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Another outlook into energy-growth nexus in Mexico for sustainable development: Accounting for the combined impact of urbanization and trade openness

Tomiwa Sunday Adebayo[1] | **Festus Victor Bekun**[2,3] | **Ilhan Ozturk**[4,5,6] | **Murat Ismet Haseki**[7]

[1]Faculty of Economics and Administrative Science, Cyprus International University, Nicosia, Turkey

[2]Faculty of Economics Administrative and Social sciences, Istanbul Gelisim University, Istanbul, Turkey

[3]Adnan Kassar School of Business, Department of Economics, Lebanese American University, Beirut, Lebanon

[4]College of Business Administration, University of Sharjah, Sharjah, UAE

[5]Faculty of Economics, Administrative and Social Sciences, Nisantasi University, Istanbul, Turkey

[6]Department of Medical Research, China Medical University Hospital, China Medical University, Taichung, Taiwan

[7]Department of Business Administration, Kozan Faculty of Business Administration, Cukurova University, Adana, Turkey

Correspondence
Ilhan Ozturk, College of Business Administration, University of Sharjah, Sharjah, UAE.
Email: iozturk@sharjah.ac.ae

Abstract

This study corroborates the importance of United Nations Sustainable Development Goal 7 (SDG-7), intended to ensure access to affordable, reliable, sustainable energy for all, and SDG-8, designed to promote decent work and sustainable economic growth. This article is motivated by the highlighted SDGs and empirically explores the long-run and causality relationship between energy consumption, urbanization, trade openness, and economic growth for annual frequency data from 1965 to 2021 for the case of Mexico. To this end, we leverage the use of fully modified ordinary least squares, dynamic ordinary least squares, and canonical regression estimation methods, while for the direction of causality, the gradual shift and wavelet coherence methods are used. According to the Autoregressive distributed lag (ARDL), the bounds test traces a long-run relationship between the outlined variables over the sampled period. Empirical evidence validates the energy-induced growth hypothesis. This result resonates with the causality analysis, where energy consumption drives economic growth one way in Mexico. This suggests that Mexico cannot embark on energy-conservative policies, as such actions will hurt economic progress. In addition, unidirectional causality is seen between urbanization, trade openness, and economic growth. These findings have far-reaching implications for economic growth and macroeconomic indicators in Mexico. More insights are highlighted in the concluding section.

KEYWORDS
energy-led growth hypothesis, Mexico, sustainable growth, trade openness, urban population

1 | INTRODUCTION

The four vital factors for economic development are energy, technology, capital, and labor (Kraft & Kraft, 1978). The demand for primary energy, which is true for both advanced and developing economies including Mexico, will continue to rise (approximately 1.4% per year until 2035) (EIA, 2020). Energy is a major contributor to the transport, distribution, and production of almost all services and goods (Energy Information Administration [EIA], 2019). In the context of macroeconomics, although urbanization leads to specialization in the economy, acceleration and industrialization of economic development rely on both industrial and residential energy use. Urbanization and economic growth are positively connected. This is because although urbanization allows for a change in the system of production from the agriculture sector to the manufacturing and industrial sectors, it also shows a movement towards a production structure that is technology-oriented. This contributes to an acceleration in the energy consumption. In this sense, economic change and growth phenomena produce both urbanization and a structure in which energy demand rises because of the consumption and output structure to which urbanization contributes. For this reason, we investigated whether they have this framework.

The gross domestic product (GDP) growth rate in Mexico in 2018 was 2.2%. It is less than the 2.9% US growth rate but higher than the 2.1% rate in Canada. Mexico is the world's 12th biggest exporter. In 2017, the United States earned 79% of Mexico's exports. Because of the growth of the economy and urbanization, primary energy demand in Mexico has risen by 25% since 2000 (International Energy Agency [IEA], 2019). The primary energy balance is subjugated by fossil fuels. In the last two decades, they have accounted for approximately 90% of primary energy production. Over the last decade, there has been a shift from oil to natural gas, primarily in power production. Mexico's main energy consumer is the transportation industry. Recently, Mexico's share of the world's primary energy consumption has increased significantly. According to BP (2020), Mexico's share of primary energy consumption increased from 0.68% to 1.48%. Mexico is one of the world's leading suppliers of other liquids and petroleum, and it is ranked the fourth position behind the Americas behind the United States, Canada, and Brazil (EIA, 2019). Figure 1 shows the total energy consumption in Mexico by fuel in 2019 which comprises petroleum and other liquids (43%), natural gas (42%), coal (7%), renewables (7%), hydroelectricity (3%), and nuclear energy (1%). The quantification and understanding of the energy-growth interconnection have insightful consequences for the policymaker to propose planning for efficient energy consumption.

Over the years, the discussion on the association between energy consumption, urbanization, and economic growth has been on the rise, and accessible empirical research has struggled to offer a reliable answer. For instance, the groundbreaking study of Kraft and Kraft (1978) showed that the Conversation theory was backed by one-way causality from GDP growth to energy use in the United States between 1947 and 1974. In contrast, there is no proof of causality in the study of Yu and Hwang (1984) using the same methods. The ambiguity and contradictions of earlier research have been verified by several studies. For instance, the study of Nathaniel and Bekun (2021) established a negative link between urbanization and GDP growth in Nigeria while the study of Talbi et al. (2022) for Tunisia and Zheng and Walsh (2019) for China found a negative association between urbanization and economic growth. In the study of Kirikkaleli, Adebayo, Khan et al. (2021), there is evidence positive link between GDP growth and energy use.

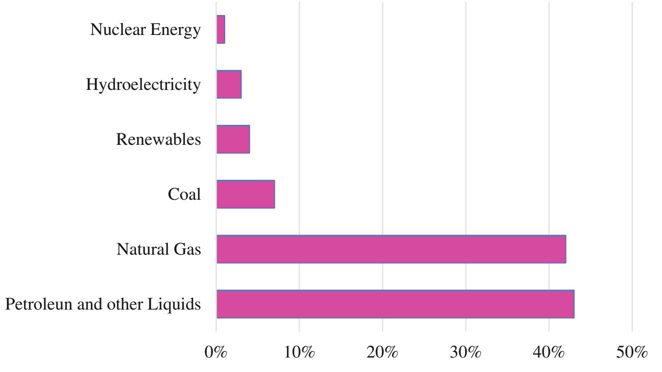


FIGURE 1 Total energy consumption in Mexico by fuel 2019. BP statistical review, 2020

Therefore, it is evident that the debate on the nexus between urbanization, energy use, and economic growth is contentious and still requires further research, especially for emerging economies like Mexico, which is currently experiencing rapid urbanization, expansion in exports, and aggressive use of energy to spur economic growth.

For instance, Mexico's per capita CO_2 emissions are rapidly increasing, surpassing the world's total per capita CO_2 emissions. In addition, Mexico is among the world's top biggest exporters, and due to the current increase in urbanization, and economic growth in the country, the primary energy demand in Mexico has risen by 25% since 2000 (IEA, 2019). Thus, it is imperative to examine the association between urbanization, energy use, trade, and economic growth. Most importantly, the need for sustainable development characterized by environmental conservation has intensified globally. This is eminent in the implementation of the United Nations Sustainable Development Goals (particularly, SDG-7 and SDG-8) and the 2022 Climate Change Conference (COP 27) which are targeted at taking action towards the collective achievement of the climate change goals globally.

Therefore, this study aims to evaluate the causal effect and long-run nexus between energy use, urbanization, and economic growth in Mexico. It also examines the role of trade openness in shaping economic growth in Mexico. The novelty of this study lies in the use of the most appropriate state-of-the-art techniques to capture the causal nexus between the variables. This study provides interesting insights for the formulation and implementation of sustainable energy-saving and environmentally friendly policies, which will help minimize the high per capita CO_2 emissions in Mexico. Thus, the current study analyzes the causal/long-run effects of energy use and urbanization on economic growth and examines the role of trade openness. The present paper adds to the extant studies in the following ways; (i), we utilized the Zivot and Andrews (ZA) unit root test to capture stationarity attributes and break in series; (ii) The study utilizes the ARDL bounds tests with Kripfganz and Schneider (2018) approximations to capture long-run cointegration among the series; (iii) The full modified ordinary least square (FMOLS), dynamic ordinary least squares (DOLS), and canonical regression (CCR) long-run estimators are used to catch the long-run association; (iv) the study employed the wavelet coherence test to capture the correlation and causality between series. The novelty of the wavelet technique is that it can capture causality and correlation simultaneously between series at various frequencies and periods, and (v) we used a gradual shift causality test to capture causal interaction between the series in the presence of structural breaks. Thus, this study contributes to the literature in terms of scope in the case of Mexico, which has received fewer entries in the extant literature. Second, we contribute to the literature in terms of the methods used. Research on this nature is timely and worthy, given the quest for energy for SDGs among other macroeconomic growth drivers.

The next section entails a summary of past studies ad theoretical framework which is followed by Section 3 “Methodology”. Section 4 confers the outcomes and Section 5 concludes and suggests policy recommendations.

2 | LITERATURE REVIEW

This section of the paper is divided into two distinct parts: (a) an empirical review, which discusses prior studies conducted on the interconnection between energy growth, urbanization, trade openness, and urbanization, and (b) a theoretical review, which discusses the theoretical framework of the research.

2.1 | Empirical review

In recent years, numerous research on the interconnection among urbanization, energy usage, trade openness, and GDP growth shave been conducted (Appiah et al., 2022; Bulut et al., 2022; Cetin et al., 2018; Cetin & Seker, 2012; Kirikkaleli, Adedoyin & Bekun, 2021; Magazzino, 2016; Magazzino, 2017; Magazzino et al., 2020; Seker et al., 2015; Wang et al., 2022). However, in the empirical literature on energy economics, the discussion is still intense as to whether economic growth precedes energy consumption or vice versa. The seminal studies of Kraft and Kraft (1978) first scrutinize this connection, where they explored the causal nexus between energy usage and economic growth in the United States. The Kraft and Kraft research was an analysis for several studies (Khan & Hou, 2021a; Khan & Hou, 2021b; Khan & Hou, 2021c; Kurniawan & Managi, 2018; Nathaniel & Bekun, 2021; Ozturk, 2010; Tang et al., 2016; Tawiah et al., 2021).

2.1.1 | Energy consumption and economic growth

The study of Nathaniel and Bekun (2021) found that electricity use influences economic growth positively. Surprisingly, urbanization exerts an opposite effect on GDP. Furthermore, there is a two-way causality between electricity consumption and GDP in the long run. Further, Nathaniel (2020) examined the linkage between energy consumption and economic growth in Indonesia between 1971 and 2014. The empirical results show that urban population and energy use deteriorate the quality of the environment. In addition, economic growth and energy use Granger-cause the ecological footprint. In Nigeria, Ali et al. (2020), utilizes the FMOLS, DOLS, and CCR techniques to investigate the association between electricity consumption, economic growth, and urbanization. The outcomes of this study revealed a positive association between electricity usage and economic growth in Nigeria. Using a panel of 65 BRI nations between 1981 and 2016, Rauf et al. (2020) explores the link between energy consumption and economic growth, and findings show that energy utilization exerts a positive impact on economic growth. The study of Bekun & Agboola (2019) on the interaction between electricity consumption and economic growth revealed a long-run association between the economic variables. Furthermore, the outcomes of FMOLS and DOLS reveal that electricity consumption exerts a positive impact on economic growth which validates the electricity-induced growth hypothesis. Furthermore, there is evidence of unidirectional causality from electricity usage to economic growth as revealed by the Toda-Yamamoto causality test.

Using data between 1997 and 2015 from 16 EU nations, Adedoyin et al. (2020) explored the nexus between economic growth and renewable and non-renewable energy using recent panel techniques. Moreover, there is a negative association between research and development and economic growth in the short run. Furthermore, energy use exerts a positive impact on economic growth, and there is evidence of two-way causality between economic growth and energy use. The study of Kose et al. (2020) on the interconnection between economic growth, and renewable energy in the EU between 1997 and 2014 uncovered that renewable energy and non-renewable energy exert a positive impact on economic growth. In addition, renewable energy Granger causes economic growth. The study by Elfaki et al. (2020) in Sudan established a positive association between electricity consumption and economic growth. Moreover, trade openness positively affects economic growth. The reason for this outcome is that participation in international trade provides opportunities for the Sudanese economy to profit from the comparative advantage of exporting goods with a comparative advantage in Sudan, as well as importing new technology, in specific industrial machinery linked to agriculture and industrial sectors, to boost economic growth. Magazzino (2012) also identified energy production as an important driver of economic growth in Italy.

2.1.2 | Economic growth and urbanization

Solarin and Shahbaz (2013) examined the impact of urbanization on economic development in Angola between 1971 and 2009. The investigators used Gregory–Hansen structural break cointegration and VECM Granger causality tests to assess this association and the findings showed bidirectional causality between urbanization and economic development. Using cross-country panel data from the period 1960–1990, Bertinelli and Strobl (2007) investigated the impact of urbanization on GDP growth and the findings show that urbanization drives economic growth. Faisal et al. (2018), explored the linkage between economic growth, and urbanization in Iceland using data stretching from 1965 and 2013. The investigators utilized the ARDL approach and the outcomes of how that urbanization triggered economic growth in the long run. Liu et al. (2015) assessed the interconnection between real growth and urbanization in China across different regions using the Granger causality test. The empirical outcomes show that urbanization Granger causes economic growth, whereas economic growth does not Granger cause urbanization. The research of Shahbaz et al. (2015) in Malaysia revealed that urban population and energy use are positively connected. Moreover, the Granger causality test unveils two-way causality between urban population and energy use. In China, Zheng and Walsh (2019) scrutinize the interconnection between GDP, urbanization, and energy consumption. The empirical outcomes show that urbanization significantly influences economic growth positively. Moreover, there is evidence of a U-shaped association between economic growth and urbanization. In Tunisia, between 1980 and 2018, Talbi et al. (2022) analyzed the connection between urbanization, renewable energy demand, and GDP growth. The empirical results show that urbanization has a positive impact on renewable energy demand. Awosusi et al. (2021) examined the impact of urbanization on economic growth in Japan using data stretching between 1970 and 2018. The investigators utilized the wavelet coherence test, and the findings showed that urbanization has a positive impact on the economic growth of Japan, which implies that an increase in globalization and urbanization caused economic growth in Japan.

2.1.3 | Trade openness and economic growth

Over the years, several studies (Alam & Sumon, 2020; Amna Intisar et al., 2020; Awokuse, 2008; Hye & Lau, 2015; Keho, 2017; Ulaşan, 2015) have been conducted regarding the relationship between trade openness and economic growth. However, their findings are mixed. For instance, using selected South American countries, the study of Awokuse (2008) revealed trade openness to enhance economic growth. Likewise, Huchet-Bourdon et al. (2018) explored the association between real growth and trade openness in 169 countries using data between 1988 and 2014. The investigators used a GMM estimator to establish this association, and the results revealed that trade openness has a positive impact on economic growth in high-exporting nations. Furthermore, the study of Hye and Lau (2015) on the linkage between trade and real growth in India between 1971 and 2009 revealed that trade openness decrease economic growth. Similarly, the study of Amna Intisar et al. (2020) also affirms the negative association between trade openness and economic growth. In China, Kong et al. (2021) examined the linkage between real growth and trade openness by using data from the period 1994 to2018 and the ARDL approach. The empirical results show that trade openness improves economic growth. The study by Alam and Sumon (2020) on the linkage between real growth and trade openness and ngfinding shows that the impact of trade openness on economic growth is found to be positive as well as two-way causality between economic growth and trade openness. Using cross-country growth regression, Ulaşan (2015) assessed the impact of trade openness on the economy using GMM and the findings show that trade openness does not exert a significant impact on economic expansion. Keho (2017) examined the linkage between trade openness and real growth in Cote d'Ivoire using data from the period 1965–2014. The investigator utilized ARDL and Toda and Yamamoto Granger causality tests to investigate this association and the findings show that trade openness exerts a positive impact on GDP growth which implies that an increase in trade openness is accompanied by an increase in economic growth. Moreover, the study of Ozatac et al. (2017) in Turkey on the nexus between trade and economic growth shows a long-run association among the variables. In addition, there is evidence of a one-way causal link between economic growth and trade openness.

Other determinants of economic growth have also been identified in literature. The factors include employment/unemployment (Cetin et al., 2015), education (Cetin & Dogan, 2015), health and health expenditure (Beylik et al., 2022; Çetin & Ecevit, 2010), government size (Cetin, 2017), information technology (Magazzino et al., 2021) among others.

Despite the plethora of studies reviewed, there is no precise direction of relationship or consensus on the interaction between energy consumption, trade openness, and economic growth. Furthermore, studies have used time-domain techniques, such as ARDL, FMOLS, CCRS, PMG-ARDL, and VECM, which might concede information. Thus, this study utilized a novel wavelet coherence test. The advantage of wavelet coherence tests is that they can capture the correlation and causality between the variables of interest at different frequencies and periods. Furthermore, this study utilized gradual shift causality tests as a robustness check for the wavelet coherence test. Unlike the conventional Granger and Toda Yamamoto causality tests, the Gradual shift causality test can capture causality between series in the presence of structural break(s).

2.2 | Theoretical framework

The purist of economic development by government officials in a variety of regions, country(s), and blocs in the literature has become a topic of discussion. To this end, four main factors have been described as stimuli for economic development: technology, labor, energy, and capital investment. The affirmation is supported by the classic growth paradigm of Solow (1988), where money, technological innovation, and labor are seen as the main engine of economic growth. The proposal is backed by the previous report (see Lucas, 2000; Sato, 1964). Nonetheless, since the related research of Kraft and Kraft (1978), primary energy use has led to economic development in the USA. This is in line with the energy-induced growth hypothesis, in which energy is an important contributor to both advanced and emerging economies' economic growth (EIA, 2018). Understanding and quantifying the energy-growth connection has crucial consequences for policymakers to advance adequate planning for productive energy use. In the context of Mexico's economies, macro-economic dynamics occur via channels of electricity access regulations, the human development index, trade, and property rights. Over the decades, the literature has seen many implications for higher income levels. For example, the seminal research by Simon Kuznets (1955) showed that higher income growth increased the income inequality disparity to a particular level and then declined. It is on this ground that this current research leverage the energy-induce growth hypothesis for theoretical backing to explore the causality relationship between energy, urbanization, trade openness, and economic growth for the case of Mexico. This study leverages the novel wavelet coherence test with the Gradual shift causality test for soundness of empirical analysis. The chosen techniques are superior to the conventional Granger causality analysis. The outcome from the causality analysis will come in handy to craft policy direction on the direction of predictability flow of the outlined variables under review.

3 | DATA, MODEL, AND METHODOLOGY

3.1 | Data

This study explores the drivers of economic growth in Mexico. The dependent variable is economic growth (GDP) while the independent variables are urbanization (URB), trade openness (TO), and primary energy consumption (EN).

Table 1 presents a clear information of the variables description, units and sources. Subsequently, the basic summary statistical properties that report the measure of central tendencies and dispersion outlined in Table 2 show that urbanization has the highest average, followed by energy consumption, and the least trade openness. All series show negative skewness with a light tail as reported by the Kurtosis which is less than three for all examined series. Subsequently, we proceed to explore the unit root features of the series under analysis. Figure 2a,b also provide information on the variables of investigation.

3.2 | Specification of model

This study explored the energy-growth nexus in Mexico, which is one of the most urbanized countries in the world. This current study is built on the works of Ali et al. (2020), Bekun and Agboola, (2019) to analyze the long-run/causal impact of energy usage, trade openness, and urbanization on economic growth. The data used in this empirical analysis span between 1965 and 2021. The study's economic function and econometric model is depicted in Equation (1) and (2) respectively. Table 1 depicts the data description.

$$\mathrm{LnGDP} = f(\mathrm{LnEN}, \mathrm{LnURB}, \mathrm{LnTO}) \tag{1}$$

$$\mathrm{LnGDP} = \vartheta_0 + \vartheta_1 \mathrm{LnEN}_t + \vartheta_2 \mathrm{LnURB}_t + \vartheta_3 \mathrm{LnTO}_t + \varepsilon_t \tag{2}$$

In Equation (1), GDP, EN, URB, and TO illustrate economic growth, energy usage, urbanization, and trade openness. Furthermore, $\vartheta_{1......3}$ depicts the coefficients of the regressors while ε_t is the error term.

The reason for incorporating the independent variables in the model is explained as follows. First, we incorporate energy usage into the framework in line with the study of Udembe et al. (2020). Energy use is expected to have

TABLE 1 Variables units and sources.

Variable	Description	Units	Sources
GDP	Economic growth	GDP per capita constant $US, 2015	WDI, (2021)
TO	Trade openness	Trade % of GDP	
URB	Urbanization	Urban population	
EN	Energy consumption	Primary energy consumption (TWh)	BP, (2021)

TABLE 2 Descriptive statistics.

	LnGDP	LnEN	LnTO	LnURB
Mean	8.9482	7.0435	3.5882	17.878
Median	8.9809	7.2096	3.6511	17.957
Maximum	9.2223	7.6977	4.4262	18.446
Minimum	8.4572	5.6812	2.7648	16.971
Std. Dev.	0.2068	0.6032	0.5413	0.4262
Skewness	−0.8211	−0.8721	−0.1345	−0.5153
Kurtosis	2.7080	2.5781	1.5985	2.1473
Jarque-Bera	6.6073	7.6490	4.8362	4.2498
Probability	0.0367	0.0218	0.0890	0.1194

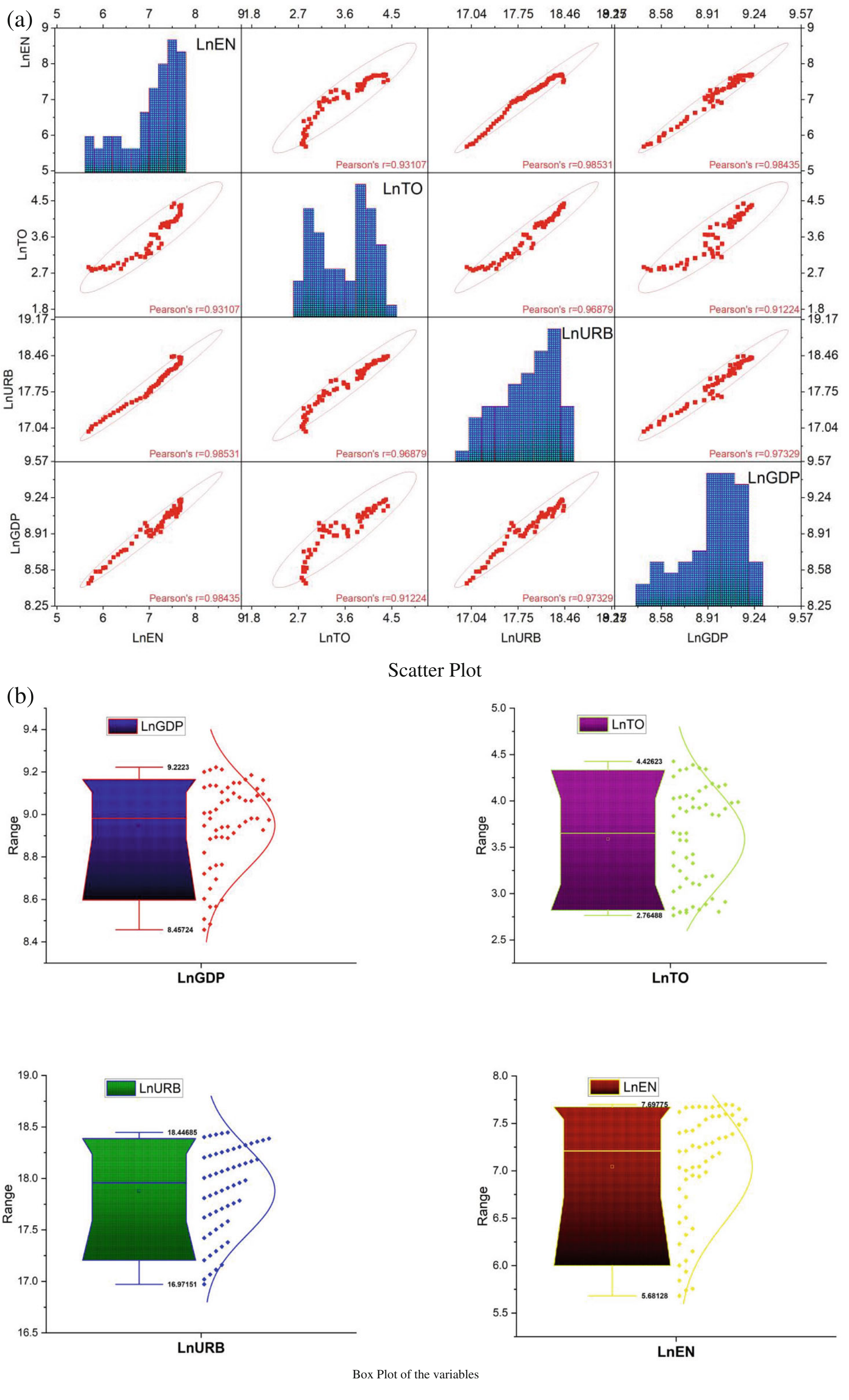


FIGURE 2 (a) Scatter plot and (b) box plot of the variables.

a positive impact on economic growth. Thus, an increase in energy use would increase GDP, that is, $\left(\vartheta_1 = \frac{\partial GDP}{\partial EN} > 0\right)$. In line with the study of Alam et al. (2007), the current paper introduced urbanization into the model. Urbanization is anticipated to have a positive impact on economic growth. Hence, a rise in urban population will enhance growth in the economy that is, $\left(\vartheta_2 = \frac{\partial GDP}{\partial URB} > 0\right)$ otherwise $\left(\vartheta_2 = \frac{\partial GDP}{\partial URB} < 0\right)$. Trade openness was incorporated into the model in line with the studies of Alam & Sumon, (2020), Kong et al. (2020), Raghutla, (2020), and Dritsaki & Dritsaki, (2020). The association between trade openness and GDP is anticipated to be positive that is, $\left(\vartheta_3 = \frac{\partial GDP}{\partial TO} > 0\right)$ otherwise $\left(\vartheta_3 = \frac{\partial GDP}{\partial TO} < 0\right)$.

3.3 | Techniques employed

3.3.1 | Stationarity tests

It is imperative to investigate the stationarity features of the series before conducting further analyses. Thus, this study utilized conventional unit root tests (ADF and PP). Sensitivity to serial correlation in error terms and heteroscedasticity is the main distinction between ADF and PP tests. The Equations of ADF and PP are illustrated below;

ADF test:

$$\Delta Y_t = \beta' D_t + \pi Y_{t-1} + \sum_{j-1}^{p} \sigma_j \Delta Y_{t-j} + \varepsilon_t \tag{3}$$

whereby D_t depicts the deterministic term vector while the error term is represented by ε_t.

PP test:

$$\Delta Y_t = \beta' D_t + \pi Y_{t-1} + \mu_t \tag{4}$$

The serial correlation and heteroscedasticity in the error terms are disregarded in the PP test.

As stated by Alola et al. (2019), the conventional unit-root tests may present disingenuous outcomes if there is evidence of structural break(s) in series. Based on this, the present study utilized Zivot & Andrews (ZA) unit root test introduced by Zivot and Andrews (2002) to capture both stationarity features and a single break in series. The Equation of ZA is illustrated as follows:

$$\text{Model 1}: \Delta x_t = \varphi + \varphi x_{t-1} + \pi t + \delta DU_t + \sum_{j=1}^{k} d_j \Delta x_{t-j} + \mu_t, \tag{5}$$

$$\text{Model 2}: \Delta x_t = \varphi + \varphi x_{t-1} + \pi t + \gamma DT_t + \sum_{j=1}^{k} d_j \Delta x_{t-j} + \mu_t, \tag{6}$$

$$\text{Model 3}: \Delta x_t = \beta + \beta x_{t-1} + \beta t + \theta DU_t + \theta DT_t + \sum_{j=1}^{k} d_j \Delta x_{t-j} + \mu_t \tag{7}$$

where DU_t depict dummy variable for mean shift occurring at each possible break-date (TB) while DT_t is the respective trend shift variable. Formally,

$$\mathrm{DU}_t = \begin{cases} 1.....if & t > \mathrm{TB} \\ 0.....if & t < \mathrm{TB} \end{cases} \text{ and } \mathrm{DU}_t = \begin{cases} t - \mathrm{TB}.... \text{if} & t > \mathrm{TB} \\ 0..... \text{if} & t < \mathrm{TB} \end{cases} \tag{8}$$

3.3.2 | ARDL bounds test

Auto-Regressive Distribution Lag Model (ARDL) developed by Pesaran and Shin (1995) and Pesaran et al. (2001) was been used to capture the long-run cointegration association between the dependent and independent variables. Benefits of the ARDL bounds test over the other conventional or traditional cointegration techniques areas: (i) it can be used when there is a mixed order of integration; (ii) it incorporates both the short and long-run coefficients simultaneously; (iii) it is perfectly fit for small sample size (Narayan and Narayan, 2004); (iv) accommodating different lag length; (v) autocorrelation problem is removed. The calculated F-statistics were compared with the lower- and upper-bound critical values. When the calculated F-statistics are below, the null hypothesis is not rejected; when the calculated F-statistics are greater, the null hypothesis is rejected, showing evidence of a long-run relationship among the variables. The Equation (9) below explains the ARDL bounds model;

$$\Delta \mathrm{GDP}_t = \theta_0 + \sum_{i=1}^{t} \theta_1 \Delta \mathrm{GDP}_{t-i} + \sum_{i=1}^{t} \theta_2 \Delta \mathrm{TO}_{t-i} + \sum_{i=1}^{t} \theta_3 \Delta \mathrm{URB}_{t-i} + \beta_1 \mathrm{GDP}_{t-1} + \beta_2 \mathrm{TO}_{t-1} + \beta_3 \mathrm{URB}_{t-1} + \varepsilon_t \tag{9}$$

The null hypothesis and the alternative hypotheses are no co-integration and evidence of co-integration, respectively. We fail to accept the null hypothesis if the F-statistics is more than the lower and upper bond critical values. The alternative and null hypotheses are illustrated by Equations (10) and (11) correspondingly;

$$H_0 = \vartheta_1 = \vartheta_2 = \vartheta_3 = \vartheta_4 \tag{10}$$

$$H_a \neq \vartheta_1 \neq \vartheta_2 \neq \vartheta_3 \neq \vartheta_4 \tag{11}$$

Where H_0 denotes the null hypothesis and H_a illustrates the alternative hypothesis.

The study utilizes the criteria of Kripfganz and Schneider (2018) which requires the generated T-statistics and F-statistics to be higher than the corresponding upper critical values, an essential requirement for deciding on cointegration, unlike the prior decision-making criteria that demand the F-statistic higher than the upper critical values for cointegration. In addition, the *p*-values produced should be below the target level.

3.3.3 | Long-run estimators (FMOLS, DOLS, and CCR)

This study utilized FMOLS, DOLS, and CCR long-run estimators to capture the long-run linkage between GDP and its regressors. Although several methods can be used to capture the long-run interaction between parameters, FMOLS, DOLS, and CCR techniques were used in this empirical analysis. These techniques enable asymptotic coherence to be collected by considering the serial correlation effect. In addition to these techniques, it is essential to establish a cointegration among the series. Therefore, long-term elasticity with FMOLS and DOLS estimators was calculated in this study. The FMOLS estimator is depicted by Equation (12) as follows;

$$GDP_t = \vartheta_0 + \vartheta_1 EN_t + \vartheta_2 URB_t + \vartheta_3 TO_t + \sum_{i=q}^{q} \beta_1 \Delta EN_{t-i} + \sum_{i=q}^{q} \beta_2 \Delta URB_{t-i} + \sum_{i=q}^{q} \beta_3 \Delta TO_{t-i} + \varepsilon_t \tag{12}$$

Where the lag order is depicted by utilizing SIC and the time trend is illustrated by t. FMOLS has the benefit of addressing the issue of endogeneity, auto-regression, and also the bias arising from the prejudice of the sample (Narayan & Narayan, 2005).

3.3.4 | Wavelet approach

The wavelet approach is utilized in the current research to gather information about the time-frequency dependency between economic growth (GDP) and urbanization (URB), energy use (EU), and trade openness (TO) in Mexico. Goupillaud et al. (1984) initiated the Morlet family. It is commonly accepted that when time series variables are estimated and they are not stationary, the result will yield bias estimates if the conventional time-domain method is not employed. In addition, in the field of economics and finance, time-series data are prone to break (s); hence conventional causality test outcomes with parameters fixed are susceptible to surface (Kirakilali and Adebayo, 2020). In contrast to time-domain causality, the standalone frequency domain method, also known as the Fourier transform, is a major concern. Therefore, to eliminate these issues in the estimations, the wavelet coherence technique was utilized in this study. Moreover, the wavelet coherence test is that it can capture both causality and correlation simultaneously.

3.3.5 | Gradual shift causality test

Toda and Yamamoto (TY) (1995) established a framework, which is anchored on vector autoregressive (VAR) built by Sims (1980). In calculating the optimal lag length, $p + d_{max}$ is added to the lag of d_{max}, which is ascertained by the series maximum order of integration in the VAR framework. However, ignoring the structural shifts can cause the VAR model to be unreliable and contradictory (Enders & Jones, 2016; Figueiredo et al., 2012). For this reason, to examine the causal linkage between economic growth, trade openness, urbanization, and energy consumption. Nazlioglu et al., (2016) developed the Fourier-TY causality test, which captures the structural shifts in Granger causality analysis and includes the gradual and smooth shift. It can also be called the "gradual-shift causality test". The Fourier Granger causality test was developed using a single frequency (SF) and cumulative frequencies (CF) respectively, known as Fourier approximation. By adding the TY-VAR analysis and Fourier approximation, the modified Wald test statistic (MWALT) is generated. Unlike the traditional causality tests, the Gradual shift can capture causality in the presence of structural break(s). Here, the testing of the null hypothesis of non-causality is zero (H_0: $\beta_1 = \beta_\theta = 0$), the Wald statistic can be used for testing the hypothesis.

4 | FINDINGS AND DISCUSSION

4.1 | Pre-estimation results

This section of this study presents a discussion of the results in a stylized manner. Table 3 outlined the traditional unit root test of ADF and PP that shows stationarity at first difference. Zivot-Andrews unit root test is conducted in Table 4 to reinforce the unit root results which affirm unit root properties.

4.2 | Bounds test result

This research proceeds to explore the long-run equilibrium interaction between the study parameters as reported by the ARDL bounds testing in Table 5 in conjunction with the Kripfganz and Schneider (2018) critical and *p*-values which both confirm cointegration among the variable under review. The bounds test confirmed the long-run association between these indicators. This indicates that the explanatory variable converges with the dependent variables. To affirm the robustness of this study we conducted a serial correlation test, normality test, and Ramsey test for model specification as reported in the button of Table 5. While Figure 3a,b shows the residual diagnostic test of CUSUM and CUSUMsq, which shows the fitted model is stable as it falls within the 5% confidence interval threshold. This study satisfactorily passed all outlined tests. Indicating that the fitted models are robust and suitable for crafting policy direction.

TABLE 3 Conventional unit root test.

	ADF		PP	
	I(0)	I(1)	I(0)	I(1)
LnGDP	−2.579	−4.573*	−2.391	−6.047*
LnEN	−0.961	−5.141*	−1.019	−6.141*
LnTO	−1.374	−4.482*	−1.427	−11.25*
LnURB	−1.382	−3.6515*	−1.370*	−0.344*

Note: Significance level of 1%, 5% and 10% is depicted by *,** and ***.

TABLE 4 ZA unit root test.

	At level I(0)		First difference I(1)	
	Intercept & Trend	Break-date	Intercept & Trend	Break-date
LnGDP	−4.534	1983	−7.570*	1982
LnEN	−3.180	1978	−8.385*	1985
LnTO	4.127	1987	−7.570*	1982
LnURB	−4.037	2005	−5.412*	1988

Note: Significance level of 1%, 5% and 10% is depicted by * and **.

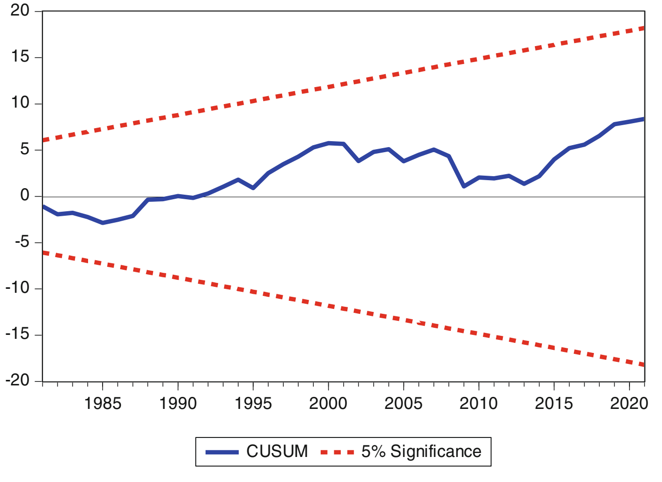
TABLE 5 Bound test.

Model	F-statistics		T-statistics	χ2 ARCH	χ2 RESET	χ2 normality	χ2 LM
	6.347*		−5.830*	0.568 (0.84)	0.604 (0.44)	0.173 (0.906)	0.391 (0.67)
Kripfganz and Schneider (2018) critical and *p*-values							
	10%		5%		1%		PV
F-statistics	2.204	3.320	2.615	3.891	3.572	5.112	0.00
T-Statistics	−2.495	−3.798	−2.843	−4.207	−3.54	−5.021	0.00

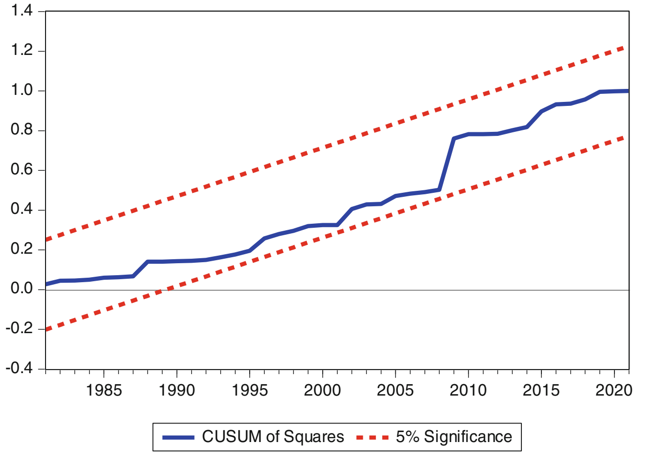
Note: * represents a 1% level of significance and PV denotes the probability value that both F-stat and T-stat are greater than critical values.

4.3 | Long-run estimators (FMOLS, DOLS and CCR) results

This study explores the magnitude of this long-run relationship. We applied a battery of analyses for soundness of coefficients and estimations Table 6 outlined the FMOLS, DOLS, and CCR with the dependent variable as GDP growth while TO, URB and EC as explanatory variables. We observe that energy consumption enhances economic growth, as we observe that a 1 % increase in energy consumption increases economic growth by a magnitude of 0.280%, 0.340%, and 0.272% by the FMOLS, DOLS, and CCR estimators, respectively. This outcome gives credence to the energy-induce growth hypothesis which resonates with the study of Ali et al. (2020) for the Nigerian and also in Pakistan by Shahbaz et al. (2012). This outcome implies that the Mexican economy is energy-driven and cannot embark on energy-conservation strategies, as such actions will compromise economic growth. Furthermore, urbanization influences economic growth in Mexico, as reported by all regression estimators, which is in agreement with the positive relationship between GDP growth and urbanization. We see that a 1% increase in urbanization increases GDP growth by 0.280%, 0.340%, and 0.272%, as outlined by the FMOLS, DOLS, and CCR, respectively. We make the claim based on the empirical revelation that the teaming growing population in Mexico is productive to her



(a) CUSUM



(b) CUSUM of Square

FIGURE 3 (a) CUSUM and (b) CUSUM of square.

TABLE 6 Long-run estimators.

Variable	FMOLS			DOLS			CCR		
	Coefficient	t-stat	Prob.	Coefficient	t-stat	Prob.	Coefficient	t-stat	Prob.
LnEN	0.280**	2.347	0.023	0.3395**	2.610	0.0119	0.272**	2.272	0.027
LnTO	−0.054	−0.629	0.531	−0.060	−0.681	0.4985	−0.055	−0.654	0.515
LnURB	0.374**	2.151	0.036	0.3234***	1.779	0.0812	0.382**	2.215	0.031
R2	0.95			0.96			0.94		
Adj-R2	0.94			0.95			0.93		
S.E.	0.018			0.017			0.018		

Note: ** and *** depict significance level of 5% and 10%.

economic trajectory. However, there is a need for caution for policymakers when matching urban infrastructure and amenities in rural areas. This is to avoid rush to urban cities, given that most government officials develop urban areas more than rural areas. Otherwise, the urban infrastructure might be overwhelmed and impede economic growth in the long run. In addition, government officials need to encourage public-private partnerships (PPP) in terms of building infrastructure in less urbanized regions to balance the infrastructural deficit in both rural and urban areas. This alludes to the fact that small and medium enterprises (SMEs) are a key driver of any economy which will have a ripple effect on the pace of other macroeconomic indicators and economic development at large. On the relationship between trade openness and GDP growth, we observe an inverse relationship. This suggests that trade in Mexico has dampened the effect on economic growth suggesting that the openness of the Mexican economy to the outside world does not promote economic progress. This study aligns with the finding of Hossain (2012) in Japan. Thus, policymakers need to insulate the economy against detrimental economic impacts. This further explains the nature of the trade pattern between Mexico and the rest of the world due to Mexico's economic structure and size. That is, the trade deficit in Mexico might explain the negative effect nexus between economic growth and trade openness, which has infant industries and might be at threat given the exposure to external trade with the rest of the world. This alludes to the fact that the small infant industry is a key driver of economic activities in developing economies like Mexico.

4.4 | Gradual shift causality results

In Table 7 the causality analysis of the Gradual -Shift is reported. The causality results confirm that energy consumption Granger causes economic growth in Mexico. Thus, energy consumption is a key determinant of GDP. This result resonates with the outcomes of Ali et al. (2020) in the case of Nigeria and Shahbaz et al. (2012) in Pakistan. In addition, we observe that urbanization and trade openness Granger-cause economic growth. These results confirm the finding of Ali et al. (2020). that is, urbanization and openness are better predictors to explain economic growth in Mexico over our study period.

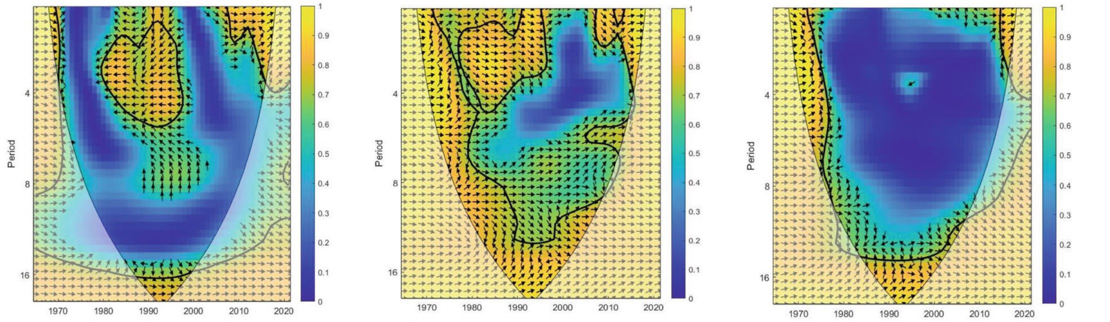
4.5 | Wavelet coherence results

The current study further utilizes the wavelet coherence (WTC) test to catch the causality and correlation between economic growth and the regressors. This method was developed from physics to obtain formerly undetected information. Therefore, this study investigates the connection between GDP and its regressors in the short-, medium-, and long-run. The cone of influence (COI) is a white cone, where discussion is conducted in the WTC. The thick black

TABLE 7 Gradual shift causality test.

Causality path	Wald-stat	No of fourier	*p*-value	Decision
LnGDP→ LnEN	3.6759	2	0.8162	Do not Reject Ho
LnEN → LnGDP	13.599***	2	0.0587	Reject Ho
LnGDP → LnURB	1.9683	2	0.9615	Do not Reject Ho
LnURB→ LnGDP	14.948 **	2	0.0366	Reject Ho
LnGDP → LnTO	5.6540	3	0.5806	Do not Reject Ho
LnTO → LnGDP	15.2808**	3	0.0325	Reject Ho

Note: Significance level of 1%, 5% and 10% is depicted by *, ** and ***.



(a) Wavelet Coherence between Economic Growth & Trade Openness (b) Wavelet Coherence between Economic Growth and Energy Consumption (c) Wavelet Coherence between Economic Growth and Urbanization

FIGURE 4 Wavelet coherence between economic growth and (a) trade openness, (b) energy consumption, and (c) urbanization.

contour illustrates a level of significance based on simulations of Monte Carlo. Figure 4a–c, 0–4, 4–8, and 8–16 illustrate short, medium, and long term correspondingly. Moreover, the vertical and horizontal axis in the Figure depicts frequency and time respectively. The blue and yellow colors depict the low and high dependence, respectively, between the series. The in-phase and out-of-phase connections are depicted by rightward and leftward arrows, respectively. Moreover, rightward-down (leftward-up) illustrates that the first variable leads (causes) to the second parameter, while rightward-up (leftward-down) indicates that the second variable leads (causes) to the first variable. Figure 4a illustrates the WTC between TO and GDP between 1965 and 2021. At high frequency between 1980 and 1999, the arrows are leftward-up which illustrates the negative interconnection between the series with TO leading. Figure 4b depicts the WTC between EN and GDP between 1965 and 2021 in Mexico. The majority of the arrows are rightward-up which illustrates a strong connection (dependency) at different frequencies with energy use leading. Figure 4c illustrates the WTC between URB and GDP in Mexico between 1965 and 2021. At different scales, from 1970 to 1980 and from 2005 and 2016, the bulk of arrows are facing rightward-up which shows positive association (dependency) at different frequencies. Furthermore, the rightward-up arrows show that URB lead (cause) GDP. The outcomes from the wavelet coherence test comply with the results of DOLS, FMOLS, and ARDL.

5 | CONCLUDING REMARKS AND POLICY IMPLICATIONS

The United States Energy Information Administration (EIA, 2018) highlights that a nation's energy and economic growth are positively correlated. This development gives credence to the pertinent role of energy use as a growth catalyst in both emerging and advanced nations. In this country-specific study, we revisit this topical theme in the extant literature with a new perspective for the case of Mexico with a rich energy mix and prospects. This study is distinct from previous documented in the extant literature in terms of scope for Mexico, where few entries have been recorded. Furthermore, using a battery of robust econometric strategies, namely DOLS, CCR, FMOLS, and ARDL bounds testing techniques, and the robust Wavelet and Gradual-shift causality analysis, which is superior to the conventional Granger causality test.

The ARDL bounds testing to cointegration affirms the presence of a long-run equilibrium bond between the study variables. This indicates convergence of the explanatory variables and explains the growth association. The long-run regression from FMOLS, DOLS, and CCR tests give credence to the energy-induced economic growth hypothesis. This is very insightful for government officials in Mexico, that is, energy is a key determinant to stimulate economic growth. This suggests that the county cannot embark on energy-conservative growth policies, as this will hurt the growth path.

The positive impact of urbanization and economic growth is insightful in Mexico, this suggests that the urban growing population is productive as urbanization is seen to stimulate economic growth. This further implies that the population is productive which is desirable for the study area given that Mexico is still an emerging economy is a novel revelation that urbanization triggers economic growth implying that the infrastructure and amenities in the urban cities are growth-inducing. However, caution should be placed to avoid rural–urban drift that might put pressure on the urban cities, which might harm economic growth in Mexico. This position of urban-economic growth is validated by the causality analysis where a uni-directional causality is seen running from urbanization to economic growth. This suggests that urbanization is a good predictor of economic growth in Mexico. Furthermore, the association between economic growth and trade openness shows a statistically negative relationship for the sampled region. This implies that the openness of Mexico's economy to the rest of the world for trade might hurt local infant industries, which might explain the negative linkage between economic growth and trade openness. A plausible explanation could be that trade openness is not favorable to a fragile developing economy, which should be insulated from such threats to economic progress, especially in the infant industry. Officials of the economy should pursue the task of protecting the economy to sustain the current growth trajectory experience.

This study subsequently provides policy direction based on the empirical outcomes. This policy prescription includes

a. The validation of the energy-induced growth is desirable and worthwhile and government officials need to sustain her energy sector given that energy is a determinant for GDP growth in Mexico. However, there is a concern on the part of the government if an external shock hits the energy sector or if the country cannot deal with the energy cut and might need to diversify the economy into other growth paths to ameliorate the unforeseen. In addition, the country cannot embark on energy-conservative strategies as such acts will jeopardize economic progress.
b. The positive statistical relationship between urbanization and economic growth is an indicator for decision-makers. This is a call to sustain such a milestone as it shows the urban population contributes to economic progress. However, caution is needed to strike a balance between rural dwellers and urban dwellers to avoid drift to urban cities and overpressure on urban infrastructures thereby serving as a threat to economic growth
c. Viewing the nexus between economic growth and trade openness from a policy lens reveals that trade openness and economic growth in Mexico with the rest of the world is detrimental to her economic growth. This relationship calls for ingrestructuring her trade dynamics to engender economic growth by balancing the trade deficit and its impact on infant industries.

Conclusively, this study has examined the nexus between energy use, urbanization, trade openness, and economic growth in Mexico using recent time-series data. However, the study is limited to one country and thus opens gaps for further studies. First, further studies can be conducted for the other emerging nations or panels of countries. It will also be of great contribution to the literature when the asymmetry in the nexus between the variables is considered in the econometrics modeling. Moreover, the use of micro disaggregated data can help in providing more specific insights concerning the association between energy use, urbanization, trade openness, and economic growth. Finally, other studies can account for other growth drives not explored in this study.

DATA AVAILABILITY STATEMENT

Data from worldbank database WDI 2021.

ORCID

Tomiwa Sunday Adebayo https://orcid.org/0000-0003-0094-1778
Festus Victor Bekun https://orcid.org/0000-0003-4948-6905
Ilhan Ozturk https://orcid.org/0000-0002-6521-0901

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