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How is energy intensity affected by industrialisation, trade openness and financial development? A dynamic analysis for the panel of newly industrialized countries

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ABSTRACT

Exploring the factors that affect energy intensity is a worthy research topic because a decline of energy intensity lowers greenhouse gas emissions and increases energy security. Therefore, using the World Bank data from 2000 to 2020, this study examined how industrialisation, trade openness, financial development, and urbanisation affected energy intensity in 12 Newly Industrialized Countries (NICs). We used panel autoregressive distributed lag/pooled mean group (ARDL/PMG), cross-sectional ARDL (CS-ARDL), and fully modified ordinary least squares (FMOLS) to determine the long- and short-run effects of explanatory variables on the dependent variable, energy intensity. All variables are found stationary after the unit root test and cointegration test confirms that variables are linked in the long run. Panel ARDL/PMG and CS-ARDL results show that industrialisation increases energy intensity in the long and short runs. These tests also show that financial development increases energy intensity over time but not immediately. Trade openness decreases energy intensity in the long run but not in the short run. Urbanisation has negligible effects. Dumitrescu and Hurlin (2012) Granger causality test result shows that energy intensity causes trade openness. The test also shows two-way causality between industrialisation, financial development, and energy intensity. Results-driven policy recommendations, such as investment in efficient and environmentally friendly technologies, and facilitation of trade openness, are made following the conclusion.

1. Introduction

Energy intensity, measured by the amount of energy consumed per unit of gross domestic product (GDP), indicates the energy efficiency of a nation or region [1,2]. One of the key strategies for lowering carbon emissions and worldwide energy consumption is to reduce energy intensity. Due to the advancement in energy consumption technology in advanced economies, the world's energy intensity has declined in recent years, demonstrating a decline from 7.3 Megajoule (MJ) in 1995 to 5.0 MJ in 2017 (US$ constant 2011, PPP), a 1.4% yearly decline on average [1]. Since 1990, the average pace of world energy intensity drop has been 1.2% annually, with lower middle—income economies seeing a far quicker rate of decline, with an average annual decrease of 1.8% [3]. [4] noted that the amount of energy intensity around the world fell by 2% in 2019, but when weather was taken into consideration, it fell by only 1.6%, which is about the same in 2018. This decrease is far below the average for the years 2010–2017, and it is also well below the threshold of 3.6% that is necessary to satisfy the International Energy Agency's (IEA) Sustainable Development Scenario for the year 2020–2040 [5].

Energy intensity helps with several issues, including lowering greenhouse gas emissions, and increasing energy security [6]. Similarly, energy intensity is strongly correlated with income, with wealthier nations having lesser energy intensity than that of low—income nations. In the same way, energy intensity may be influenced by components other than income, such as industrialisation and urbanisation [7]. Many other studies have linked energy intensity to industrialisation, energy price, trade openness, economic growth, globalization, financial development, ageing population, energy costs, and urbanisation [4,8–10]; Ahmed

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2017; [7,11,12]. Industrialisation, which uses the most energy, can reduce energy intensity by the development and rationalization of the industrial sector [7,13]. Under identical output conditions, industrial sectors with low energy consumption use less energy than those with high energy. When secondary industries are replaced by tertiary industries that use less energy, energy intensity significantly decreases [14].

High energy consumption has also been driven by trade. Global trade involves exporting resource-intensive items, which is linked to high energy consumption, emissions, and low industrial value [15]; other goods also use a lot of energy even though energy itself is not being traded; all these increase energy intensity [16]. Hence, trade openness may affect energy intensity. To conceptually examine the impact of trade openness on energy usage, we can look at it from three different angles: composition, scale, and technique effects (Antweiler et al., 2001). The scale effect is predicted on the idea that more economic activity, such as trade, would lead to more industrial output, which in turn may lead to more energy usage. In contrast, the composition impact is the basic shift in an economy's industry structure. A move in the industry towards less-energy-intensive sectors, including service, could enhance energy saving, and thus decrease energy usage [17]. The technique effect very often reduces energy intensity as trade facilitates imports of improved technology that improves energy efficiency.

Urbanisation is also thought to influence energy intensity in two different ways. One group of researchers argues that the urbanisation process inspires demand for energy services, thus increasing overall energy use and energy intensity [18,19]. However, other researchers opined that urbanisation could mitigate energy intensity as planned urbanisation process can optimize the energy use structure and enhance energy efficiency [18]. Consequently, urbanisation's impacts on energy intensity are inconclusive.

Furthermore, researchers have yet to thoroughly explain the link between financial development and energy intensity which could be useful for lowering energy use and CO_2 emissions [20]. Available literature indicates that aside from technological variables and economic performance, financial development has been crucial in obtaining an appropriate energy intensity level [20]. [21] claim that energy intensity and consumption may increase with higher financial development. Also, financial development can make it easier for people to get loans to buy homes, which can speed up the urbanisation process and change the way people use energy [22]. According to Ref. [23]; it's possible that energy intensity will be influenced by financial development since it has the capacity to affect both energy consumption and economic growth. A positive impact of financial development on energy consumption through the expansion of industry, the spread of urbanisation, and the construction of new infrastructure may result in greater energy intensity. Yet, the impact of financial development on energy intensity is a priori uncertain. As per [24]; financial development has two opposing effects on energy demand; one is a reduction in demand due to greater usage of energy—efficient goods and cutting—edge technology, and the other is an increase in demand due to greater business fixed investment and consumer consumption of durable goods.

Considering the above background, the aim of this study is to explore the influence of industrialisation, trade openness, financial development, and urbanisation on energy intensity of the 12 Newly Industrialized Countries (NICs): Brazil, China, India, Indonesia, Korea, Malaysia, Mexico, Philippine, Singapore, South Africa, Thailand, Turkey. NICs are selected as a study area because these countries' energy consumption is continuously increasing with the growth of industrialisation and urbanisation, which in turn adversely affects the environmental quality of the region by increasing carbon emissions [25]. Therefore, the main objectives will be as follows:

(i) To determine whether increased industrialisation, trade openness, financial development, and urbanisation negatively impact energy intensity in NICs;
(ii) To measure the strength of the long-run and short—run effects of industrialisation, financial development, trade openness, and urbanisation on energy intensity; and
(iii) To assess the presence of causal linkages (bi-directional, unidirectional, or no-direction) between industrialisation, financial development, trade openness, urbanisation, and energy intensity.

The study's primary contributions are as follows. Firstly, to the best of authors' knowledge, this is the first study to systematically evaluate the effects of industrialisation, financial development, trade openness, and urbanisation on energy intensity, specifically in the context of the 12 NICs. Secondly, for this purpose, the latest and complete set of data, covering 21 years (2000–2020) is used. Thirdly, coherent findings are obtained by using a wide range of econometric approachessuch as Pedroni, Kao, and Westerlund panel co-integration tests, FMOLS, CS-ARDL, and Panel ARDL/PMG methods and the D-H causality approach. Lastly, policy proposals with wide applicability are presented, considering the results. These suggestions are effective and useful in helping countries to take the essential policy steps to reduce energy intensity/energy consumption in the sample nations.

Following the introduction, the remainder of this research is organized as follows. In Section 2, past literature related to this topic is reviewed. The methodology is described in Section 3. The findings and analysis are presented in Section 4. Concluding remarks and policy implications are noted in Section 5.

2. Literature review

A good number of empirical studies exist in the literature on the causes of energy intensity. Yet, perceptions vary widely as to how much each component matters. This could be because of the different economic structures that were looked at in these studies. In this section, we will only evaluate the earlier research that falls under the following categories, which are most directly related to the objectives of this study.

2.1. Industrialisation and energy intensity

The effects of industrialisation on energy intensity have been researched by a number of studies. For example, the study of [26] reveals the importance of industrialisation and trade openness on renewable energy intensity over 1986–2020 in China using panel model analysis. The result demonstrated that industrialisation has significant positive effect on energy intensity. A similar result was found by Ref. [27] utilizing marginal M-quantile (MMQ)-regression, Fully Modified OLS (FMOLS), and dynamic ordinary least square (DOLS) approaches in BRICS countries from 1990 to 2019. Furthermore [28], studied the industrialisation -energy intensity nexus in Turkey during 1968–2019. Similarly, for the period of 1976–2020 [29] applied the ARDL model and explored that industrialisation and energy intensity has a positive correlation. Also, the result showed that there is a one—way relation from industrialisation to energy intensity. For the country of Bangladesh, Pan et al. (2019) investigated the impact of industrialisation on energy intensity during 1986–2015. They concluded that industrialisation has a detrimental impact on energy intensity. It is noteworthy to mention that the energy intensity is closely associated with the economic growth in countries that consume renewable energy [30], in the top ten energy-consuming countries [31]), and even within OECD economies [32]. [33] empirically investigated the relationships between industrialisation, urbanisation, economic growth, and energy intensity in 36 Sub—Saharan Africa countries over the period 1980–2015. The result of the System-GMM model revealed that industrialisation has a positive impact on energy intensity. Below in Table 1, one can find additional research on the links between industrialisation and energy intensity.

Table 1
Additional studies on industrialisation and energy intensity.

Author (s)	Country(s), Data, Methodology	Dependent variable	Independent variables	Objectives
[34]	China; 2012–2019; GMM	Energy Intensity	Industrialisation, urbanisation	To explore the impact of industrialisation and urbanisation on energy intensity
[9]	Bangladesh; 1986–2015; path model	Energy Intensity	Industrialisation, Trade openness,	To examine the direct and indirect influence of trade openness and industrialisation on energy intensity
[35]	30 Provinces in China; 1990 to 2015;	Energy Intensity	Industrialisation, Urbanisation, economic growth, FDI	Adopting new technique to examine the influence of urbanisation on energy intensity
[36]	29 provinces in China; 1997–2010; AMG	Energy Intensity	Industrialisation, Urbanisation	To explore the effect of industrialisation and urbanisation on energy intensity
[7]	76 developing countries; 1980–2010; MG, CCE	Energy Intensity	Industrialisation, Urbanisation,	To reduce the effects of climate change, energy security issues, and peak oil.

2.2. Trade openness and energy intensity

Several studies examined the nexus between trade openness and energy intensity and found a mixed result [17,26,37–39]. For example [26], studied the effect of trade openness on renewable energy intensity during 1986–2020 in China using panel path model analysis. The result demonstrated a negative association between the two variables. Further [27], discovered the correlation of trade openness with energy intensity in BRICS economies over the period 1990–2019. The authors utilized different econometric techniques for empirical analysis including GMM, FMOLS, and dynamic OLS (DOLS) approaches. The authors explored that trade openness negatively affects energy intensity. Likewise, employing panel Autoregressive—Distributed-Lag (ARDL) and Cross-Sectional-ARDL approaches [37], studied Organization of the Petroleum Exporting Countries (OPEC) economies from 1990 to 2016 and determined how the level of trade openness and energy intensity are linked. The research demonstrated the negative effect of trade openness on energy intensity, The influence of trade openness on energy intensity was also analyzed by Ref. [38] in 59 Belt and Road Initiative (BRI) economies during 1996–2015. The researchers used panel smooth transition regression for empirical estimation. The findings of the study noted that trade openness and energy intensity have a positive link. Furthermore [17], also examined the impact of trade openness on energy intensity in high and middle—income economies from 1992 to 2014. They employed the system GMM and conclude that trade openness increases energy intensity. Utilizing a bound co-integration test [39] analyzed the influence of trade openness on energy intensity in selected African economies during 1970–2011 and found a positive relation between the two variables. In Ghana [40], employed FMOLS and Canonical cointegration regression techniques to test the correlation between energy intensity and trade openness. The empirical findings indicate a negative correlation between the degree of trade openness and energy intensity. Table 2 presents additional studies that are relevant to the topic at hand. However, it should be noted that trade openness not only has a notable impact on altering energy intensity but also plays a substantial role in contributing to the economic growth of the respective economies, as evidenced by previous studies including [40,41–43] and [44].

Table 2
Additional studies on trade openness and energy intensity.

Author (s)	Country(s), Data, Methodology	Dependent variable	Independent	Objectives
[45]	30 provinces in China; 2005–2018; dynamic panel model	Energy Intensity	Trade openness, economic growth	To analyse the impact of Trade openness and economic growth on Energy Intensity
[46]	OECD; 1994–2018; FMOLS, DOLS, panel quantile regression	Energy Intensity, Energy consumption	Trade openness, financial development, economic growth, urbanisation, environmental taxes	To analyse the environmental taxes on energy intensity and energy consumption
[9]	Bangladesh; 1986–2015; path model	Energy Intensity	Trade openness, industrialisation	To examine the direct and indirect influence of trade openness and industrialisation on energy intensity
[9]	Bangladesh; 1976–2014; SVAR model	Energy Intensity	Trade openness, financial development,	To investigate the nexus between financial development, trade openness, and energy intensity
[47]	South Africa; 1970 to 2011; FMOLS	Energy Intensity	Trade openness, Industry Value added, FDI, Price of energy,	The objective of this study is to examine how various factors have contributed to the decrease in South Africa's energy intensity
[47]	Nigeria; 1971–2011; FMOLS, Canonical Cointegration regressions	Energy Intensity	Trade openness, FDI, Crude Oil, Industry structure	To investigate the effects of determinants of energy intensity

2.3. Financial development and energy intensity

While looking into the relationship between financial development and energy use, some studies have focused exclusively on one country's case (see, for instance, Refs. [12,53]. However, several studies have investigated the relation between energy intensity and financial development from the point of view of groups of countries, looking specifically at both developed and developing nations. For instance Ref. [4], observed the effect of financial development (FD) in 67 developing countries ranging 1995–2018. They employed the System GMM method and found that financial development has a negative effect on energy intensity. Furthermore [29], explored the influence of financial development on energy intensity over the period 1976–2016 in Turkey. The result of the ARDL approach indicated a significant positive connection between financial development and energy intensity. He also revealed a one-way causal relation from financial development to energy intensity [54]. observed the impact of financial development on energy intensity

Table 3
Additional studies on financial development and energy intensity.

Author (s)	Country(s), Data, Methodology	Dependent variable	Independent	Objectives
[48]	30 provinces of Chinese; 2007 to 2019; Spatial Error mode, Spatial Durbin mode, Spatial Autoregressive model	Energy Intensity	Financial development, green finance	To explore the effect of financial development and green finance on energy intensity
[49]	23 European countries; 1995–2015; Panel threshold regression model	Energy Intensity	Financial development, technological innovation	To know the effect of financial development on energy intensity
[50]	India; 2000–2019; ARDL	Energy Intensity	Financial development, GDPPC, Openness, GFCF	To know how financial development decline energy intensity
[51]	30 countries where Islamic banks are present; 1999 to 2013; Pooled OLS	Energy Intensity	Financial development, GDP, CO2 emission, energy import,	The main objective of this study is to analyse the influence of Islamic financial development on energy intensity
[52]	Ghana; 1970–2016; FMOLS, DOLS, Canonical Cointegration	Energy Intensity	Financial development	Does financial development decrease energy intensity?
[3]	98 countries; 1990–2014; two-way fixed model	Energy Intensity	Financial development	To investigate the impact of financial development on energy intensity

over the period 1997–2013 in 81 countries. The study employed GMM approach and revealed that financial development positively influences energy intensity. In a similar vein for 28 Chinese provinces [55] employed Difference-GMM model and examined the influence of financial development on energy intensity over the period 1999–2014. The study found that financial development enhances energy intensity. Further [56], investigated that the association between economic growth, FDI, and financial development in Cabo Verde during 1987–2014. The result of ARDL and ECM approaches found that FDI and financial development are contributing factors to economic growth. More studies can be seen in Table 3.

2.4. Urbanisation and energy intensity

[57] investigated the impact of urbanisation on energy intensity in 38 OECD countries during 1990–2015. They employed GMM method and noted that urbanisation enhances energy intensity. Urbanization has been found to have a positive impact on energy intensity. However, it also has a negative effect on economic growth (see Ref. [58]. For China [59], examined the direct-and-indirect influence of urbanisation on energy intensity during 1995–2022. The study employed Augmented-Mean-Group (AMG), Mean-Group (MG), Fixed-Effect (FE), and Pooled-Ordinary-Least-Square (POLS) methodologies and demonstrated that the direct influence of urbanisation increases energy intensity whereas indirect influence decreases energy intensity. Between 1990 and 2014 [60], discovered the effect of urbanisation on energy intensity in 10 Asian countries where PMG and AMG models are employed. The result found that urbanisation improves energy intensity both in the short and long runs. Furthermore [61], studied the effect of urbanisation on energy intensity from 1980 to 2010 and utilized PMG, FMOLS, DOLS, and GMM techniques. They revealed that urbanisation influences energy intensity positively. Using the ARDL approach, the study of [62] empirically tested the effects of urbanisation on energy intensity in Saudi Arabia during 1971–2012. They demonstrated that urbanisation increases energy intensity both in the short-run and long-runs. In another study [33], applied the System-GMM model and revealed that urbanisation has a negative effect on energy intensity in 36 Sub—Sahara-Africa countries over the period 1980–2015. Furthermore, for 99 countries [63], assess the influence of urbanisation on energy intensity. The study used STIRPAT model and cover the period 1975–2005. The authors found that urbanisation reduces energy intensity in low-income countries, whereas increases in middle-income countries. Moreover, [64]; used panel dataset from 1986 to 2011 to investigate the relation between urbanisation and energy intensity in China (30 provinces). The result of the common correlated effect mean group (CCEMG) method showed that urbanisation increases energy intensity. During 1975–2011 [40], used FMOLS Canonical cointegration regression models and found that urbanisation increases energy intensity in Ghana. In addition to the previously described studies, Table 4 provides other studies on urbanisation and energy intensity.

Though the above studies do shed light on the significance of the stated variables in energy intensity reduction, much ambiguity remains in the literature. Consequently, the purpose of this research is to explore the effects of these specific variables in a panel of NICs, which has not been done previously. Our main goal is to fill this gap in the existing literature. Our research will aid in the spread of solid and transparent policy implications for preserving the natural world. The results of this

Table 4
Additional studies related to urbanisation and energy intensity.

Author (s)	Country(s), Data, Methodology	Dependent variable	Independent	Objectives
[65]	193 Chinese cities; Two step system GMM; FE, OLS	Energy intensity	Urbanisation	The main purpose of this study is to investigate the role of urbanisation on energy intensity
[66]	224 cities in China; 2005–2016; Spatial Durbin model & Spatial decomposition approach	Energy Intensity	Urbanisation,	To analyse the direct, indirect, and regional heterogeneous effects of urbanisation on energy intensity
[67]	Asian Developing Countries; 1980–2010; ARDL	Energy Intensity	Urbanisation, population, openness, CO2	To explore that does urbanisation and CO2 increases energy intensity
[68]	60 countries; 2002–2013; fixed effect approach	Energy Intensity	Urbanisation, GDP growth, GDP per capita,	To investigate the impact of urbanisation and aging on energy intensity
[69]	30 provinces in China; 2000–2012; Panel estimation approach	Energy Intensity	Urbanisation,	To analyse the influence of urbanisation on energy intensity
[70]	China; 1978–2010; TVECM	Energy Intensity	Urbanisation,	To examine the impact of urbanisation on energy intensity
[71]	9 Pacific Island Countries; 1980 to 2005; Panel DOLS	Energy Consumption	Urbanisation, GDP	To find out the energy-GDP nexus

research will shed light on effective energy strategies for the target countries and help to calm the ongoing discussion surrounding the energy intensity nexus with other factors.

3. Data, model, and methods

3.1. Data set

In this paper, panel data from the 12 NICs from 2000 to 2020 are used to study the effects of industrialisation (IVA), financial development (FD), trade openness (TDO), and urbanisation (UPG) on energy intensity (ENT). The time span 2000–2020 is limited by the availability of data for the main variable i.e., energy intensity. All data are collected from World Development Indicator (WDI) of the [72]. The description of the variables and the data sources are detailed in Table 5.

3.2. The empirical model

Using data from 12 Newly Industrialized Countries (NICs), this research examines the factors that affect energy intensity in the long and short runs. Following [7,9]; and [57]; the model's functional form for empirical investigation is:

$$\boldsymbol{ENT_{it}} = \boldsymbol{f}(\boldsymbol{IVA_{it}}; \boldsymbol{TDO_{it}}; \boldsymbol{FD_{it}}; \boldsymbol{UPG_{it}}) \tag{1}$$

After taking the natural logarithm of each variable, the panel model is expressed as follows:

$$\boldsymbol{LENT_{it}} = \boldsymbol{\delta} + \boldsymbol{\pi_1 LIVA_{it}} + \boldsymbol{\pi_2 LTDO_{it}} + \boldsymbol{\pi_3 LFD_{it} \pi_4 LUPG_{it}} + \boldsymbol{\mu_{it}} \tag{2}$$

Where, ENT is energy intensity and refers to the dependent variable, and independent variables IVA, TDO, FD and UPG stand for industrialisation, trade openness, financial development, and urbanisation, respectively. Furthermore, δ is constant and μ is the error term, $i, \textit{and } t$ refer to countries in panel and time period, respectively.

3.3. Estimation procedures

In estimation strategy, we executed four different steps. First, we examined the cross-sectional dependence (C$\mathbb{S}$D) and unit root for each series of the model. Second, cointegration is tested between variables of the study, followed by the long-run and short-run estimates of energy intensity using different methods like FMOLS, PMG and CS—ARDL approach. Finally, the causal relationship between variables of the model is tested using the D-H Granger causality approach. It should be noted that alternative methods of estimation are adopted to account for different integration orders and cross-sectional dependence. This comprehensive approach also improves our findings' reliability and validity, adding to the study's originality and innovation. The details of tests and methods are described in the following subsections.

3.3.1. CSD and panel unit root test

$C\mathscr{S}D$ and panel unit root tests are the fundamental pre-tests that we must perform to select the best estimation approach for panel regression. Further, disregarding the issue of $C\mathscr{S}D$ can result in inconsistent and incorrect estimates (Hussain et al., 2020 [73]; and [74]. In the panel of NICs for verification of possible CSD we used two tests Breusch—Pagan (1980) LM and Pesaran CD (2004) methods. Reportedly, both the tests can be applied in case of balance panel data and the use of Breusch-Pagan is preferred when T > N. In both cases the null hypothesis can be rejected when $p \leq 0.05$, and can be concluded that the series exhibit CSD. The equational forms of the tests are as given:

$$\text{Breusch} - \text{Pagan LM test} = \mathscr{Y}_{it} = \alpha_i + \beta_i \mathscr{X}_{it} + \mathscr{u}_{it} \tag{3}$$

$$\text{Pesaran (2004) CD test} = \mathscr{C}\mathscr{D} = \sqrt{\frac{2\mathbb{T}}{\mathscr{N}(-1)}} \left(\sum_{i=1}^{\mathscr{N}-1} \sum_{j=i+1}^{\mathscr{N}} \rho_{ij} \right. \tag{4}$$

Where $\mathscr{N}$ *and* $\mathbb{T}$ stand for sample size and time, and *ij* stands for the direct correlation error for each cross—section *i and j*.

Further to check for stationarity, we used different tests from both the "first generation" and "second generation" panel unit root tests. These include IPS, Fisher ADF, and Cross-sectional IPS proposed by Im, Pesaran and Shin (IPS) (2003), Maddala & Wu (1999), and [75]; respectively. In literature, Pesaran's (2006) tests (i.e., CIPS) of panel unit root are preferred over others, because IPS and ADF assume cross-sectional independence and do not consider the possibility of $C\mathscr{S}D$ ([76]; and [77]. The equational form of CIPS test is as follows:

$$\mathscr{C}I\mathscr{P}S_{it} = \frac{1}{\mathscr{N}} \sum_{i=1}^{\mathscr{N}} t_i(\mathscr{N}, T) \tag{5}$$

3.3.2. Panel Co—integration tests

After an estimation of panel unit root tests, we used the tests of panel cointegration namely Pedroni test proposed by Ref. [78]; 2004), Kao test developed by Ref. [79] and Westerlund test of cointegration proposed by Ref. [80]. The later test is more acceptable in case of CSD, however, the traditional techniques of cointegration proposed by Pedroni and Kao are also used to produce more robust results. Within these tests, the null hypothesis is assumed as no cointegration between energy consumption, industrialisation, trade openness, and urbanisation in 12 NICs, while the alternative hypothesis is a cointegration i.e., long—run relation between variables of the model.

3.3.3. FMOLS, panel ARDL/PMG, and CS-ARDL

After running the unit root tests and panel cointegration tests, the long run coefficients are identified using FM−OLS suggested by Ref. [81]. An application of FMOLS provides more robust results if the series of the model is integrated in first order and the intercept is heterogeneous [82]. This method solves the heterogeneity and serial correlation issues with conventional OLS estimators [83].

Following the studies of [83]; the coefficient of independent variables under FMOLS can be expressed in equational form as:

$$\beta_{F.\mathscr{M}\mathscr{O}\mathscr{L}\mathscr{S}} = \left[\sum_{i=1}^{\mathscr{N}} \sum_{t=1}^{\mathbb{T}} \mathscr{X}_{it} \mathscr{X}'_{it} \right]^{-1} \left(\sum_{i=1}^{\mathscr{N}} \sum_{t=1}^{\mathbb{T}} \mathscr{X}_{it} \overline{\mathscr{Y}}^{+}_{it} - \mathscr{Y}^{+}_{12} \right) \tag{6}$$

Where, $\mathscr{X}_{it}$*and* $\mathscr{Y}_{it}$ are cointegrated variables for the panel regression specified in equation (2). $\overline{\mathscr{Y}}^{+}_{it}$ is an adjusted dependent variable, which leads to the transformed dependent variables (energy intensity) and corrected serial correlation. This can be written *such as*, $\overline{\mathscr{Y}}^{+}_{it} = (\mathscr{Y}_{it} + \overline{\mathscr{Y}}_{it}) - \widehat{\mathscr{W}}_{12}\Omega_{22}^{-1}\Delta_{22}$, where Ω and Δ are the expected long-term covariance, respectively, i.e., $\mathscr{Y}^{+}_{12} = r_{12} - \widehat{\mathscr{W}}_{12}\Omega_{22}^{-1}\Delta_{22}$.

Furthermore, the estimates $P\mathscr{M}G$ proposed by Pesaran and Shin (1995) and Pesaran et al. (1999) are preferred over FMOLS, in case we have stationary series at mix order of integration. However, this $P\mathscr{M}G$ approach presumed a lesser degree of heterogeneity because this approach incurs heterogeneity in the short run and homogeneity in the long run [84], and examines heterogeneous dynamic issues across nations [74,85]. The method of PMG estimates both the long run and short

Table 5
Description and source of variables.

Variables	Description	Source
ENT	Energy intensity level of primary energy (MJ/$2017 PPP GDP)	WDI
IVA	Industry (including construction) value added (% of GDP)	WDI
TDO	Trade Openness (% of GDP)	WDI
FD	Financial Development is broad money % of GDP	WDI
UPG	Urban population growth (annual %)	WDI

Note: WDI stand for World Development Indicators.

run coefficients, and specify the regression model as follows:

$$\mathscr{Y}_{i,t} = \sum_{j=1}^{\rho} \lambda_{ij} \mathscr{Y}_{i,t-j} + \sum_{j=0}^{q} \delta_{ij} \mathscr{X}_{i,t-j} + \prod_i + \mathscr{u}_{it} \tag{7}$$

Where the dependent variable in our case is energy intensity, denoted by the notation $\mathscr{Y}_{i,t}$. Further, $\mathscr{Y}_{i,t-j}$ stands for the lagged form of the dependent variable and $\mathscr{X}_{i,t-j}$ is the set of independent variables such as industrialisation, financial development, trade openness and urbanisation. *i and t* represents countries and time. Moreover, $\prod_i$ indicates the fixed effects, λ_{ij} shows the coefficient of the lagged regressor; the term δ_{ij} are $\eta \times 1$ coefficient vector; and $\mathscr{u}_{it}$ shows residual.

It is usually easier to work with the re—re-parameterisation version of equation (7) to evaluate the long and short—run estimates of the parameter at the same time. Therefore, the re—re-parameterisation form of the panel $P\mathscr{M}G$ is used and specified as follows:

$$\Delta LENT_{i,t} = \varphi_i \left(LENT_{i,t-1} + \beta_i \mathscr{X}_{i,t-1} \right) + \sum_{j=1}^{\rho-1} \lambda_{i,j} \Delta LENT_{i,t-j} + \sum_{j=0}^{q-1} \delta_{i,j} \Delta \mathscr{X}_{i,t-j} + \prod_i + \mathscr{u}_{it} \tag{8}$$

$$\Delta LENT_{i,t} = LENT_{it} - LENT_{it-1}, \varphi_i = -\left(1 - \sum_{j=1}^{\rho} \lambda_{i,j}\right), \beta_i$$

$$= \sum_{j=0}^{q} \delta_{ij} \lambda_{i,j} = -\sum_{k=j+1}^{\rho} \lambda_{ik}, j = 1, 2, 3, \ldots, \rho - 1, \delta_{ij}$$

$$= -\sum_{k=j+1}^{q} \delta_{ik}, j = 1, 2, 3, \ldots, q - 1$$

The coefficient in equation (8) indicates the long—term relation between the dependent and independent variables, and φ_i in the equation stands for the speed of adjustment of the energy intensity towards the long run. The short—run effects between variables are also represented by the coefficient $\lambda_{i,j}$ *and* δ_{ij}.

Further, we employed the method of CS-ARDL proposed by Ref. [86]. This method is useful to adjust the long-run and short run estimates for an issue of the CSD. Reportedly, CS-ARDL approach is more reliable and works more effectively when compared with other approaches like P $\mathscr{M}$ G, $\mathscr{M}$ G, A $\mathscr{M}$ G and CCE $\mathscr{M}$ G [87]. This CS-ARDL approach overcomes the problems of endogeneity, heterogeneous slopes coefficient, unobserved common shocks, and mixed integration order [86]. propose the equational form of CS-ARDL as follows:

$$LENT_{i,t} = \sum_{j=1}^{\rho} \lambda_{ij} LENT_{i,t-j} + \sum_{j=0}^{q} \delta_{ij} \mathscr{X}_{it-j} + \sum_{j=0}^{s} \beta_i^{'} I \overline{Z}_{t-1} + \mathscr{u}_{it} \tag{9}$$

Where, $\overline{Z}_{t-1} = [\overline{LENT}_{i,t-j}, \overline{\mathscr{X}}_{i,t-j}]$, which is the averages of dependent and independent variables of the model. Z-bar basically represents cross-sectional averages and eliminates cross-sectional dependence (Hasanov et al., 2018). In the superscript, denote lags for the given series. The following equation can be used to determine the long—run coefficient estimation using CS—ARDL method:

$$\widehat{\gamma}_{CS-ARDL,ij} = \frac{\sum_{j=0}^{q} \widehat{\delta}_{ij}}{1 - \sum_{j=1}^{\rho} \widehat{\lambda}_{ij}} \tag{10}$$

Equation (10) can be written in error correction form as:

$$\Delta LENT_{i,t} = \Theta_i \left(LENT_{i,t-1} - \pi_{ij} \mathscr{X}_{i,t} \right) - \sum_{j=1}^{\rho-1} \lambda_{i,j} \Delta_I LENT_{i,t-1} + \sum_{j=0}^{q} \delta_{ij} \Delta \mathscr{X}_{i,t} + \sum_{J=0}^{S} \beta_i^{'} I \overline{Z}_{t-1} + \mathscr{u}_{it} \tag{10a}$$

Where, $\Delta_I = t - (t-1)$, for instance

Finally, we analyzed the model parameters' causal association. The panel causality D-H technique, proposed by Demutrescu and Hurlin (2012), is used. Under the D-H approach, the dynamic association between Y and X can be expressed as:

$$L_{it} = \pi + \sum_{n=1}^{\mathscr{N}} \varphi_1^n i, t - n + \sum_{n=1}^{\mathscr{N}} \lambda_1^n it - n \sum \sum \sum + \mathscr{u}_{it} \tag{11}$$

$$\sum \sum \sum \sum \sum$$

Where π are the estimated constant parameters, φ are the coefficients of auto-regressive variables, and λ are the coefficients of regressor variables under the specification of different regression for each series of the model. In our case, Y can be written as ENT, IVA, TDO, FD, and UPG, whereas for each dependent the remaining can be represented as X-variables in the specification of equation (11). The $\overline{W}$—statistic and Z—statistic are the two statistics that the D-H causality approach generates. These stats can be calculated as:

$$\mathscr{W}_{\mathscr{N},T}^{H\mathscr{N}C} = \mathscr{N}^{-1} \sum_{i=1}^{\mathscr{N}} \mathscr{W}_{i,t} \tag{12}$$

$$\mathscr{Z}_{\mathscr{N}T}^{H\mathscr{N}C} = \frac{\frac{1}{\sqrt{\mathscr{N}}} \left| \sum_{i=1}^{\mathscr{N}} \mathscr{W}_{i,t} - \sum_{i=1}^{\mathscr{N}} E\left(\mathscr{W}_{i,t}\right) \right|}{\sqrt{\frac{1}{N} \sum_{i=1}^{\mathscr{N}} Var\left(\mathscr{W}_{i,t}\right)}} \tag{13}$$

In equations (12) and (13), the $\mathscr{W}_{i,t}$ stands for the $C\mathscr{S}D$ Wald-statistic, and $E(\mathscr{W}_{i,t})$ *and* $Var(\mathscr{W}_{i,t})$ represent the probability and variance of the Wald test statistic, correspondingly.

4. Empirical results and discussion

4.1. The results of descriptive statistics and correlation matrix

This study employed the balanced panel data during 2000–2020; for all variables the results of descriptive statistics and correlation matrix are provided in Table 6. In description statistics mean values and standard deviations are shown in row 2 and 6 of Table-6, respectively. The data shows that model variables' mean values vary, showing their

Table 6
Descriptive statistics and correlation matrix.

Descriptive statistics					
	$LENT_{it}$	$LIVA_{it}$	$LTDO_{it}$	LFD_{it}	$LUPG_{it}$
Mean	1.529	3.463	4.263	4.350	0.663
Median	1.506	3.477	4.073	4.335	0.765
Maximum	2.384	3.882	6.081	5.356	1.672
Minimum	0.718	2.874	3.096	3.109	−2.424
Std. Dev.	0.383	0.233	0.695	0.526	0.582
Skewness	0.336	−0.083	0.915	−0.241	−1.898
Correlation matrix					
$LENT_{it}$	–				
$LIVA_{it}$	0.329	–			
$LTDO_{it}$	−0.196	0.229	–		
LFD_{it}	0.375	0.221	0.412	–	
$LUPG_{it}$	0.129	0.371	0.018	−0.053	–

Table 7
Cross-sectional dependence test results.

Tests	$LENT_{it}$	$LIVA_{it}$	$LTDO_{it}$	LFD_{it}	$LUPG_{it}$
Pesaran CD	20.61*** (0.000)	14.85*** (0.000)	2.25*** (0.000)	16.93*** (0.000)	14.57*** (0.000)
Breusch-Pagan LM	721.60 *** (0.000)	630.02 *** (0.000)	369.83 *** (0.000)	654.08 *** (0.000)	598.06*** (0.000)

Note: Values in ( ) indicate p-values; *** indicate 1% significance level.

different performance or features. Financial development has a higher mean score (i.e., 4.35), showing a strong and rising financial sector. The average value of trade openness is 4.26, making it the second highest after financial development. In contrast, urban population growth has a lower mean of 0.66. The standard deviation values also vary across the variables of the model, reflecting data distribution differences. For instance, the standard deviation is higher for trade openness but lower for industrial output. The mean and standard deviation of energy intensity are 1.529 and 0.383, respectively.

The correlation coefficient results reveal that while the correlation coefficient varies from −1 to +1, some variables have positive correlations while others have negative correlations. Energy intensity and financial development are strongly correlated with a correlation coefficient of 0.375. With a value of −0.196, Trade openness and energy intensity has a relatively weak and negative correlation. With the exception of trade openness, all of the model variables are positively correlated with energy intensity.

4.2. The results of CSD test

CSD and panel unit root are common issues with panel data analysis. These are pre-tests before assessing the long-run and short-run estimations. Thus, before cointegration analysis, the outcomes of the CSD and panel unit root tests are noted in Tables 7 and 8, respectively. In Table-7, the results of CSD are shown for two different tests: the Pesaran CD test and Breusch-Pagan LM test. In both cases, CSD test results demonstrate a clear rejection of the $H_O = C\mathscr{S} - Independence$. The findings showed that the calculated *CD* and *LM* tests are statistically significant at 1% level of significance which indicate the presence of CSD in series of the model.

4.3. The results of unit root and cointegration tests

Following the presence of cross-sectional dependence, we proceeded to utilise both first- and second-generation panel unit root tests, namely the IPS, ADF and CIPS tests. The CIPS test of the panel unit root is used to adjust for the issue of $C\mathscr{S}D$. All tests assume the corresponding null as no unit root. The results of both the IPS and ADF test show that all variables are stationary after first difference, whereas the CIPS test reveals that variables are stationary at the level I (0) and at first difference I (1), concluding a mix-order of integration. Unit root results indicate that the study could further conduct the cointegration test for the long-run analysis.

We tested variable co-integration after the panel unit root testing.

Table 9
Panel Cointegration test (Pedroni & Kao).

Panel $\mathscr{S}$ tatistics (within $\mathscr{d}$ imension)	$\mathscr{S}$ tatistic	$\mathscr{P}$ rob	Weighted $\mathscr{S}$ tatistic	$\mathscr{P}$ rob
Panel v-$\mathscr{S}$ tatistic	0.521	0.3011	−0.787	0.7844
Panel rho-$\mathscr{S}$ tatistic	0.624	0.7338	1.013	0.8444
Panel PP-$\mathscr{S}$ tatistic	−3.565***	0.0002	−2.599***	0.0047
Panel ADF-$\mathscr{S}$ tatistic	−2.473***	0.0067	−2.349***	0.0094
Group $\mathscr{S}$ tatistics (between $\mathscr{d}$ imension)				
Group rho- $\mathscr{S}$ tatistic	2.697	0.9965		
Group PP- $\mathscr{S}$ tatistic	−2.033**	0.0210		
Group ADF- $\mathscr{S}$ tatistic	−2.397***	0.0083		
Kao Cointegration				
ADF	−2.071**	0.0192		
Residual Variance	0.0030***			
HAC variance	0.0028***			
Westerlund Cointegration				
Variance ratio	2.3700***	0.0089		

** and *** indicate 5%, and 1% significance level, respectively.

Table-10
Long run estimates of the model using FMOLS, ARDL and CS-ARDL.

Method	$LIVA_{it}$	$LTDO_{it}$	LFD_{it}	$LUPG_{it}$
FMOLS	0.309 (0.088) *** [3.533]	−0.273 (0.053) *** [-5.117]	0.367 (0.067) *** [5.513]	0.0515 (0.058) [0.887]
PMG/ ARDL	1.061 (0.253) *** [0.000]	−0.924 (0.142) *** [0.000]	0.459 (0.157) *** [0.004]	−0.004 (0.056) [0.941]
CS-ARDL	0.3467 (0.153)** [0.024]	−0.1096 (0.065)* [0.092]	0.4246 (0.216)** [0.049]	−0.0694 (0.058) [0.236]

Note: *, ** and *** indicate 10%, 5%, and 1% level of significance, respectively, and bracket values are standard errors, values in [ ] show p-values.

The relationship between non-stationary variables that results in a linear combination of these variables being stationary is known as cointegration. In Panel analysis, the Pedroni and Kao tests are particularly helpful for examining the long-term links between economic variables. The Pedroni test, which allows for various individual trends and intercepts, is more reliable than the Kao test for heterogeneous panels [86]. As mentioned in the methodology section that the Kao test is suitable for homogenous panel rather than heterogenous panel. On the other hand, Waterlund test is used which accounts for CSD. Table 9 shows the cointegration results of these alternative tests. The Pedroni test reports seven different test statistics where four statistical tests were found statistically significant. We further found that the Kao's test results are also statistically significant and validate the presence of panel co-integration in the specified regression model. The Westerlund test also rejects the null hypothesis and confirms that ENT, IVA, TDO, FD and UPG are cointegrated. Afterward, we estimated the regression model in equation (2) and compared the results using FMOLS, PMG, and CS-ARDL estimates.

Table 8
Panel Unit root test results.

Variables	IPS		ADF		CIPS	
	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)
$LENT_{it}$	3.030	−4.940***	8.342	67.753***	−1.921	−3.655***
$LIVA_{it}$	2.721	−6.318***	12.885	88.686***	−2.209*	–
$LTDO_{it}$	0.971	−6.230***	15.836	84.873***	−0.987	−3.160***
LFD_{it}	3.883	−4.358***	8.853	63.519***	−2.262	−3.814***
$LUPG_{it}$	3.778	−7.400***	16.873	104.113***	−1.946	−3.897***

* and *** represent 10% and 1% level of significance, respectively.

4.4. The results of panel estimation

The outcomes from FMOLS, PMG and CS-ARDL are reported in Table 10. The FMOLS results indicate that all variables of the model are statistically significant at 1% level, except the population growth. The coefficients of industrial value added, and financial development are with positive signs while of trade openness with a negative sign. In second row of Table-10, the PMG results of the model also indicate that the coefficients of relevant explanatory variables are significant with higher magnitude compared to the FMOLS estimates. There are some variations between the coefficients of PMG and FMOLS, whereas the PMG estimate shows higher effects of industrial value added, financial development, and trade openness on energy intensity in the countries of analysis. The CS-ARDL estimates are also significant, however, these are significant at different levels of significance with smaller magnitude compared to the PMG estimates. It is evident that the estimators from all approaches produce significant results for industrial value added, trade openness and financial development. The consistent significance across different estimation methods strengthens the robustness of these findings and supports the notion that these variables play key roles in shaping energy intensity levels. Also, underscores their relevance for policy considerations and sustainability initiatives. Instead, the urban population growth is found with a positive sign under FMOLS and with a negative sign under PMG and CS-ARDL, but insignificant irrespective of the methods. Indicating that urbanisation in our panel of NICs is not a more impressive factor of the energy intensity.

Quantitatively, the coefficient value of industrial value-added ranges from 0.31 to 1.06. This suggests a positive link between industrialisation and energy intensity. According to Ref. [33]; heavy machinery, improved production techniques, and higher electrical demand make the industrial sector more energy-intensive than farming. In our results, industrialisation's effects are consistent with the findings of [9,33,34, 47] & [7]. This similarity with prior studies strengthens our findings and emphasizes the importance of industrial energy efficiency for sustainable economic growth. Additionally, the estimated coefficient of trade openness ranges from −0.109 to −0.924, indicating that a percentage increase in trade openness is expected to decrease energy intensity by less than a percentage change. In other words, the trade openness has a negative influence on energy intensity, meaning countries that trade more have lower energy intensity. Trade often transfers energy-efficient technologies in industrialized countries, encouraging trading partners to use more energy-efficient production methods and reduce energy intensity. The result is also consistent with the findings of earlier research studies, such as [4,9,37,45]; and [33]. All of this supports the premise that international trade can improve energy efficiency. The estimates of financial development are more consistent across the different estimation methods employed, with coefficient values ranging from 0.37 to 0.46. These results suggest that financial development has increased energy intensity by 0.37%–0.46% in NICs. Our findings suggest that robust financial systems in newly industrialized economies play a crucial role in promoting energy efficiency. The obtained results are consistent with the findings of different previous studies, including the research conducted by Ref. [88] for Nordic countries [51]; for 30 countries [54], for 81 countries [55], for 28 Chinese Provinces [47], for Nigeria, and [24] for 22 countries. However, a few other research disagrees with these results, notably [50] for India [52], for Ghana and [3] for non-OECD countries.

The above findings are also summarised in Fig. 1 below:

Table 11 provides the results of the short run equations specified under the methods of PMG and CS- ARDL. The results show that most of the coefficients are not statistically significant in the short run. The coefficient of error correction term and of industrial value added is statistically significant. The industrial value-added estimate is with positive sign and of value 0.28 and 0.29, respectively. This finding indicates that a 1% rise in industrial value-added increases the dependent variable by 0.28% and 0.29%, demonstrating the model's sensitivity to industrial growth within the panel of NICs. In PMG results, the error correction coefficient value −0.18 indicates a moderate pace towards

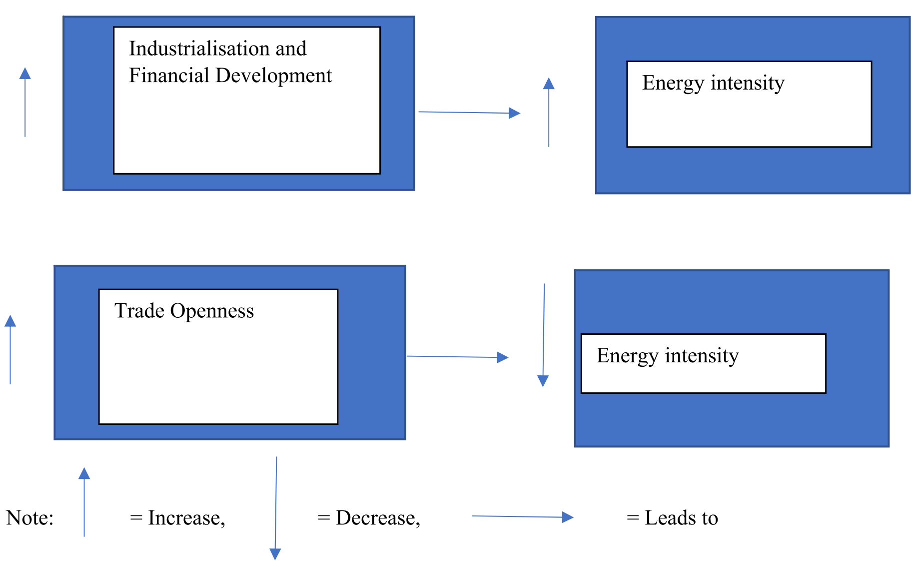

Fig. 1. The summary of findings.

Table 11
Short run results of PMG and CS-ARDL.

Short—run equation		
	ARDL/PMG	CS-ARDL
ECT	−0.186 (0.082)** [0.025]	−1.068 (0.104)*** [0.000]
D (LIVA)	0.286 (0.135)** [0.036]	0.294 (0.110)*** [0.008]
D (LIVA (-1))	0.065 (0.164) [0.688]	—
D (LTDO)	−0.005 (0.078) [0.946]	−0.118 (0.075) [0.114]
D (LTDO (-1))	0.015 (0.069) [0.828]	—
D (LFD)	0.005 (0.071) [0.940]	0.398 (0.254) [0.118]
D (LFD (-1))	0.083 (0.086) [0.341]	—
D (LUPG)	0.028 (0.063) [0.660]	0.078 (0.056) [0.161]
D (LUPG (-1))	−0.043 (0.062) [0.940]	—
C	0.029 (0.048) [0.548]	—
Root MSE	0.022	0.05
S.D. dependent var	0.042	–
Mean dependent var	−0.015	–
S.E. of regression	0.032	–
Root MSE	–	0.05
R-Squared	–	0.65
R-Squared (MG)	–	−0.09
Lag	(1,2,2,2,2)	—

, and * represent 5%, and 1% level of significance, respectively ( ) shows standard error. Values in [ ] show p-values.

Table 12
D-H Granger causality test.

Variables	$LENT_{it}$	$LIVA_{it}$	$LTDO_{it}$	LFD_{it}	$LUPG_{it}$
$LENT_{it}$	…	6.644*** (1.228) [6. E−08]	7.523*** (1.155) [7. E−11]	5.467*** (1.390) [8. E−05]	3.358 (1.272) [2.639]
$LIVA_{it}$	3.892* (1.990) [0.051]	….	5.957*** (1.710) [5. E−06]	3.382 (2.569) [0.1880]	6.694*** (5.434) [5. E−08]
$LTDO_{it}$	3.076 (3.301) [0.351]	5.302*** (1.423) [0.000]	….	2.936 (3.878) [0.448]	7.546*** (1.161) [8. E−11]
LFD_{it}	5.178*** (1.451) [0.000]	4.170** (1.809) [0.021]	5.712*** (1.348) [2. E−05]	….	2.658 (6.666) [0.690]
$LUPG_{it}$	2.604 (7.876) [0.741]	8.700*** (7.938) [2. E−15]	5.4801*** (1.096) [9. E−05]	5.171*** (1.463) [0.0004]	…

*, **, *** represent 10% 5%, and 1% level of significance, respectively; values [ ] shows p-values and values in ( ) are standard errors which is calculated by using the coefficient and z-test values.

long run equilibrium i.e., the short run deviation converts to its long run equilibrium in a year by around 18%. On the other hand, the CS-ARDL model has a greater error correction coefficient, indicating a faster adjustment to the long run equilibrium. The CS-ARDL model corrects deviations from equilibrium faster than the PMG model. Furthermore, the significant error correction term in both models indicates a consistent long-run association between the variables.

4.5. The results of causality test

Finally, Table 12 shows the granger causality test results based on Dumitrescu and Hurlin (2012) approach of panel causality. This test is superior to earlier panel causality tests in three ways: (i) it takes into consideration of C 𝒮 D, (ii) it does not consider cross—section size and time dimension, (iii) it performs well in panels with imbalances (D-H, 2012). In the context of panel estimation following co-integration, this test is widely applicable to find the causal relationship between variables, specifically the direction of causality from one variable to another. The result reveals a unidirectional causality from energy intensity and financial development to trade openness, financial development to industrialisation, and urbanisation to financial development. The study also indicates two−−way causality between industrialisation and energy intensity, financial development and energy intensity, trade openness and industrialisation, urbanisation and industrialisation, urbanisation and trade openness. However, no causality is found between urbanisation and energy intensity, showing that urban population changes do not significantly affect energy intensity. The findings are highly consistent with the estimates obtained from the long-term model and provide additional insights into the study's variable interactions.

The main bidirectional causality results are also depicted in Fig. 2 below:

4.5.1. Robustness check

The FMOLS technique is employed for checking the robustness of the results. All the variables with natural logarithmic expressions have their long—run elasticity. The result of FMOLS revealed that IVA has positive impact on ENT. A one percent increase in IVA would further enhance ENT by 0.31%. The results of this study are aligned with the result of [4]. The findings also demonstrated that the coefficient of TDO is negative and significant at a 1% significance level, implying that if TDO rises by 1%, it will reduce ENT by 0.27%. Our outcomes are in line with the findings of [88]. Furthermore, FMOLS approach shows that FD has a positive influence on the ENT. The estimated coefficient of FD is 0.37, which implies that a 1% point increase in FD enhances ENT by 0.37%. This result is consistent with the result of [51] for 30 countries. Again, UPG has an insignificant impact on the ENT like the earlier results. Overall, the results obtained from the FMOLS analysis are consistent with the findings obtained from the PMG and CS-ARDL analyses, thereby providing additional support for the observed causal patterns. These findings strengthen the study's conclusions and improve understanding of the variables' linkages.

5. Conclusion and policy implications

This research analyzed the impacts of industrialisation, financial development, trade openness, and urbanisation on the energy intensity in 12 NICs utilizing the World Bank Data from 2000 to 2020. The study has used sophisticated econometrics techniques, such as panel−A ℛ DL/ P ℳ G, CS-A ℛ DL, and FMOLS, to determine the long—and short—run impacts of explanatory variables on the dependent variable. For CSD, we utilized Breusch-−; Pagan (1980) LM and Pesaran (2004) CD test; the results of these techniques suggest that there is CSD between variables. After CSD tests, we applied panel unit root methods of first and second generation (IPS, ADF, and CIPS) and the first generation unit root test shows that all variables are stationary at the first difference I (1), whereas second generation unit root test, CIPS, indicates that all variables are stationary (I (0) and I (1)). Next to the CSD, we employed panel

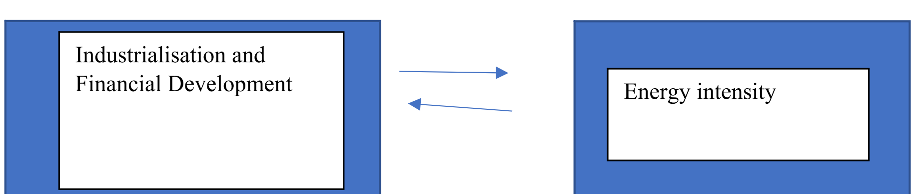

Fig. 2. Bidirectional causality between dependent and independent variables.

co-integration tests such as Pedroni, Kao, and Westerlund tests, and these tests confirm that there is a long-term linkage between variables of the model. The results of Panel A $\mathscr{R}$ DL/P $\mathscr{M}$ G and CS-A $\mathscr{R}$ DL approaches reveal that industrialisation has a positive impact on energy intensity both in the long and short runs. Further, these tests demonstrate that financial development positively affects energy intensity in the long run but not significantly in the short run. Moreover, we also found that trade openness negatively affects energy intensity in the long run but is not significant in the short run. Surprisingly, the results of urbanisation are explored as insignificant. For causality between variables, we used Dumitrescu and Hurlin (2012) test. This test shows a unidirectional causality running from energy intensity to trade openness. D-H test also reveals bidirectional causality between industrialisation and energy intensity, financial development, and energy intensity, whereas this technique did not explore any link between urbanisation and energy intensity.

Based on the research findings the following policy recommendations are worthy of mention for NICs. (i) Industrialisation increases energy intensity, meaning that industrial growth increases energy consumption which in turn increases emissions. Therefore, there is a need to create industrial policies that encourage technological innovation to mitigate the adverse effects of industrialisation. This could be accomplished by supporting the use of energy-efficient technologies and the development of renewable energy sources to minimize energy intensity while industrialisation progresses. (ii) Furthermore, the results indicate that energy intensity can be decreased by facilitating trade openness. So, policymakers should assess the impact of trade policies on energy intensity and work to develop trade policies that allow the transfer of information and technology relevant to energy efficiency and renewable energy. (iii) The expansion of financial development has also increased the energy intensity of the panel nations. Hence, NICs must encourage the financial sector to aid the energy sector in boosting their investment in efficient and environmentally friendly technologies. Moreover, NICs should expand their investments in domestic energy sources, especially in renewable energy sources, to meet their energy needs and reduce their reliance on energy imports. Financial development must be managed to reduce energy intensity. All these policy recommendations are linked to the research objectives of this study.

Like many other studies, this study is also not free from limitations. This is a panel data study; so, the study outcomes and policy implications are more generalised which is applicable to the panel of 12 countries as a whole. It lacks the country-specific focus. Each country is heterogeneous in nature, and country-specific policy may be required to achieve the desired goal. Therefore, future studies are recommended for country-specific time series analysis to better capture the specific factors unique to the country under investigation, leading to more context-specific policy implications. However, this limitation in no way weakens the findings and credibility of our research as panel data increases statistical power, and conclusions and policy implications can be applied to a broader range of contexts.

Credit author statement

M.M. Rahman: Conceptualisation, Visualization, Methodology, Supervision, Writing and Editing.Z. Khan: Software, Data curation, Investigation and Writing.S. Khan: Draft Preparation, and Validation and Analysis of Results, M. Tariq: Reviewing, Editing, Formal analysis and writing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.esr.2023.101182.

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