process; 3) Assigning alpha values to the experts based on their level of expertise; 4) Transforming the survey responses into expert weights; 5) Applying the FAHP method to the expert weights; 6) Normalizing the fuzzy weights to produce the interval weights which are midpoint between the fuzzy weights and the expert weights, and are the final weights to be applied to the BBI.

To summarize how the study came about the BBI weights, expert weights were generated with the support of 5 experts of the field of economics, who are asked to individually assign weights to the BBI proxies using a scale of relative importance. The internal consistency score of the survey responses was 0.932, which indicates that the expert responses are highly consistent, allowing one to proceed with the expert weighting and FAHP integration process. To improve upon the expert weights, alpha values were assigned to the experts, and their responses and were recalculated using the soft-max function. A Pearson correlation test was conducted to check the consistency of the expert weights pre- and post-alpha adjustment, which returned a value of 0.985 which indicates that the alpha adjustments have not skewed the results and the expert opinions are consistent.

Regarding the FAHP process, a fuzzification of the expert weights was conducted, which involved developing a fuzzy pairwise comparison matrix to synthesize the judgements of the panel experts, as well as provide a vis-à-vis comparison of the proxies. Calculating the fuzzy weights followed, which involved utilizing the geometric mean (Buckley, 1985) to aggregate multiple fuzzy sets into a single set. De-fuzzying the weights followed, which involves calculating the average of the fuzzy weights for each proxy. The last step is to find the interval weights which are the midpoint between the expert weights and the fuzzy weights. The interval weights address the limitation of highly exaggerated or skewed fuzzy weights by normalizing them and bringing them closer to the expert values, but not to the extent that the FAHP method and subsequent fuzzy weights become obsolete. Figure no. 2 provides a summary of the process of generating the expert weights, integrating them with the FAHP method, and transforming them into interval weights, whereas Table no. 3 exhibits the fuzzy weights, expert weights, and the interval weights, the latter of which will be applied to the BBI.

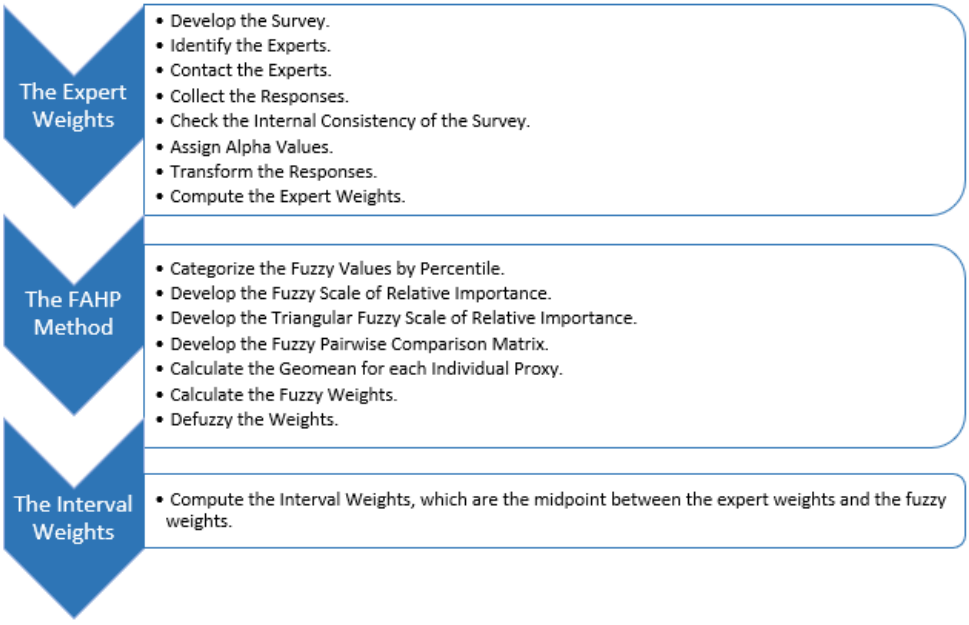

Figure no. 2 – BBI weighting process
Sources: Al Fozaie and Wahid (2022)

Table no. 3 – Fuzzy Weights, Expert Weights, and the Interval Weights

Proxy	w_i[1]	w_i[2]	Interval w_i[3]
CPI	15.80%	7.10%	**11.50%**
PI	15.80%	7.20%	**11.50%**
EF	15.80%	7.00%	**11.40%**
RL	8.50%	6.70%	**7.60%**
MM	8.50%	6.40%	**7.40%**
INFRA	8.50%	6.20%	**7.40%**
CLNW	4.10%	6.00%	**5.10%**
INF	4.10%	5.90%	**5.00%**
KC	4.10%	5.80%	**5.00%**
SAV	4.10%	5.80%	**4.90%**
UR	2.10%	5.70%	**3.90%**
RENT	2.10%	5.40%	**3.70%**
AML	2.10%	5.40%	**3.70%**
SD	1.10%	5.30%	**3.20%**
FLW	1.10%	5.10%	**3.10%**
CO2E	1.10%	5.00%	**3.00%**
SR	1.10%	4.10%	**2.60%**

Note: [1] Fuzzy Weights; [2] Expert Weights; [3] Interval weights which are the midpoint between the fuzzy weights and the expert weights.

FAHP Benefits & Limitations

The advantage of the FAHP method is that it facilitates for a 1v1 comparison of the proxies, which the scale of relative importance does not allow, thereby serving a similar role to principal component analysis (PCA) where the most prominent proxies become apparent. The difference between PCA and FAHP is that the former can only be applied to compensatory indices, whilst the latter does not have such limitation (Mazziotta & Pareto, 2017). However, it has been argued that the FAHP method adds unnecessary fuzziness to the AHP method (Saaty, 2006). Moreover, the FAHP does not entirely eliminate the subjectivity, uncertainty, and inconsistency of the expert opinions, it rather mitigates their effect. That said, integrating expert weights with the FAHP method should result in weights which are more accurate relative to equal or arbitrary weights. Evidence to this statement is the ranking of the proxies in Table no. 3, which is supported by theory and literature as the most important drivers for socio-economic development. Moreover, the discussion section provides a comparison between the BBI rankings with and without the application of the FAHP method, and as it will become clearer later on, the application of the FAHP method is justified.

3.10 Diagnostic Methods

Regarding the *validity* testing, the index will be tested for robustness using both *sensitivity* and *uncertainty* analysis. Sensitivity analyses involves quantifying the effects of each individual uncertainty, or parameter variations, on the results or outputs (Saisana *et al.*, 2005; Mazziotta & Pareto, 2017; Greco *et al.*, 2019). Uncertainty analysis centers on the effects of parameter uncertainties, and how the uncertainties in the inputs can impact the results or outputs (Ibid, 2005). The benefit of validity testing is that it adds a level of transparency to the index construction process, aids in the proxy selection process, and conveys a level or robustness which dispels the criticism of using composite indices (Saisana *et al.*, 2005; Mazziotta & Pareto, 2017; Greco *et al.*, 2019).

Correlation analysis was also conducted to study the relationship between the proxies. Highly correlated indices could lead to double counting and skew the index (OECD & Joint Research Centre-European Commission, 2008). However, this can be considered a non-issue if a 'false-positive' relation exists between the variables. To elaborate, two proxies could be highly correlated even though they measure different phenomena. The recommended course of action is to judge each instance where there is high correlation among the variables, i.e., a correlation coefficient of +/- 0.7 to 1.0 (Ratner, 2009), on a case-by-case basis, i.e., a vis-à-vis comparison of the indicators with high correlation.

3.11 BBI Methodology Summary

The BBI consist of 17 proxies pertaining to different measures of bad behavior by individuals and institutions. The data has been normalized using the ranking approach and missing data has been interpolated using the moving average method. In addition, data has been aggregated using the geomean method, and the weighting method of choice is the integration of expert weights and the FAHP method to arrive at the interval weights, which are more objective and reliable relative to expert weights, equal weights, or arbitrary weights. In addition to the forestated, the methodology includes diagnostic tests to check for the

reliability and validity of the index results, which involves conducting sensitivity, uncertainty, and correlation analysis. Except for the weighting method, the study follows the methodology of Mazziotta and Pareto (2017) for the construction of composite indices.

4. RESULTS

4.1 Index Results

Table no. 4 – BBI results

Rank	Country	Rank	Country	Rank	Country
1	Angola	31	South Africa	61	Poland
2	Sierra Leone	32	Guatemala	62	South Korea
3	Nigeria	33	Serbia	63	Slovakia
4	Mozambique	34	Colombia	64	Panama
5	Nepal	35	Egypt	65	Hungary
6	Nicaragua	36	Ecuador	66	United Arab Emirates
7	Ukraine	37	Dominican Republic	67	Canada
8	Niger	38	Sri Lanka	68	Italy
9	Burkina Faso	39	Mexico	69	United States
10	Zambia	40	Vietnam	70	Qatar
11	Laos	41	Morocco	71	Japan
12	Kenya	42	Peru	72	Australia
13	Uganda	43	El Salvador	73	Czech Republic
14	Bolivia	44	Turkey	74	Portugal
15	Brazil	45	Philippines	75	Spain
16	Pakistan	46	Jordan	76	New Zealand
17	Algeria	47	Botswana	77	Belgium
18	Ivory Coast	48	Costa Rica	78	Austria
19	Benin	49	China	79	France
20	Tunisia	50	Uruguay	80	Norway
21	Ghana	51	Indonesia	81	United Kingdom
22	Tanzania	52	Saudi Arabia	82	Finland
23	Kazakhstan	53	Kuwait	83	Ireland
24	India	54	Bulgaria	84	Netherlands
25	Russia	55	Romania	85	Germany
26	Honduras	56	Thailand	86	Denmark
27	Paraguay	57	Greece	87	Sweden
28	Cambodia	58	Chile	88	Singapore
29	Senegal	59	Malaysia	89	Switzerland
30	Azerbaijan	60	Bahrain		

Figure no. 3 provides a visual illustration in the form of a heat map of the BBI rankings. Countries are color coded where the blue spectrum represents countries that are lower in the index, i.e., lowest engagement in development hindering behavior, whilst the red spectrum represents countries that are higher on the index, i.e., highest engagement in developing hindering behavior.

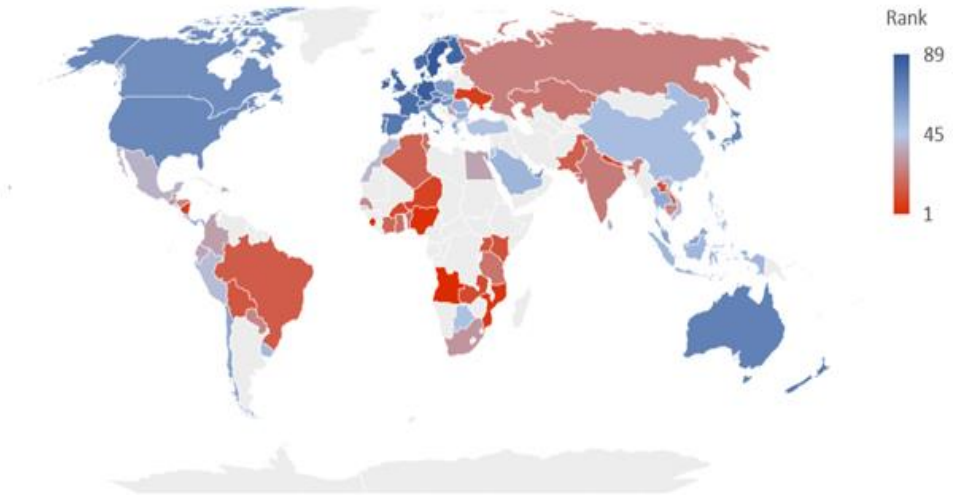

Figure no. 3 – BBI Heat Map

4.2 Diagnostic Results

Before moving on to analyzing and interpreting the BBI results, it is essential to discuss the validity of the results according to several diagnostic tests initiated. Beginning with a *correlation analysis* test conducted in R, various proxies are highly correlated to one another, i.e., a correlation coefficient of +/- 0.7. An example of such is the high and positive correlation between the proxy for *Money Laundry*, i.e., AML, and the proxy for *Poor Access to Clean Water*, i.e., CleanW. Another example of high correlation is the significant and negative relationship between the proxy for CO2 *Emissions*, i.e., CO2E, and the proxy of Poor *Infrastructure*, i.e., INFRA. There are many instances of high correlation as exhibited by Figure no. 4, but for the sake of directness and simplicity, the upcoming text will discuss the forestated examples.

Regarding the high correlation between Money Laundry and Poor Access to Clean Water, this is a case of a false-positive which should be ignored. The rationale behind such action is because both proxies are quite distinct from one another, as each proxy is a measure of a very different phenomenon. Regarding the high correlation between CO2 Emissions and Poor Infrastructure, not only do the two proxies measure phenomena which are distinctive, but there is a lack of a theoretical and rational reason for such a high and negative correlation. To elaborate, the significant and negative relationship between CO2 Emissions and Poor Infrastructure indicates that as CO2 Emissions per Capita increase, the quality of a country's road, port, air, and rail infrastructure decreases. Such a relation is inconceivable, as it is irrational to assume that as countries improve the quality of their infrastructure, which subsequently leads to higher air, road, and port traffic, the country's CO2 emissions per capita will decrease. As such, and despite the benefits of a correlation analysis, which facilitates for the exclusion of similar proxies which could lead to double counting and subsequently skewing the index, it does not always lead to accurate estimates as to the nature of the relationship between the proxies.

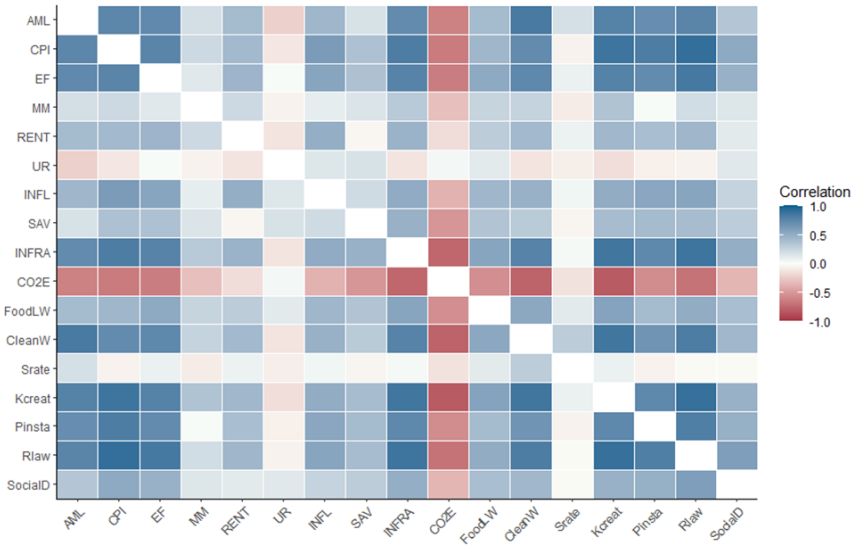

Figure no. 4 – BBI Proxies Correlation Heat Map

A better alternative is to engage in a vis-à-vis comparison to eliminate proxies which measure similar phenomena, or might include variables which could lead to double counting, i.e., just as this study has done by removing some of the variables which make up the economic freedom index as it only included 5 of the 12 variables which make up the index because they were irrelevant to the phenomena being measured, as well as due to the presence of measures such as inflation which is represented by the consumer price index in another proxy. Another proxy which had a similar treatment is the measure of political instability which is represented by the Fragile States Index (FSI). This measure includes 12 dimensions of which only 4 were selected based on their relevance to the phenomenon being measured, as well as to avoid conflict with other variables included in the index. Nevertheless, the index does include one measure which included double counted variables and that is the proxy for Money Laundry (AML). This proxy consists of 17 variables of which includes Corruption (CPI) [5% weight], Rule of Law [2.5% weight], and Bribery Matrix [5%] – albeit the latter 2 are from different sources. However, this should be of no impact on the outcome of the index as their influence on the AML index is a mere 0.46% [12.5% × 3.7%]. The reason for not removing these variables from the AML index is because the data source does not separate the variables relative to other data sources and present them as an aggregated value instead. No other issues pertaining to double counting are present in the index to the best of the researcher's knowledge.

Regarding the *sensitivity analysis*, which aims to estimate which of the input uncertainties are driving the output uncertainties (Becker, 2021), there are two types of uncertainties, i.e., the normalization method and the index weights, which were tested in R statistical software by subjecting the BBI to the Monte Carlo method, i.e., a technique which recalculates the index by manipulating the value of the uncertainties each time. According to the test results of 100 iterations, the BBI is highly sensitive to the weights and indifferent to the normalization method. Such findings indicate that the output of the index is highly

dependent on the weights selected, and changing these weights subsequently changes the BBI results. The results of the sensitivity analysis are presented in Figure's no. 5 & no. 6 which visualize the uncertainties in the form of a bar chart and a box plot. Given that the weights are the most important uncertainty in the aggregation process, it is of the utmost importance to perform high due diligence when selecting the weights for the BBI; hence why experts were delegated the weighting process, and their responses were transformed into expert weights, and subsequently integrated with the FAHP method to facilitate for a 1v1 comparison of the proxies, and assign the highest weights to the most important proxies to produce the fuzzy weights, which were then normalized to produce the interval weights, with the purpose of reducing skewness in the index.

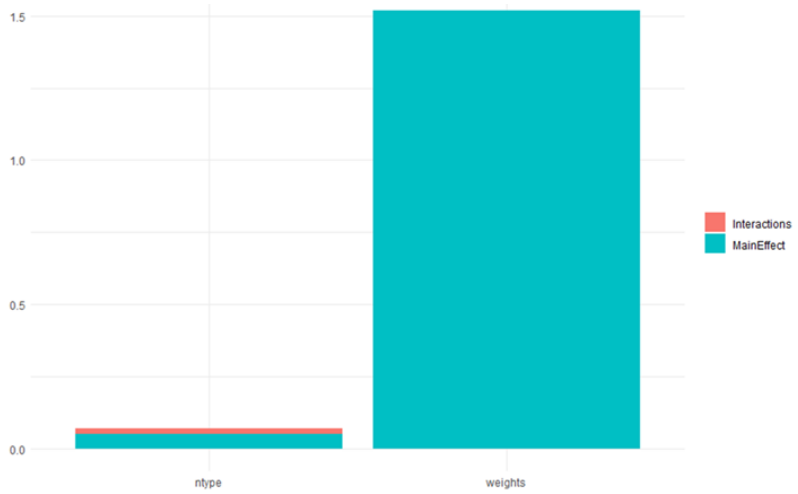

Figure no. 5 – Sensitivity Analysis: Bar Chart[1]

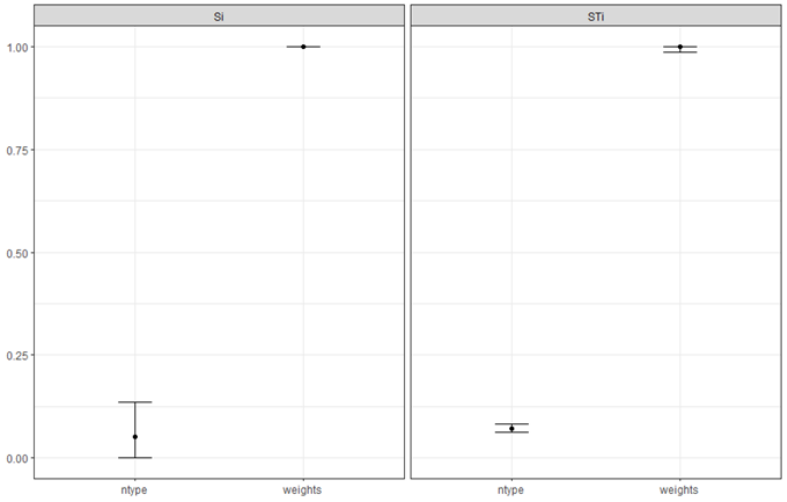

Figure no. 6 – Sensitivity Analysis: Box Plot

Regarding *uncertainty analysis*, which aims to quantify the uncertainty in the outputs, it was also conducted in R using a Monte Carlo simulation of 100 iterations, and the results are presented in Figure no. 7. According to the uncertainty analysis output, which plots the nominal, mean, and median ranks (y-axis) of various replications of the BBI, the results of the BBI are consistent for the countries included (x-axis), as the variance between the various ranks is insignificant given the linear nature of the chart. The interpretation of the uncertainty analysis test indicates that the BBI country ranks are fairly consistent given the multiple recalculations of the index, providing validity to the results of the index, as well as the greenlight to the researcher to proceed with the analysis and interpretation of the results.

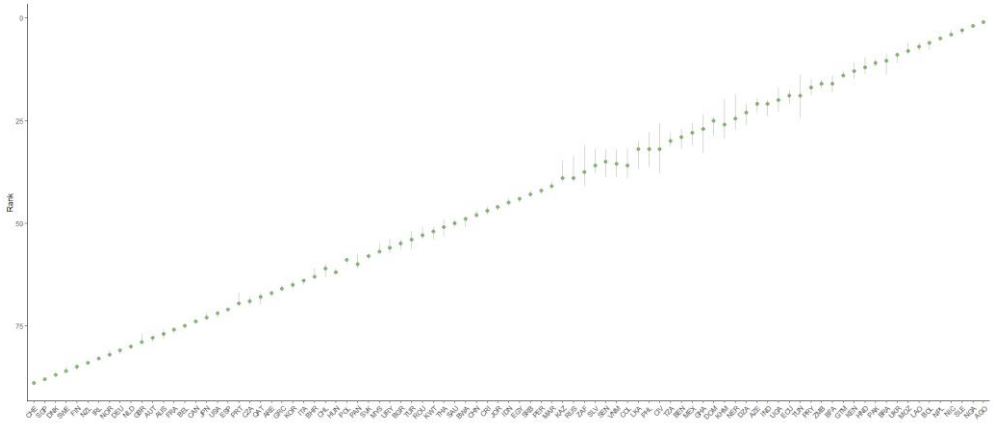

Figure no. 7 – Uncertainty Analysis

5. ANALYSIS & INTERPRETATION

The BBI is a negative index, meaning that countries that rank lower in the index are highly developed countries since they engage in the least levels of development hindering behavior relative to the other countries in the index. On the other hand, countries ranking higher on the index are highly underdeveloped countries, since they engage in the highest levels of development hindering behavior.

Analyzing and interpreting the BBI rankings involves breaking down the rankings into groups and clusters. The advantage of this method is that it provides a clearer picture of the rankings, i.e., allowing researchers to identify patterns, as countries are categorized based on variables such as geographic location, culture etc.

Regarding the grouping process, countries were grouped by region, i.e., geographic categorization, and divided into 11 groups. Grouping allows one to cluster countries that are quite similar to one another, i.e., grouping Norden countries such as Denmark, Finland, Sweden, and Norway. Grouping has many benefits, one of which is that it allows one to see how countries that share similar geographies and culture perform in the index, and whether there are any discrepancies in the rankings. To elaborate, if these countries perform well in the index, i.e., rank at the bottom end of the BBI, it provides one with valuable information which could lead to further research, i.e., why are Norden countries highly developed? If there are discrepancies in the rankings however, and despite sharing various geographic, cultural,

and social similarities, it also provides one with information which could lead to further research, i.e., why is country 'x' less developed than its neighbors' given similar geographic, cultural, and social facets? The grouping of countries by region is presented in Figure no. 8 as follows:

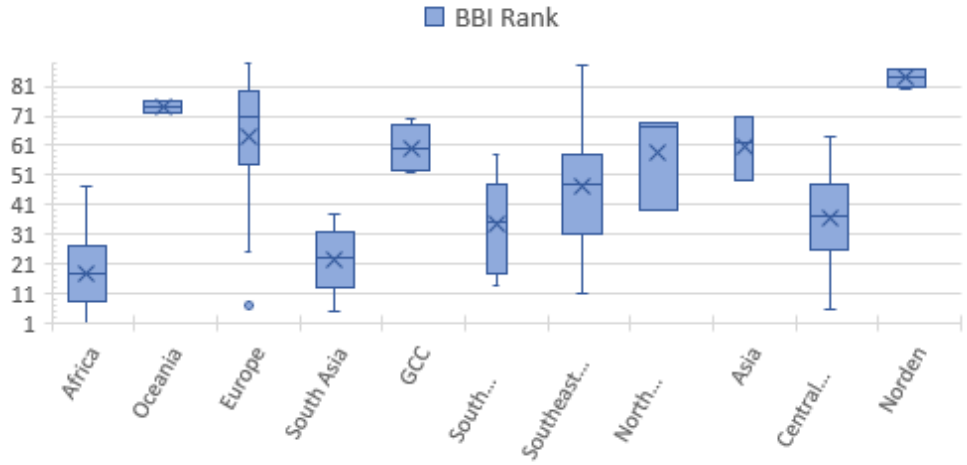

Figure no. 8 – BBI by Region

Regarding clustering, it facilitates for the categorization of countries into groups which could be quite distinct from one another, i.e., different geographies, culture, religion, language etc. Countries in the BBI are clustered based on their level of performance in the BBI, which itself is an indicator of the countries level of socio-economic development. To elaborate, countries are divided into four clusters, i.e., underdeveloped (Cluster 1), developed (Cluster 2) developing (Cluster 3), and highly developed (Cluster 4). Clusters were created using the percentile clustering technique discussed by Janowitz and Schweizer (1989) where countries are assigned a percentile value based on their rank in the BBI. Quantile clustering is utilized due to its simplicity and ease of use in partitioning data into clusters based on percentiles of a particular variable or rank. The use of percentiles ensures a well-balanced representation of the data, aiding in identifying outliers and making it an effective method for partitioning complex or heterogeneous data. It also helps at providing insights into unique characteristics or values within the data, making it a valuable tool in a wide range of applications.

The percentile method, i.e., 'p = 1-(ranki/n)', was adjusted to reflect the negative nature of the index, and an inverse percentile method was utilized instead, i.e., 'p = ranki/n' or '%-1' where 'p' is the percentile, 'ranki' is the rank of country 'i' in the index, and 'n' is the number of countries included in the index. For example, under the percentile method of Janowitz and Schweizer (1989), the percentile for Angola, which ranks first in the BBI, is 98.9%. Under the inverse percentile method, i.e., 'p-1', the percentile value of Angola is 1.12%. The use of inverse percentile method instead of the original percentile method in this study was chosen to provide a clearer visualization of the clusters. The negative nature of the index, which reflects development hindering behavior, was better represented using this method. Clustering countries into groups, rather than assigning absolute ranks, provides a more useful way to understand the results. While a country's rank in an index may not provide

actionable information, clustering countries into groups helps to identify patterns and trends. It is important to note that being part of the 'highly developed' cluster is a goal for countries. This cluster represents countries that exhibit low levels of development hindering behavior. The BBI index, like all indices, provides a simplified representation of reality and it is important to be aware of its limitations. It is not meant to be taken at face value, but rather as a starting point for analysis. Policy and decision makers should use the results of the index to identify areas where a country is lagging and how to improve its performance in the future. The results of clustering countries by level of socio-economic development using the inverse percentile method (%-1) are presented in Table no. 5:

Table no. 5 – Clusters by Development Status

Cluster 1 Underdeveloped		**Cluster 2 Developing**		**Cluster 3 Developed**		**Cluster 4 Highly Developed**	
Country	**%$^{-1}$**	**Country**	**%$^{-1}$**	**Country**	**%$^{-1}$**	**Country**	**%$^{-1}$**
Angola	1.1%	Kazakhstan	25.8%	Philippines	50.6%	Canada	75.3%
Sierra Leone	2.2%	India	27.0%	Jordan	51.7%	Italy	76.4%
Nigeria	3.4%	Russia	28.1%	Botswana	52.8%	USA	77.5%
Mozambique	4.5%	Honduras	29.2%	Costa Rica	53.9%	Qatar	78.7%
Nepal	5.6%	Paraguay	30.3%	China	55.1%	Japan	79.8%
Nicaragua	6.7%	Cambodia	31.5%	Uruguay	56.2%	Australia	80.9%
Ukraine	7.9%	Senegal	32.6%	Indonesia	57.3%	Czech Republic	82.0%
Niger	9.0%	Azerbaijan	33.7%	Saudi Arabia	58.4%	Portugal	83.1%
Burkina Faso	10.1%	South Africa	34.8%	Kuwait	59.6%	Spain	84.3%
Zambia	11.2%	Guatemala	36.0%	Bulgaria	60.7%	New Zealand	85.4%
Laos	12.4%	Serbia	37.1%	Romania	61.8%	Belgium	86.5%
Kenya	13.5%	Colombia	38.2%	Thailand	62.9%	Austria	87.6%
Uganda	14.6%	Egypt	39.3%	Greece	64.0%	France	88.8%
Bolivia	15.7%	Ecuador	40.4%	Chile	65.2%	Norway	89.9%
Brazil	16.9%	Dominican	41.6%	Malaysia	66.3%	United Kingdom	91.0%
Pakistan	18.0%	Republic		Bahrain	67.4%	Finland	92.1%
Algeria	19.1%	Sri Lanka	42.7%	Poland	68.5%	Ireland	93.3%
Ivory Coast	20.2%	Mexico	43.8%	South Korea	69.7%	Netherlands	94.4%
Benin	21.3%	Vietnam	44.9%	Slovakia	70.8%	Germany	95.5%
Tunisia	22.5%	Morocco	46.1%	Panama	71.9%	Denmark	96.6%
Ghana	23.6%	Peru	47.2%	Hungary	73.0%	Sweden	97.8%
Tanzania	24.7%	El Salvador	48.3%	United Arab	74.2%	Singapore	98.9%
		Turkey	49.4%	Emirates		Switzerland	100.0%
Mean	**12.9%**	**Mean**	**37.6%**	**Mean**	**62.4%**	**Mean**	**87.6%**

5.1 Integrating the inverse percentile method and grouping by region

The inverse percentile method can also be applied to the BBI results by group, i.e., similar geographies and culture, to provide a visual illustration of the rankings for the purpose of further analysis. The results of such integration and provided in Table no. 6 and visualized in Figure no. 9.

Table no. 6 – BBI Results by Region Summary

Region	Avg of BBI Rank	Avg of $\%^{-1}$ Rank
Africa	18.10	20.3%
Asia	60.67	68.2%
Central America	36.57	41.1%
Europe	64.09	72.0%
GCC	60.20	67.6%
Norden	83.75	94.1%
North America	58.33	65.5%
Oceania	74.00	83.1%
South America	34.50	38.8%
South Asia	22.67	25.5%
Southeast Asia	47.25	53.1%

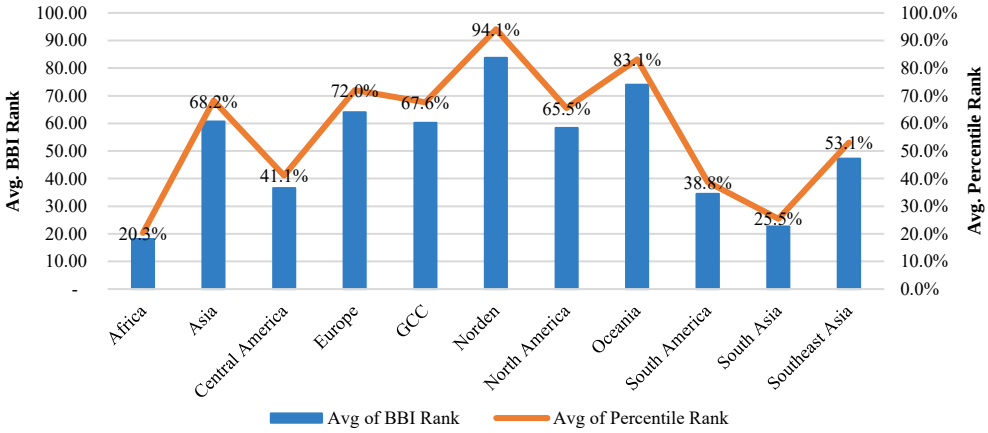

Figure no. 9 – BBI Results by Region visualized

Analyzing the BBI results by region, i.e., Figure's no. 8 & no. 9, and Table no. 6, countries that pertain to the Norden region perform highly in the index with an average BBI rank of 84 among 89 countries. This places Norden countries in the 94th percentile in terms of level of development. It must be noted that the ranking variability of Norden countries is minimal given the short length of their boxplot in Figure no. 8. Oceanian countries, i.e., Australia and New Zealand, rank second highest in the index with an average BBI rank of 74 and a percentile of 83%. European countries rank third in the index with an average BBI rank of 64 and a percentile of 72%. Of the 22 European countries included in the BBI, 52% are considered highly developed, i.e., cluster 4, 27% are considered developed, i.e., cluster 3, 14% are considered developing, i.e., cluster 2, and 5% are considered developing, i.e., cluster 1. African countries are considered the poorest performing countries in the index, i.e., they rank highly in the BBI, with an average rank of 18 and a percentile of 20%. No African country is categorized as a highly developed country, whereas only 1 African country, i.e., Botswana, is considered as a developed country. The rest of the African countries included in the index, i.e., 19 out of 20 countries, are categorized either as developing or underdeveloped countries. A full breakdown of the clusters by region and their respective socio-economic development status categorization are provided in Table no. 7 as follows:

Table no. 7 – Clusters by Region

Cluster 1 Underdeveloped			Cluster 2 Developing			Cluster 3 Developed			Cluster 4 Highly Developed		
Region	**#**	**%$^{-1}$**	**Region**	**#**	**%$^{-1}$**	**Region**	**#**	**%$^{-1}$**	**Region**	**#**	**%$^{-1}$**
Africa	15	68%	Africa	4	18%	Europe	6	27%	Europe	12	52%
South America	2	9%	Central America	4	18%	GCC	4	18%	Norden	4	17%
South Asia	2	9%	South America	4	18%	Southeast Asia	4	18%	North America	2	9%
Central America	1	5%	South Asia	4	18%	Asia	3	14%	Oceania	2	9%
Europe	1	5%	Europe	3	14%	Central America	2	9%	Asia	1	4%
Southeast Asia	1	5%	Southeast Asia	2	9%	South America	2	9%	GCC	1	4%
Asia	0	0%	North America	1	5%	Africa	1	5%	Southeast Asia	1	4%
GCC	0	0%	Asia	0	0%	Norden	0	0%	Africa	0	0%
Norden	0	0%	GCC	0	0%	North America	0	0%	Central America	0	0%
North America	0	0%	Norden	0	0%	Oceania	0	0%	South America	0	0%
Oceania	0	0%	Oceania	0	0%	South Asia	0	0%	South Asia	0	0%

Grouping and clustering countries by region, development status, or otherwise, can facilitate the identification of patterns that warrant further research. For instance, 91.3% of the countries in the highly developed cluster are OECD members. This observation raises various questions that can be investigated in future research, such as the impact of the OECD's anti-bribery convention on corruption levels in its member countries and its potential effect on development. In addition, one might explore how political instability in Africa influences the level of development in the continent and why a country like Botswana, with a BBI rank of 47 among 89 countries, is in the top 74th percentile in the proxy for political instability (PI), while other African countries are in the 28th percentile, with an average rank of 16.5 among 89 countries. These questions are illustrative of how grouping and clustering can aid in analyzing and interpreting indices, rather than relying solely on absolute ranks.

5.2 Proxy Comparison for selected Countries

Despite the benefits of grouping and clustering over absolute ranks, including how they highlight the discrepancies in the development level of countries with similar characteristics, these methods do not facilitate in explaining such discrepancies. To achieve such purpose, one can either: 1) develop an economic model and conduct a regression analysis to test the relationship between various variables on the country ranks in the BBI by utilizing dynamic panel data and applying the generalized method of moments (GMM) estimation technique developed by Arellano and Bover (1995), i.e., difference GMM, or Blundell and Bond (1998), i.e., system GMM, to address the problem of endogeneity and heteroskedasticity in simple linear regression models; or 2) select a sample of countries at the higher and lower spectrums of the BBI and analyze their performance using a proxy comparison technique.

Regarding the selection of the countries in the sample, countries pertaining to the 'highly developed' cluster were selected along with the country which ranks highest on the BBI, i.e., Angola. The basis for selecting the countries is development status and geographic location. Selecting countries from diverse cultures and geographies in cross-country comparisons has several benefits. It allows for a more comprehensive understanding of how cultural and geographical factors impact development. This information can inform researchers and decision-makers by showing how development-promoting or hindering behaviors may vary across different cultural and geographical contexts. Thus, incorporating diverse countries in

cross-country comparisons provides a more nuanced understanding of the relationships between behavior, culture, geography, and development outcomes. The sample of countries and their respective performance in the form of percentiles, based on Janowitz and Schweizer (1989) and not the inverse percentile method discussed earlier, are presented in Table no. 8 as follows:

Table no. 8 – Proxy Comparison based on percentiles for selected countries

Proxy	Angola %	Switzerland %	Singapore %	New Zealand %	Qatar %
EF	93%	8%	1%	3%	42%
MM	90%	34%	33%	73%	62%
RENT	99%	2%	1%	53%	96%
UR	76%	49%	22%	44%	1%
INF	100%	1%	26%	25%	31%
SAV	16%	12%	3%	49%	2%
INFRA	80%	2%	1%	19%	28%
AML	78%	36%	25%	2%	37%
CPI	98%	4%	7%	1%	26%
PI	71%	1%	9%	4%	38%
RL	92%	8%	6%	2%	27%
SD	89%	7%	24%	4%	22%
KC	100%	1%	3%	13%	25%
FLW	89%	30%	34%	2%	51%
CLNW	90%	16%	17%	47%	49%
SR	83%	49%	71%	36%	22%
CO2E	15%	69%	83%	79%	97%
Average	**80%**	**19%**	**21%**	**27%**	**39%**

5.3 Angola & the BBI: Leading the Rankings

The BBI rankings in Table no. 4 show that Angola exhibits the highest levels of bad behavior relative to other countries in the index. To better understand why Angola leads the BBI rankings, it is imperative to analyze its performance in the various BBI proxies, and why it is categorized as an underdeveloped country despite its abundant natural resources – Angola ranks above 22 other countries with a rank of 67 out of 89 and is regarded as one of the world's largest exporters of oil (IEA, 2021).

Analyzing their performance in the various BBI proxies exhibited in Table no. 8, Angola is performing poorly in most indicators. For example, the country ranks in the 90th percentile in the proxies of 'Restricting Economic Freedoms' (EF), 'Monopolistic Markets' (MM), 'Rentierism' (RENT), 'Inflation' (INF), 'Public Sector Corruption' (CPI), 'Poor Rule of Law' (RL), 'Poor Knowledge Creation' (KC), and 'Poor Access to Clean Water' (CLNW). All in all, the country performs poorly in all of the BBI proxies, i.e., assuming a threshold of 70th percentile, with the exception of their performance in the proxies for 'Poor Savings' (SAV) and 'CO2 Emissions Per Capita' (CO2E). According to Munslow (1999) & García-Rodríguez *et al.* (2015), Angola is poorly developed despite the abundance of natural oil resources is due to corruption and the unequal distribution of wealth. Hammond (2011) on the other hand, argues that Angola's poor development could be attributed to the resource curse thesis developed by Auty (1995), arguing that high dependence on external rent leads to unsustainable development which fuels corruption. This argument can be countered however by pointing that several high oil producing countries such as Qatar perform well in the index. As such, rentierism should not be solely blamed for the country's development misfortunes, as other rentier states are well-

developed despite their high dependence on oil. Comparing the performance of Angola to a select sample highly developed countries of different geographic and culture characteristics, it becomes clear that these countries are highly developed due the low engagement of their formal and informal institutions in development hindering behavior, in particular the low engagement in public sector corruption (CPI), the high application of the rule of law, low levels of social dissension (SD), and the high levels of knowledge creation (KC).

It must be noted that the countries included in the proxy comparison exercise only represent 17% of the countries in the highly developed cluster, i.e., Cluster 4. As such, it would be unwise to assume that the aforementioned proxies are the sole drivers of socio-economic development. For example, there is a positive and high correlation between a countries level of corruption and political instability as exhibited by Figure no. 4. Such a significant relationship between political instability and corruption means that as one variable increase, so does the other. As such, similar to corruption, a country's level of political stability is an important variable to a country's level of socio-economic development. The question here is not whether political instability impacts socio-economic development, a position that is widely supported by literature, but to what extent does it impact development, and is it more important, for example, to socio-economic development relative to corruption.

5.4 Not all proxies are created equally

It must be stated that not all proxies are created equally. To elaborate, some proxies are more important than others to achieve high socio-economic development. Although one might argue that the results of the index are entirely dictated by weights, this is not entirely the case. To elaborate, a *correlation* analysis by summation is utilized to analyze the performance of the 10 countries that in accordance with their BBI rankings engage in the least levels of development hindering behavior, i.e., they are the 10 lowest ranking countries in the BBI (See Table no. 4). This technique involves summing the country ranks per proxy, i.e., '$\sum Rank_{x,i}$' where *'i'* represents the country and *'x'* represents the proxy, with the purpose of identifying the proxies with the least variability and highest consistency among the selected sample of countries. The results of this technique are presented in Table no. 9.

Table no. 9 – Result of Correlation Analysis by Summation

Proxy	Rank	$\sum$ Rank $_{x,i}$	Weight
CPI	1	69	11.5%
KC	2	71	5.0%
RL	3	78	7.6%
SD	4	86	3.2%
PI	5	90	11.5%
INFRA	6	97	7.4%
EF	7	103	11.4%
CLNW	8	122	5.1%
AML	9	149	3.7%
INF	10	191	5.0%
RENT	11	219	3.7%
SAV	12	249	4.9%
MM	13	254	7.4%
FLW	14	268	3.1%
UR	15	414	3.9%
SR	16	504	2.6%
CO2E	17	652	3.0%

It has become clear that the index weights do not entirely reflect the BBI rankings. For example, even though public sector corruption (CPI) has the highest weight in the index (11.5%), and it has the least variability among the other proxies meaning that it is the most important proxy for the socio-economic development of countries, the rest of the proxy rankings, i.e., Column 2, Table no. 9, are inconsistent with the index weights. For example, even though poor knowledge creation (KC) was assigned a weight of 5% utilizing the FAHP method, ranking 9th among 17 proxies according to both the FAHP weights and the expert weights, according to the BBI rankings of the 10 most highly developed countries and the correlation analysis by summation, it is the 2nd most important variable for socio-economic development. The importance of knowledge creation to socio-economic development is in-line with Romer's (1994) endogenous growth theory, which states that growth comes from within by investing in human capital. Another proxy which has been assigned lower weights but has a significant impact on the BBI rankings of the highly developed countries is the proxy of social dissension (SD) which is a measure of the absence of social cohesion. According to the correlation analysis by summation, and despite being ranked 14th among the 17 BBI proxies by both the FAHP and the expert weights, it is the 4th most important variable for socio-economic development. This finding is in accordance with the views of both Weber (1958) and Ibn Khaldūn (1967) who posit that societies who are highly connected, cohesive, and collaborative are highly developed societies. In summary, the results of the correlation by summation presented in Table no. 9 not only highlight the most important variables for socio-economic development, but they also show that not all proxies are created equally, even in the presence of weights which could favor one proxy over another.

5.5 Comparing BBI results with & without FAHP method: Is the use of FAHP justified?

The use of correlation by summation analysis and ranking proxies based on their perceived importance raises questions about the justification for integrating the FAHP method with expert weights to produce interval weights. The BBI results when expert weights were solely used in the aggregation process are presented in Table no. 10. A comparison and analysis of the BBI results with and without the application of the FAHP method could inform whether the use of the FAHP method is justified and whether the weights should be re-evaluated and the index re-aggregated.

Comparing the BBI results with and without the application of the FAHP method, i.e., expert weights were taken as is, shows very different results which are farther from reality. For example, viewing the results of the BBI given expert weights (Table no. 10), a highly developed nation such as Norway is now characterized as a developing country according to the expert weights, i.e., ranks 37th on the BBI. The same can be said for various countries such as Australia (36), Qatar (23), and Kuwait (13), the latter now being classified as an underdeveloped nation whereas under the BBI rankings with the FAHP method applied it was considered a developed nation. The aforementioned countries, and many others, are now assumed to be engaging in high levels of bad behavior according to the expert weights, whereas under the interval weights, i.e., the normalized fuzzy weights, the assumption is quite the opposite.

Table no. 10 BBI results aggregated without applying the FAHP method

Rank	Country	Rank	Country	Rank	Country
1	Angola	**31**	India	**61**	Poland
2	Sierra Leone	**32**	Nicaragua	**62**	Morocco
3	Nigeria	**33**	Mexico	**63**	Turkey
4	Mozambique	**34**	Benin	**64**	United States
5	Azerbaijan	**35**	Indonesia	**65**	Sri Lanka
6	Algeria	**36**	Australia	**66**	Bulgaria
7	Kazakhstan	**37**	Norway	**67**	United Kingdom
8	Zambia	**38**	Bahrain	**68**	Czech Republic
9	Niger	**39**	Kenya	**69**	Hungary
10	Russia	**40**	Senegal	**70**	Jordan
11	Ghana	**41**	Paraguay	**71**	Slovakia
12	Uganda	**42**	Pakistan	**72**	Greece
13	Kuwait	**43**	Peru	**73**	Finland
14	Saudi Arabia	**44**	Chile	**74**	Denmark
15	Burkina Faso	**45**	Guatemala	**75**	Portugal
16	Ecuador	**46**	Honduras	**76**	South Korea
17	Egypt	**47**	Uruguay	**77**	Austria
18	Bolivia	**48**	Serbia	**78**	Sweden
19	Laos	**49**	Nepal	**79**	Panama
20	Brazil	**50**	China	**80**	Italy
21	Colombia	**51**	Canada	**81**	Netherlands
22	South Africa	**52**	Thailand	**82**	Japan
23	Qatar	**53**	Cambodia	**83**	Spain
24	United Arab Emirates	**54**	Costa Rica	**84**	Germany
25	Vietnam	**55**	Philippines	**85**	France
26	Ivory Coast	**56**	Botswana	**86**	Belgium
27	Ukraine	**57**	El Salvador	**87**	Ireland
28	Tunisia	**58**	New Zealand	**88**	Switzerland
29	Malaysia	**59**	Dominican Republic	**89**	Singapore
30	Tanzania	**60**	Romania		

In summary, the irrational rankings of the BBI under the expert weights provides justification for the application of the FAHP method. The reason for these irrational rankings could be justified by the limitations of expert opinion which are troubled by high levels of subjectivity, inconsistency, and uncertainty. The FAHP method however, although far from being flawless itself, reduces these limitations and tends to produce weights which are more valid and reliable, especially if they are subjected to further treatment to reduce skewness, i.e., interval weights.

5.6 Is the BBI a better measure of development than the HDI?

How do the BBI rankings compare to the HDI rankings? And why does this research posit that the BBI is a better measure of development? Regarding the former, one way to compare the results of the BBI to that of the HDI is to develop a simple Ordinary Least Squares (OLS) regression model and study the relationship between the two. An alternative method is to utilize the *Mean Absolute Difference* (MAD) which is a measure of variability in a dataset, particularly the average distance between each individual data point and the mean.

The advantage of MAD over OLS is that the latter is highly sensitive to outliers. Moreover, a simple model which only includes two variables, i.e., HDI rank and BBI rank, could lead to misleading interpretations due to the likely presence of heteroscedasticity. As such, the MAD approach is utilized instead where both the BBI and HDI ranks are normalized, i.e., the BBI ranks will be inverted (BBI^{-1}) whilst the HDI ranks will be normalized for n=89, to determine the variability and possible correlation between the datasets. Regarding the latter, the MAD can be utilized as an alternative to the Pearson correlation coefficient test to study similarities in the dataset (McGraw & Wong, 1994; Gorard, 2015). The advantage of MAD over the Pearson test is that the former can be utilized when the dataset has identical statistical values, i.e., mean, standard deviation, and variance. The results of the BBI and the HDI country rank comparison are presented in Table no. 11.

Table no. 11 – BBI vs. HDI Rankings (2019)

Country	HDI	[1]Adjusted HDI	[2]Inverse BBI	[3]Diff	[4]ABS	Country	HDI	[1]Adjusted HDI	[2]Inverse BBI	[3]Diff	[4]ABS
Algeria	91	55	73	-18	18	**Italy**	30	22	22	0	0
Angola	147	78	89	-11	11	**Ivory Coast**	161	83	72	11	11
Australia	8	6	18	-12	12	**Japan**	20	17	19	-2	2
Austria	18	16	12	4	4	**Jordan**	102	58	44	14	14
Azerbaijan	88	53	60	-7	7	**Kazakhstan**	51	34	67	-33	33
Bahrain	42	30	30	0	0	**Kenya**	142	75	78	-3	3
Belgium	14	12	13	-1	1	**Kuwait**	64	42	37	5	5
Benin	157	80	71	9	9	**Laos**	136	72	79	-7	7
Bolivia	108	61	76	-15	15	**Malaysia**	63	41	31	10	10
Botswana	100	57	43	14	14	**Mexico**	75	45	51	-6	6
Brazil	84	50	75	-25	25	**Morocco**	120	66	49	17	17
Bulgaria	56	38	36	2	2	**Mozambique**	180	86	86	0	0
Burkina Faso	181	87	81	6	6	**Nepal**	141	74	85	-11	11
Cambodia	143	76	62	14	14	**Netherlands**	9	7	6	1	1
Canada	16	14	23	-9	9	**New Zealand**	15	13	14	-1	1
Chile	43	31	32	-1	1	**Nicaragua**	127	69	84	-15	15
China	85	51	41	10	10	**Niger**	188	89	82	7	7
Colombia	83	49	56	-7	7	**Nigeria**	160	82	87	-5	5
Costa Rica	62	40	42	-2	2	**Norway**	1	1	10	-9	9
Czech Republic	27	21	17	4	4	**Pakistan**	153	79	74	5	5
Denmark	10	8	4	4	4	**Panama**	57	39	26	13	13
Dominican Republic	89	54	53	1	1	**Paraguay**	103	59	63	-4	4
Ecuador	86	52	54	-2	2	**Peru**	80	48	48	0	0
Egypt	116	64	55	9	9	**Philippines**	109	62	45	17	17
El Salvador	123	67	47	20	20	**Poland**	35	25	29	-4	4
Finland	11	9	8	1	1	**Portugal**	38	26	16	10	10
France	26	20	11	9	9	**Qatar**	45	32	20	12	12
Germany	6	4	5	-1	1	**Romania**	49	33	35	-2	2
Ghana	138	73	69	4	4	**Russia**	52	35	65	-30	30
Greece	32	24	33	-9	9	**Saudi Arabia**	41	29	38	-9	9
Guatemala	126	68	58	10	10	**Senegal**	167	85	61	24	24
Honduras	131	71	64	7	7	**Serbia**	65	43	57	-14	14
Hungary	40	28	25	3	3	**Sierra Leone**	182	88	88	0	0
India	130	70	66	4	4	**Singapore**	12	10	2	8	8
Indonesia	107	60	39	21	21	**Slovakia**	39	27	27	0	0
Ireland	2	2	7	-5	5	**South Africa**	114	63	59	4	4
						South Korea	24	18	28	-10	10
						Spain	25	19	15	4	4

Country	HDI	[1]Adjusted HDI	[2]Inverse BBI	[3]Diff	[4]ABS
Sri Lanka	72	44	52	-8	8
Sweden	7	5	3	2	2
Switzerland	3	3	1	2	2
Tanzania	162	84	68	16	16
Thailand	79	47	34	13	13
Tunisia	96	56	70	-14	14
Turkey	54	36	46	-10	10
Uganda	158	81	77	4	4
Ukraine	76	46	83	-37	37
United Arab Emirates	31	23	24	-1	1
United Kingdom	13	11	9	2	2
United States	17	15	21	-6	6
Uruguay	55	37	40	-3	3
Vietnam	117	65	50	15	15
Zambia	145	77	80	-3	3

Note: [1]Adjusted HDI = Normalized HDI for n=89; [2]Inverse BBI = Inverted BBI Rank; [3]Diff = Difference; [4]ABS = Absolute Difference.

The MAD, represented by the symbol *'Δ'*, can be computed by summing the results of the absolute difference of the BBI & HDI country ranks, i.e., *'∑ABS'*; (Column 6, Table no. 11). The MAD between the two indices returns a value of 8.36, which indicates there is an average difference of 8 *positions* in the country ranks. Another way to communicate this information is transform the MAD into a percentage and quantify the variability in the rankings. This involves finding the mean of the country ranks, i.e., *'$\bar{x}$'*, and dividing the MAD by the mean, i.e., *'$\Delta/\bar{x}$'*, to compute the *Mean Relative Difference* (MRD), which is a measure of the variability of the rankings presented in percentage form. Computing the MRD presents us with a value of 18.5%, which means that the variability between the BBI and HDI country rankings is 18.5%.

Regarding the argument that the BBI is a more accurate measure of development than the HDI, this is due to the holistic nature of the BBI where 17 proxies are utilized instead of three, as well as due to the high correlation between the HDI and the GNI per capita, i.e., one of the variables utilized in the aggregation of the HDI. Repeating the same exercise for the purpose of testing to what extent the HDI and GNI per capita are highly correlated, the MAD and MRD were calculated to compare the results of the BBI and the GNI. The results indicate that the HDI and GNI are highly correlated to the extent that the variability between the BBI and the HDI and the BBI and the GNI is almost identical, i.e., given *'$\bar{x}$'* (mean) = 45, *'Δ'* (MAD) = 8.2, the Mean Relative Difference (MRD, i.e., $\Delta/\bar{x}$) = 18.2%.

The above results not only highlight the variability between the BBI and the HDI and the BBI and the GNI per capita respectively, but how significant the correlation is between the HDI and the GNI per capita. Of course, a high correlation is expected given that the GNI is one of three dimensions included in the HDI. However, the results reaffirm that the HDI is more accurately a measure of economic well-being than a measure of development.

In conclusion, the HDI has gained popularity as a measure of development due to its simplicity and ease of calculation, but its limitations are clear as it fails to capture the multifaceted nature of development factors. The BBI, on the other hand, is based on a comprehensive framework of 8 dimensions and 17 proxies, all of which are supported by both theory and literature as being essential for development. This comprehensive framework allows for a more nuanced and accurate understanding of the various factors that contribute to development disparities across nations, making it a valuable alternative to the HDI.

5.7 Results Summary

The BBI ranks countries in descending order of highest to lowest levels of bad behavior. African countries top the BBI rankings which is a result of restricting economic freedoms, political instability, corruption, and the poor application of the rule of law. All in all however, analyzing the entire dataset informs us that corruption is the most detrimental variable for development, followed by poor knowledge creation, and the poor application of the rule of law. Clustering countries by level of development informs us that Norden countries engage in the least level of bad behavior, followed by Oceanic countries. In addition, most European countries appear to perform well in the index, particularly those who are OECD members. Conversely, African and South Asia countries, i.e., Azerbaijan, India, Kazakhstan, Nepal, Pakistan, & Sri Lanka, perform poorly in the index. According to the diagnostic tests, the BBI is robust and the results are valid and reliable. However, the BBI does appear to be highly sensitive to weights, which is why a thorough weighting procedure was utilized, and an analysis of the index results with and without this procedure justify the use of expert weights and the FAHP method. In conclusion, the BBI provides a reliable and valid assessment of a country's development status from a behavioral perspective. However, to mitigate the sensitivity to weights, it is essential to employ a thorough weighting procedure, such as the expert weighting system and the FAHP method.

6. DISCUSSION

6.1 Behavior & Development

The results of the BBI provide great insight into the relationship between behavior and development. Countries that rank highest on the index, i.e., engage in the highest levels of bad behavior, are also the worlds least developed countries. One possible explanation for these findings is that such countries have a higher prevalence of corruption, which hinders their ability to achieve socio-economic development. Corruption undermines the rule of law and creates an environment in which it is difficult for businesses to operate and for people to access basic services. The absence of a stable political environment, combined with low levels of social cohesion, can also contribute to these unfavorable conditions. In contrast, countries that rank lower in the index appear to have low levels of corruption and a stringent application of the rule of law which according to theory and literature, is one of the many reasons they are considered highly developed countries. In addition, such countries appear have strong social cohesion, which helps to create a stable and supportive environment for businesses and individuals. Additionally, such countries also appear to have high levels of knowledge creation, which can drive innovation and spur economic growth. In summary, the BBI ranks countries based on their level of development hindering behavior. The results indicate that countries engaging in the highest levels of such behavior are underdeveloped, while those exhibiting the lowest levels of development hindering behavior are more highly developed.

In summary, the BBI findings highlight the importance of reducing corruption, strengthening the rule of law, promoting social cohesion, and fostering knowledge creation for promoting socio-economic development. Further research is needed to fully understand the complex relationships between these variables and to identify effective strategies for promoting socio-economic development in different countries and regions.

6.2 Other Causes of Underdevelopment

The insights yielded by the BBI are significant in explaining the reasons behind varying levels of development across nations. However, given that the BBI is limited to 17 variables, not all possible reasons have been properly explored. In addition to their engagement in behavior which hinders development, a possible cause for the poor development of countries, and a valid reason why such countries lead the BBI rankings, is due to poor generation of wealth. To elaborate, a common theme among countries at the top and bottom of the BBI is the status of their economic well-being represented by GNI per capita, i.e., most of the countries at the lower spectrum of the BBI are also one of the world's wealthiest nations, whereas most of the countries ranking at the higher spectrum of the BBI tend to be one of the world's poorest countries.

Besides wealth status, one variable that is highly cited in literature as the culprit for the poor development is colonial rule. To elaborate, Ocheni and Nwankwo (2012) posit that the backwardness of African countries can be attributed to colonialism and imperialism. Moreover, they opine that the selfish and corrupt behavior of the leaders of African countries is a consequence of such rule. This position is endorsed by Ragab (1980) who argues that colonial rule has led to "stunted institutional development". That said, the comparison provided by Lange (2004) on the contrasting development status of Botswana and Namibia, both of which were under colonial rule, prove that there is a way to move forward from a colonial past. Botswana's high development status relative to its African neighbors can be attributed to proper management of its rentier resources, where reinvestment of external rents led to tripling the countries per capita wealth and national income (Lange, 2004). The lack of such proper management in Namibia led to its poor development relative to its neighbor. In summary, the example presented of Botswana should not take away from the well-documented adverse effects of colonialism and imperialism on the fortunes of poorly developed countries that have had a colonial past, i.e., African.

Another important variable which could explain the different development levels of countries is geographical location and climate. To elaborate, Krugman (1999) finds a strong relationship between income per capita and Western European conditions, i.e., "temperate climate, absence of malaria, much of the population close to the coast or navigable rivers". Gallup *et al.* (1999) support this position opining that "location and climate have large effects on income levels and income growth through their effects on transport costs, disease burdens, and agricultural productivity, among other channels". The argument that development favors specific climate conditions is valid, as prosperous ancient civilizations were located near rivers and coasts. Moreover, geography and climate do not only impact the viability of a civilization, but it can also impact behavior as opined by Ibn Khaldun (2004). As such, favorable geographic locations and climate are indeed important for achieving high levels of development, however, this does not necessarily mean it is not possible to achieve such levels without favorable conditions. Botswana for example suffers from water scarcity due to lack of rainfall, whilst Singapore's lack of natural water sources has led to water shortages in the past. In short, even though geographic location and climate are favorable for development, it is still possible to achieve high levels of development in their absence.

To conclude, several factors may explain the differences in development across nations, some of which were not investigated in this study. For instance, factors such as cultural and religious fractionalization (Alesina *et al.*, 2003), collectivist versus individualistic societies

(Greif, 1994), illegitimate leadership (Chapra, 2008), and low levels of democracy (Olson, 1993) have also been identified as potential impediments to development. Nevertheless, this study focused on 17 proxies to develop a composite measure of bad behavior and found that corruption and corrupt behavior are the most significant impediments of development. That said, this does not take away from the validity of other hypotheses and variables as to why some nations are underdeveloped, as many factors could converge and lead to the poor development of nations. It does appear however that corruption has the most significant impact relative to these other variables – as supported by theory, literature, and the BBI findings.

6.3 Study Limitations

This research shares several limitations with studies which seek to introduce a composite index. To elaborate, since this study utilizes secondary data for the construction of the index, the proxies are limited by data availability. For example, the economic dimension of the BBI, although excludes GNI per capita, carries the highest weights. This can be explained by how most theory and literature focus on economic well-being as the primary driver of development, as well as how economic variables are easier to quantify than social, political etc. Moreover, the proxies might not truly represent the measures the researcher is attempting to quantify, which leads to the use of proxies which serve as similar alternatives. Also, some of the proxies are highly correlated, which could lead to double-counting. Furthermore, the study utilizes expert opinion in developing the index weights which are characterized by subjectivity, uncertainty, and consistency. In addition, the weights themselves are highly influential to the results of the index according to the sensitivity analysis. Another limitation of composite indices is that they often do not consider contextual factors such as historical, political, and cultural differences between countries. This can result in misleading or inaccurate comparisons. Moreover, composite indices often treat countries as homogeneous entities, ignoring internal heterogeneity and regional disparities. Overall, it is important to be mindful of these limitations when utilizing composite indices and to approach their results with a critical eye.

This research has attempted to address many of these limitations by: 1) including evidence from literature to justify the selection of the proxies; 2) improving upon the expert weights by integrating them with the FAHP method; 3) conducting uncertainty analysis which indicated that the index produces consistent outcomes; 4) arguing that highly correlation between the proxies is not always justified, as some of the correlation could be the result of a false-positive; 5) provide descriptive explanations as to why some countries are underdeveloped by discussing variables which have not been included in the index, i.e., fractionalization, colonialization, geographic location etc.

Another limitation of this study pertains to the theoretical framework of the BBI. To elaborate, the synthesized framework which provides justification for measuring the bad behavior of individuals and institutions has not been tested or replicated, as such, the study suffers from theoretical infancy. This can raise questions about the effectiveness and accuracy of the proposed framework, limiting its utility and generalizability. Moreover, a new and novel framework may lack comparability with existing frameworks or models, making it challenging to compare results or outcomes. Despite the limitations, developing a new framework can be an important step towards advancing research and knowledge on the relationship between behavior and development. Future research can test the effectiveness and accuracy of the proposed framework and replicate the BBI findings to enhance its validity and reliability.

7. CONCLUSION

Various measures have attempted to quantify socio-economic development for the purpose of cross-country comparison and policy formulation and assessment. The most popular of these measures is the Human Development Index (HDI) which ranks countries by their ability to enhance their constituents' capabilities based on the country's performance in economic, education, and health dimensions. The HDI has been criticized for its simplified definition of development and its narrow focus on economic well-being as a measure of development. Moreover, the HDI does not provide one with sufficient information as to why some countries are more developed than others due to only accounting for three dimensions in its construction.

On that regard, several authors have attempted to answer this question hypothesizing that some countries are more developed than others due to high levels of economic freedom, low levels of corruption, stable political environment, investment in human capital and innovation, among others. The forestated hypotheses have been extensively studied, many of which have developed into theories. Nevertheless, the limitation of such hypotheses is how they focus on elements external to the self and disregard the culpability of individual and institutional behavior on the poor development of nations. The reason it is essential to study the culpability of behavior on development because it serves as a precursor to the presence or absence of economic freedoms, corruption, political instability etc. Moreover, being able to define what constitutes development hindering behavior, and subsequently developing a better understanding over time as to why some people engage in bad behavior, not only allows the decision makers to reprimand such behavior but deter it as well. To facilitate for such objective, it is essential to develop a robust and empirical framework which properly defines and quantifies bad behavior within the context of development.

Properly defining the theories and the phenomena being measured is the first step in developing an index according to the composite framework of this study. The theories utilized by this study to provide justification for measuring the behavior of individuals and institutions, as well as facilitate the proxy selection process, are the concepts of 'Mafsada', i.e., societal harm, in the Maqasid of Shariah theoretical framework, i.e., purpose of Islamic jurisprudence, and Adam Smith's 'Worthless Fellow' in the Theory of Moral Sentiments (TMS) theoretical framework, i.e., the man who engages in behavior which goes against the purpose of our creation, i.e., the happiness and well-being of mankind, to quantify the development hindering behavior of individuals and institutions. Moreover, this research is influenced by the holistic framework of Ibn Khaldun on the drivers of development, leading to a construction of an index which is multidimensional, consisting of variables which are supported by theory and literature as drivers of development, and a better representation of socio-economic development relative to the HDI.

Another advantage of the BBI over the HDI is regarding the weighting system of choice. Whereas the HDI utilizes equal weights, the BBI employs an expert weighting system which has been further enhanced by the application of the FAHP method, which itself has been normalized to reduce skewness.

The results of the index indicate that countries that engage in the highest levels of development hindering behavior, i.e., bad behavior, are African countries. On the other hand, countries that engage in the lowest level of bad behavior are Norden countries. Analyzing the results of the index reveal that the most important variables for achieving high levels of socio-

economic development are low levels of corruption, high knowledge creation, stringent application of the rule of law, high levels of social cohesion, and high levels of political stability.

The main limitations of the BBI, like most indices, pertain to the high sensitivity to weights, and data limitations which influence the proxy selection process. To address this limitation, future research must attempt to replicate the index using different weighting strategies and compare the outcomes, as well as refine the proxies selected either by finding alternatives from secondary sources, or by attempting to collect data from primary sources.

The significance of this study is twofold: 1) it focuses on the culpability of behavior on development, a hypothesis which has not been well studied; 2) it attempts to synthesize a theoretical framework which provides justification for measuring the behavior of individuals and institutions.

The academic contribution and practical application of this study is in: 1) its attempt to quantify the development hindering behavior of individuals and institutions; 2) the thorough weighting system, which integrates expert opinion and the FAHP method to arrive at the index weights, i.e., the interval weights, providing researchers with an index weighting process which is more valid and reliable than the current practice of selecting equal weights; 3) the presentation of the BBI results in the form of groups and clusters, which provides higher benefit to researchers than absolute ranks as they facilitate for a better understanding as to why some countries are more developed than others, as well as providing policy makers with benchmarks and development levels to aim for; 4) the holistic nature of the index which is represented by the inclusion of 17 socio-economic variables pertaining to 8 different dimensions; 5) the application of the correlation by summation technique to identify the most important variables to achieve high levels of socio-economic development.

In closing, the ultimate goal of this study is to generate greater interest and discourse on the importance of behavior on development, and how to quantify such behavior. Future research should focus on better developing the theoretical framework, utilize primary data instead of secondary data, and attempt to replicate the study using different composite frameworks and methods.

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ANNEX

Table A-1 Supporting theories & literature for selecting the BBI proxies

IV	Supporting Theory/Lit	Findings
1	Scully (1992)	"Regarding economic, civil, and political freedom, relatively free countries are found to grow at three times the rate and are two and one-half times as efficient economically in transforming inputs into national output as countries in which freedom is relatively absent".
	Doucouliagos and Ulubasoglu (2006)	"Literature on the impact of economic freedom on economic growth and find an overall positive direct association between economic freedom and economic growth".
	Williamson and Mathers (2011)	"Economic freedom is more important than culture for growth outcomes, suggesting substitutability between the two. We posit that culture is important for growth when economic freedom is absent, diminishing in significance once economic freedom is established".
	Piątek *et al.* (2013)	"Economic freedom has a positive and significant contribution to economic growth on average both in transition and developed countries".
	Hussain and Haque (2016)	"Find strong evidence in support of a positive association between the growth rate (measured alternately with annual growth rate and five-year growth rate) and the economic freedom index".
	Brkić *et al.* (2020)	"Increases in economic freedom are related to economic growth".
	Gezer (2020)	"Economic freedom has an effect on development both in short and long run for the selected period".
2	Bae *et al.* (2021)	"Concentrated stock markets dominated by a small number of very successful firms are associated with less efficient capital allocation, sluggish initial public offering and innovation activity, and slower economic growth. "
3	Sachs and Warner (2001)	The Resource Curse Thesis (Auty, 1995) - "Countries with great natural resource wealth tend nevertheless to grow more slowly than resource-poor countries".
4	Kukaj (2018)	"Unemployment has a negative impact on the economic growth".
	Priambodo (2021)	"Unemployment and poverty negatively affect economic growth and HDI".
5	Misztal (2011)	"Increased savings may stimulate economic growth through increased investment (Bebczuk, 2000). This approach is supported by Harrod (1939), Domar (1946) and Solow (1956) growth models".
	Krieckhaus (2002)	"Public savings do matter for growth outcomes".
6	Akinsola and Odhiambo (2017)	"Inflation impacts economic growth in terms of specific thresholds (Bruno & Easterly, 1998; Vinayagathasan, 2013; Aydın *et al.*, 2016)".
	Yolanda (2017)	"Inflation on HDI is significant and positive; and Inflation on poverty is significant and positive".
7	Kusharjanto and Kim (2011)	"Improving infrastructure significantly enhances human development".
	Palei (2015)	"National competitiveness is influenced basically by the level of institutional development and other seven factors, including infrastructure, in turn infrastructure factor is determined mainly by the quality of roads, railroad infrastructure, air transport and electricity supply".
	Mohanty *et al.* (2016)	"The study establishes close linkage between infrastructure and human development".
	Apurv and Uzma (2021)	"Infrastructure enhances trade, export, foreign direct investment, and economic growth".
8	Argentiero *et al.* (2008)	"Money laundering is more volatile than aggregate GDP and it is negatively correlated with it".
	Kumar (2012)	"Money laundering has significant negative impacts on the development of a country"; as cited by Loayza *et al.* (2019).
	Hetemi *et al.* (2018)	"Money laundering has a significant and negative effect on economic growth".
	Šikman and Grujić (2021)	"There is a relation of the Anti-Money Laundering Index (AMLI) on GDP, financial market development and the HDI".
9	Mo (2001)	"1% of increase in estimated corruption level produces decrease of economy growth by 0.72%".
	Akçay (2006)	"Corruption is responsible for low economic growth, less foreign and domestic investment, high inflation, currency depreciation, low expenditures for education and health, high military expenditures, high income inequality and poverty, less tax revenue, and high child and infant mortality rates".
	Popova and Podolyakina (2014)	"The majority of researchers suppose corruption to cause immense problems to economy and society".

IV	Supporting Theory/Lit	Findings
10	Absalyamova *et al.* (2016)	"An increase in the corruption of the socio-economic system of the state by 1% caused the HCSDI (Human Capital Sustainable Development Index) to reduce by more than 1%".
	Wahyudi and Alfian (2021)	"The lower corruption level in a country, the higher the development of the quality of human life."
	Alesina *et al.* (1996)	"Political instability reduces growth".
	Yamarik and Redmon (2017)	"Greater political instability and violence can lead to more corrupt behavior along the lines of Olson's (1993) roving bandit".
	Uddin *et al.* (2017)	"Political stability is pivotal for economic growth of developing countries. Political risk is found to have detrimental effect on economic growth. Development of economic institution in developing countries affects economic growth positively".
	Rodrik *et al.* (2004)	"Consider rule of law, geography (distance from the equator), openness to trade, and colonial history as potential determinants of economic growth. They find that only rule of law explains economic growth"; as cited by Bhagat and Hubbard (2022).
11	Rigobon and Rodrik (2005)	"Democracy and the rule of law are both good for economic performance, but that the latter has a much stronger impact on incomes".
	Luong *et al.* (2020)	"Ineffectiveness of governance and rule of law, could be the main reasons for taking part in the shadow economy".
12	Weber (1958)	The Protestant Ethic - Calvinists placed the well-being of the society, and the well-being of the 'culture' over the well-being of the family. This led to a highly connected and collaborative society which further promoted economic well-being.
	Ibn Khaldūn (1967)	Theory of Development - The factors which promote or hinder development are so multi-dimensional that they include culture as well.
	Fukuyama (2001)	"Social capital is an instantiated informal norm that promotes co-operation between individuals. In the economic sphere it reduces transaction costs and in the political sphere it promotes the kind of associational life which is necessary for the success of limited government and modern democracy".
	Iyer *et al.* (2005)	"Social capital is important for economic growth and regional development".
	Romer (1994)	Endogenous Growth Theory; Development and growth are achieved due to investment in human capital, innovation, and knowledge creation.
13	Solarin and Yen (2016)	"Research output has positive impact on economic growth, irrespective of whether the sample is for developing or developed countries".
	Pinto and Teixeira (2020)	"Research output positively and significantly impacts on economic growth et al".
14	Vilariño *et al.* (2017)	"FLW negatively affects the environment, accounting for 8 % of Greenhouse emissions. It also causes direct economic costs of USD 1 trillion/year. Decreasing FLW will contribute to reducing world hunger, improve food security, and ensuring food safety and nutrition".
15	Nawaz and Alvi (2017)	"The findings confirm the importance of availability of proper nutrition and clean water to the population at large to ensure sustainable economic growth and development".
	Kong *et al.* (2020)	"Access to improved water sources is a crucial factor for a country's sustainable growth and development".
16	Shepard *et al.* (2016)	"The national cost of suicides and suicide attempts in the United States in 2013 was $58.4 billion. Lost productivity (termed indirect costs) represents most (97.1%) of this cost".
	Kinchin and Doran (2017)	"Suicide and non-fatal suicide behavior (NFSB) are significant problems faced by most countries. The present value of the economic cost of suicide and NFSB is estimated at $6.73 billion".
17	Azam *et al.* (2016)	"The ultimate impact of shrinking pollution will help in supporting sustainable economic growth and maturation as well as largely improve society welfare".
	N'Zué (2018)	"There is a tipping point beyond which increment of CO2 emissions is detrimental to per capita GDP".

Table A-2 BBI Proxies and their corresponding Maqasid of Shariah

IV	IV1: Bad Economic Behavior	Maqasid
1	Restricting Economic Freedoms	Hafth Al Mal (Wealth)
2	Monopolistic Markets	Hafth Al Din (Religion); Hafth Al Mal (Wealth); Hafth Al Nasl (Family); Hafth Al Nafs (Self)
3	Rentierism	Hafth Al Mal (Wealth); Hafth Al Nasl (Family); Hafth Al Nafs (Self)
4	Unemployment	Hafth Al Mal (Wealth); Hafth Al Nasl (Family); Hafth Al Nafs (Self)
5	Inflation	Hafth Al Mal (Wealth); Hafth Al Nasl (Family); Hafth Al Nafs (Self)
6	Poor Savings	Hafth Al Mal (Wealth); Hafth Al Nasl (Family)
7	Poor Infrastructure	Hafth Al Mal (Wealth); Hafth Al Nasl (Family)
	IV2: Corruption	
8	Money Laundry	Hafth Al Din (Religion); Hafth Al Mal (Wealth)
9	Public Sector Corruption	Hafth Al Din (Religion); Hafth Al Mal (Wealth); Hafth Al Nasl (Family); Hafth Al Nafs (Self)
	IV3: Bad Political Behavior	
10	Political Instability	Hafth Al Din (Religion); Hafth Al Nasl (Family); Hafth Al Nafs (Self)
	IV4: Poor Governance	
11	Poor Rule of Law	Hafth Al Din (Religion); Hafth Al Mal (Wealth); Hafth Al Nasl (Family); Hafth Al Nafs (Self)
	IV5: Bad Societal Behavior	
12	Social Dissension	Hafth Al Din (Religion); Hafth Al Nasl (Family); Hafth Al Nafs (Self)
	IV6: Poor Knowledge Creation	
13	Poor Academic Influence	Hafth Al Din (Religion); Hafth Al Aql (Mind)
	IV7: Preserving Health	
14	Food Loss & Waste	Hafth Al Din (Religion); Hafth Al Nasl (Family); Hafth Al Nafs (Self)
15	Poor Access to Clean Water	Hafth Al Din (Religion); Hafth Al Nasl (Family); Hafth Al Nafs (Self)
16	Suicide Rates	Hafth Al Din (Religion); Hafth Al Nasl (Family); Hafth Al Nafs (Self)
	IV8: High Environmental Footprint	
17	CO2 Emissions	Hafth Al Din (Religion); Hafth Al Nasl (Family); Hafth Al Nafs (Self)

Notes

[1] Main effects determine the impact of modifying a single input parameter while keeping all others constant, thus enabling the identification of the most influential input parameters, whereas interactions indicate the combined influence of two or more input parameters on the output, signifying the effect of adjusting several input parameters concurrently. The study's sensitivity analysis demonstrated that the BBI results are highly sensitive to weights, and the main effects are solely due to index weights. The effect of interactions between the parameters is negligible.

Instructions for authors

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Manuscripts should follow the format style of the journal. The papers should not exceed 30 pages, including figures and references. Detailed background information on the submission of papers and reviews can be found in the *Submission section*.

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The abstract will not exceed 150 words, in the Times New Roman font, 9 pts., italic, 0 cm indent. It will mention the aim of the paper, research goals and expected results. Please use a less technical language, able to provide an overview of the paper contents for people who have no special knowledge in the field.

Keywords: at most 5 (Times New Roman, 9 pts.)

JEL classification: JEL1, JEL2, Please find it at the following address: http://aeaweb.org/journal/jel_class_system.html. The codes must be written with two digits, e.g. G21, L13 (Times New Roman, 9 pts.)

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Acknowledgements

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Note(s) / Annex(es)

[1] Any notes/annexes explaining or commenting certain items in the text shall be placed at the end of the paper and NOT as footnotes (Times New Roman, 9 pts.)