Does Export product diversification help to reduce energy demand: Exploring the contextual evidences from the newly industrialized countries

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Abstract

This article investigates the impact of export product diversification, extensive margin and intensive margin on emerging economies energy demand covering the period from 1971 to 2014. The study contributes to energy economics by unveiling the interaction between export diversification and energy demand of 10 newly industries countries (NICs). Owing to the growth prospect and trade volume of these nations, it is necessary to assess the various facades of export growth on the energy demand. In this pursuit, we have considered the export product diversification index in its aggregate and disaggregated forms (i.e. extensive margin and intensive margin) in this study. The empirical estimation has been carried out based on GMM, FGLS, FMOLS, and DOLS techniques. The empirical results demonstrate that export diversification, extensive margin, and intensive margin help to reduce the overall energy demand in NICs. Further, the empirical outcomes identify that economic growth, urbanization, and natural resources increase energy consumption. The study discusses fruitful policy implications regarding the exports diversification and energy demand nexus for emerging economies.

Keywords: Export product diversification; extensive margin; intensive margin; energy consumption; Newly Industrialized Countries; panel co-integration

JEL classification: F1, F12, Q56, C32

1. Introduction and contribution

Energy demand and its determinants has been the subject of debate in the literature of energy economics. Since 19^{th} century, global energy demand has been increasing at 2.5% per annum and researchers are speculating about the growth prospect of this demand of energy. Further, non-renewable energy consumption has been considered as a driver of environmental degradation and climate change issues (Imbs and Wacziarg, 2003; Sorrell, 2015; Shahbaz and Sinha, 2019; Shahbaz, et al., 2019). In recent years, policymakers across the globe are struggling to address the environmental problems arising out of the consumption of fossil fuels, and in this pursuit, they are trying to reduce the energy demand through product and process innovations. These innovations are associated with the comparative advantage of a nation, and it is reflected in the works of Adam Smith and David Ricardo. This argument is also in line with the Heckscher-Ohlin theory, which states that the host country should design the export products basket as per its factor intensity of manufacturing (Laursen, 2015). Accordingly, this study aims to explore the impact of three indicators of export diversification (i.e. export product diversification, extensive margin and intensive margins) on energy demand. Export diversification is defined as changing of export and productive structure in an economy, which can be attained by modifying the existing basket of commodities and embellishing them through innovation. Export diversification refers to widening the range of products that a country exports, whereas, extensive margin is referred to as the variation in number of new products exported and number of new markets for existing exports (Dennis and Shepherd, 2011). The intensive margin enlists the variation in export figures among existing exports, and the intensive and extensive margin together known as new products and new markets (Cadot et al., 2011).

Imbs and Wacziarg (2003) opined that there is an inverted U-shaped association between export diversification and GDP per capita, and thereby indicating that rise in income level leads to increase in product diversification, which is replaced by export concentration after a threshold. Such narrative motivates us to consider export diversification as key policy variable for energy demand in newly emerging countries (NICs)[1]. The term NIC is coined by World Atlas, and it is defined as the countries, where economic development has crossed the threshold that of the developing countries, but have not classified as developed nations (Sawe, 2017). The choice of selecting NICs is motivated by the fact that these countries have witnessed a surge in energy consumption since the past two decades in pursuit of economic growth. In recent years, these countries are making investments for an industrial paradigm shift, by substituting the export of agricultural products by technologically advanced products. Figure 1 illustrates country-wise energy consumption outlook for 1990-2014, while Table 1(a) mentions energy consumption, exports, and GDP of the NICs for the year 2014.

<<Insert figure 1 >>

<<Insert table 1(a)>>

Export product diversification and increase in exports are considered to be important for middle and high-income countries to achieve sustainable development, while high product concentration poses threat to economic development, due to emergence of new competitors in the international markets and supply shocks to the host economy (Cadot et al., 2013; Gozgor and Can, 2016b). Export product diversification strategy contributes to the emergence of new industries, development of existing industries, and risk-diversification across industries during unfavorable trading conditions in the global market (Agosin et al., 2012). Further, increase in export, emergence of trading partners, and improvement in product quality help to avoid any potential loss in case of international trade taxes, tariffs, and hidden import barriers for some specific products or industries (Gozgor and Can, 2016b). Henceforth, the developed and emerging countries continue the efforts to enhance their export portfolio, quality of

[1] Brazil, China, India, Indonesia, Mexico, Malaysia, Philippines, South Africa, Thailand, and Turkey

international relations, and invest in pursuit of technology transfer, entrepreneurial skills, and to meet energy demand for diversified production.

The present study offers three contributions. First, to the best of our knowledge, present study is the pioneer to explore the impacts of three indicators of export diversification on energy demand in the NICs. In the existing literature, export diversification is considered as an indicator of international trade, and therefore, it can be a contributing factor for energy demand (Shahbaz et al. 2019b). It rises with economic progress, while it is replaced by concentration beyond a threshold limit (Imbs and Wacziarg, 2003; Cadot et al., 2011), which indicates that the NICs should focus on diversification strategies to improve energy efficiency during export concentration stage, as it can help to reduce the overall energy demand. According to the International Monetary Fund, competition among export products in industrialized countries is high (Boddin, 2016), while they are striving to diversify the export basket (Agosin et al., 2011). This motivates us to consider the indicators of export diversification as determinants of energy demand. There lies the theoretical contribution of the study.

Second, in this study, the NICs have been chosen for contextual development. Among NICs, China consumed around 12,840 barrels of crude oil per day in December 2017, Malaysia with 793 barrels per day and South Africa with 556.45 barrels per day in the same period (CEIC, 2019). Similarly, China consumed 240 billion cubic meters natural gas in 2017, followed by Malaysia with 400 billion cubic meters and Turkey with 53.5 billion cubic meters of natural gas (Tiryakioğlu, 2018; CEIC, 2019). The increase in oil consumption, existing natural gas reserves, and imports indicate that impacts of natural resources and oil price shocks on energy demand call for investigation regarding energy policies for the NICs. Hence, suggesting suitable policies for the NICs is the contextual contribution of the study. Third, the study provides significant implications to achieve the sustainable development goals (SDGs) designed by United Nations. The NICs are putting effort in attaining the objectives of SDGs, and to be specific, clean energy for everyone (SDG objective 7), sustainability of economic growth (SDG objective 8), sustainability in the consumption pattern (SDG objective 12) and improving the environmental quality (SDG objective 13). Through the analysis, we have suggested certain policy directives, which can further help in attaining the objectives of the mentioned SDGs. There lies the policy-level contribution of the study.

The remainder of this article is divided into the following sections: Section two explains the relevant literature. Section three describes the data sources and estimation strategy to be used. Section four discusses the empirical results and discussion. Section five discusses the implications for policy. Lastly, concluding remarks are provided in the sixth section.

2. Literature review

The existing literature has considered several determinants of energy demand for different levels of the economy, and these determinants include income, industrialization, trade, greenhouse gas emissions, urbanization, etc. (see, Adewuyi and Awodumi, 2017; Farhani and Solarin, 2017; Faisal, et al., 2017; Koengkan, 2018; Lv, et al., 2019; Gómez and Rodríguez, 2019; Sinha et al., 2020). Literature has the evidence of mixed findings for the impact these indicators, depending on the study period and level of income. We intend to discuss two strands: firstly, this study unveils the impacts of export product diversification on energy demand in emerging economies, by incorporating three indices, i.e. export diversification, extensive margin, and intensive margin, and second, this study provides conclusive evidence concerning the role of natural resources, oil prices, income level, and urbanization in the NICs.

Shahbaz et al. (2019b) analyzed the relationship between human capita, export diversification and energy demand of United States. For empirical analysis, the paper employed the bootstrapped autoregressive-distributed lag (ARDL) technique and Vector Error Correction Mechanism (VECM) based Granger causality methods by using the data of United States from 1975 to 2016. The empirical results concluded that export diversification reduces the energy demand of United States. Further, the results demonstrated that natural resources and income level negatively affect overall energy consumption. Gozgor and Can (2016a) opined that export product diversification positively influences the economic growth in low and middle-income countries. In a subsequent study, Gozgor and Can (2016b) also concluded that export diversification positively influences the energy consumption on carbon emissions of Turkey. However, for NICs, rising dependence on export might lead to rise in energy consumption. Therefore, we can hypothesize the impact of export diversification in the following manner:

H1: Export diversification exerts positive impact on energy consumption.

In addition, the existing literature has further highlighted that natural resources and oil price shocks affect energy demand. For instance, Bentzen and Engsted (1993) found that volatility in oil price significantly affects the energy consumption of Denmark. Gately and Huntington (2002) examined the impacts of oil prices and income on energy demand for 96 countries. The study concluded that changes in oil prices significantly influence the energy demand of OECD countries. Ozturk (2010) analyzed the energy-economic growth nexus by conducting an in-depth literature survey. The study indicated that energy consumption positively influences the economic progress and economic growth significantly influences energy demand. Similarly, by employing panel smooth transition regression technique with error correction term (PSECM), Lee and Chiu (2013) argued that oil price volatility and real income significantly influence the energy demand of OECD countries. Sohag et al. (2015)

examined the role of trade openness, per capita income, and technological innovation on energy demand for Malaysia by using the data from 1985 to 2012. The study employed an ARDL bound testing approach for empirical analysis. The empirical results argued that trade openness, income level, and technological innovation positively influence the energy consumption in Malaysia. Sorrell (2015) provided an overview regarding the issues and challenges of reducing global energy demand. The paper argued that reducing energy demand might be more difficult than it is commonly assumed, and the policymakers need to adopt innovative policies in this pursuit. More recently, Lv et al. (2019) investigated the impacts of income level and urbanization on energy intensity by using the data of 224 cities of China. The article applied spatial panel data methodologies in empirical analysis, by using the annual data for the period of 2005 to 2016. The authors mentioned that income level induces increase in energy intensity, while urbanization is found to reduce energy intensity. Waheed et al. (2019) conducted an in-depth empirical survey of economic growth, energy consumption, and carbon emissions by analyzing the single country and panel data studies. The researchers opined that economic growth positively affects the energy demand in developing countries. As the context for the present study is the NICs, then it can be assumed that these nations are in pursuit of high economic growth, which will call for high energy consumption. This elevated economic growth is associated with increase in vocational opportunities, which might attract people from the rural areas to urban areas, and the rise in urban population might in turn increase the demand for energy. On the flipside, this energy consumption might be affected negatively by the high price of crude oil, as the nature of energy consumed in these nations is primarily non-renewable in nature (Sinha and Sengupta, 2019). Grounded on this discussion, we can assume that for the NICs, income, natural resources, and urbanization are expected to have positive impact on the energy consumption, whereas the impact of oil prices is expected to be negative. Therefore, we can hypothesize the impact of these parameters in the following manner:

H2: Income exerts positive impact on energy consumption.

H3: Urbanization exerts positive impact on energy consumption.

H4: Abundance of natural resources exerts positive impact on energy consumption.

H5: Crude oil price exerts negative impact on energy consumption.

Based on these five hypotheses, we will now proceed with the empirical model. Table 1(b) reports a brief summary of the literature regarding the determinants of energy demand for the case of developing, developed and emerging countries.

<<Insert table 1(b)>>

3. Data and Estimation strategy

3.1. The Modeling and Data Overview

According to existing studies (Mahalik, et al., 2017; Koengkan, 2018; Neagu and Teodoru, 2019), the economic structure including; oil prices, trade, exports quality, natural resources and urbanization influence the overall energy consumption and energy structures (Gómez and Rodríguez, 2019). The export product diversification is chosen as a primary explanatory variable, because it might be considered as a predictor of economic growth as well as energy use. However, the export product diversification index (Theil index) is divided into export diversification, extensive margin and intensive margin, which is a measure of the diversification of export portfolio and trading relationship, as these variables are not included in panel analysis for energy consumption (Papageorgiou and Spatafora, 2012). The reason for including the export product diversification as the primary explanatory variable is owing to the fact that product quality, innovative production structure, and trading relations increase the overall energy usage to achieve the desired economic goals (Koengkan, 2018).

There are certain rationales behind the choice of these variables. From an endogenous growth perspective of a nation, we intend to assess the impact of export product diversification on energy demand. Now, energy demand can reduce due to number of factors, e.g. achievement of energy efficiency, level of unemployment, standard of living, shift in industrial structure, and several others. However, in this study, the variables are chosen within the purview of export diversification, which is endogenously catalyzed. Now, when export portfolio of a nation is diversified, energy-intensive products are substituted with energy-efficient products or services. This shift in the export portfolio is hypothesized to be driven by the objective of the policymakers to achieve the sustainable development, and in this pursuit, the nations need to reduce their dependence on the fossil fuel-based energy solutions. Following might be the possible sequence of events in the NICs:

1. In the NICs, the major source of energy is the natural resources and crude oil. Consumption of these natural resources and crude oil generates energy to be utilized by industrial sector and households.
2. When industry grows, per capita income rises, along with the rise in vocational opportunities in urban areas. This is when the urban areas experience a migration of labors from the rural and semi-urban areas. These growing urban areas catalyze the increase in the demand of energy due to rise in household activities.
3. Combination of all these activities gradually starts degrading the environment by creating ambient air pollution, soil contamination, and faster depletion of natural resources. In order to combat these issues, policymakers strive to boost the technological innovation in reducing the energy consumption or making efficient use of energy consumption. Therefore, impact of technological innovation taken by the industrial sector is directly seen in terms of diversification of export portfolio.

From this discussion, it seems that technological innovation should also be a part of the empirical model. We have chosen not to include technological innovation or industrial shift in our model as all the technological innovations carried out within a nation are not in pursuit of achieving energy efficiency, or the entire government expenditure in pursuit of achieving energy efficiency is not realized in full. Diversified export portfolio can therefore be a better indicator of technological advancements being carried out in a nation. On the other hand, the impact of industrial shift will have an impact on the per capita income, urbanization pattern, and demand of natural resources. Hence, considering industrial shift in the empirical model could have caused the problem of multicollinearity.

The article focuses on energy consumption (kg of oil equivalent per capita) as a dependent variable and export product diversification, extensive margin and intensive margins, natural resources and oil prices are considered as key explanatory variables. However, GDP as a proxy for economic growth, and urbanization are taken as controlling factors. The data on overall export product diversification, extensive margin and intensive margin has been obtained from the database of International Monetary Fund (IMF, 2019). The relevant data set had recently been compiled by IMF staff and considers diversification indices between product and trade partners (market or target). The high values of the Theil index represent concentration, and the low values represent diversification. The data for energy consumption, GDP, natural resources and urbanization is taken from World Development Indicators (World Bank, 2019), while the data for oil price is gathered from British Petroleum database (BP Statistics, 2019). The overall panel data for all studied variables is gathered for the period of 1971-2014 for 10 NICs, which is contingent on the data availability of energy consumption and export diversification indicators. The choice of selecting the NICs is based on the fact that these countries have surpassed the developing countries but have not reached at the level of developed nations (Elisha, 2017). Table 2(a) illustrates the data sources and variables specifications, while Table 2(b) presents the descriptive statistics and pairwise correlation estimates of the variables with respect to energy consumption. Pairwise correlations are provided in Appendix 1A to 1C and multicolinearity statistics are provided in Appendix 2. In order to handle the multicolinearity issue, variables are orthogonally transformed, i.e. the matrix of vectors is perpendicularly rotated along the diagonal of the matrix, while retaining the vector lengths and angular dimensions.

<<Insert table 2(a)>>

<<Insert table 2(b)>>

In order to explore the relationship between export product diversification and energy consumption, the panel data methodology is utilized due to its ability to control serial correlation and heterogeneity issues (Baltagi, 2005; Neagu and Teodoru, 2019). To avoid panel heteroskedasticity and to reduce data fluctuation, the variables energy consumption, oil price, and GDP are converted in natural logarithms.

$$ec_{i,t} = f(div_{i,t}, oil_{i,t}, gdp_{i,t}, res_{i,t}, urb_{i,t}) \quad \text{eq-1}$$

In equation 1, export product diversification index (*div_{it}*) is desegregated into export diversification, extensive margin and intensive margin in following three empirical models. Taking energy demand as the dependent variable, following are the three estimation models:

Model-1:

$$ec_{,it} = \beta_0 + \beta_1 div_{i,t} + \beta_2 oil_{i,t} + \beta_3 gdp_{i,t} + \beta_4 res_{i,t} + \beta_4 urb_{i,t} + \mu_{i,t} \quad \text{eq-2}$$

Model-2:

$$ec_{,it} = \beta_0 + \beta_1 ext_{i,t} + \beta_2 oil_{i,t} + \beta_3 gdp_{i,t} + \beta_4 res_{i,t} + \beta_4 urb_{i,t} + \mu_{i,t} \quad \text{eq-3}$$

Model-3:

$$ec_{,it} = \beta_0 + \beta_1 inten_{i,t} + \beta_2 oil_{i,t} + \beta_3 gdp_{i,t} + \beta_4 res_{i,t} + \beta_4 urb_{i,t} + \mu_{i,t} \quad \text{eq-4}$$

Where, i refers to country, t refers to time, $ec, div, ext, \text{int}en, oil, gdp, res, urb$ indicates total energy consumption, export diversification, extensive margin, intensive margin, oil price, per capita income, natural resources and urbanization respectively. The error term is represented by μ .

3.2. Export diversification indices

Export diversification refers to widening the range of products that a country exports (Dennis and Shepherd, 2011). The extensive margin is elaborated as the variation in the number of new products exported and number of new markets for existing exports. The intensive margin enlists the variation in export figures among existing exports, and the intensive and extensive margin together known as new products and new markets (Cadot et al., 2011). In a nutshell, the intensive margin is defined as the growth of exports in existing goods (old products), while the extensive margin is known as export growth in new categories (new products) (Pacheco and Pierola, 2008).

The overall export product diversification indices (export products, extensive margin, and intensive margin) are reported by the International Monetary Fund (IMF, 2019) by using the definition of Cadot et al. (2011). Theil index is estimated for each country in different years as:

$$Ex_b = \sum n \left(\frac{P_n}{P} \right) \left(\frac{Q_n}{Q} \right) \ln({}^{Q_n}\!/_{Q}), \qquad \text{eq-5}$$

Here, n presents different products as traditional, non-traded and new, P_n is the total number of products exported in each group and ${}^{Q_n}\!/_{Q}$ is the relative mean of total exports in each group. The Intensive Theil index is measured as;

$$Int_b = \sum n \left(\frac{P_n}{P} \right) \left(\frac{Q_n}{Q} \right) \left\{ {}^{1}\!/_{P_n} \right\} \sum i \in 1n({}^{x_i}\!/_{Q_n}) \ln({}^{x_i}\!/_{Q_n}) \qquad \text{eq-6}$$

In eq-6, x_i presents the export value for each country. While, the overall export diversification index is estimated as a mean average of extensive and intensive margins.

3.3. Estimation Strategy

Due to the interdependence and integration of global economies in the international market and common policies, a cross-sectional dependence across panels or countries may exist (Sarwar, et al., 2017; Neagu and Teodoru, 2019). The cross-sectional dependence is estimated by cross-section dependence test (Pesaran, 2004).

$$CD\sqrt{\frac{2}{n(n-1)}}\sum_{i=1}^{n-1}\sum_{j=i+1}^{n} t_{i,j}\phi_{i,j} \longrightarrow n(0,1) \qquad \text{eq-7}$$

Where, CD presents the cross-sectional dependence with Lagrange multiplier, $\phi_{i,j}$ reports the sample estimate of the pair-wise correlation of residuals. After examining the cross-sectional dependence, panel unit root tests are employed to examine the stationarity property of variables. For unit root testing, we employed the second-generation techniques CIPS unit root test developed by Im-Pesaran-Shin (2002) and cross-sectionally augmented Dickey and Fuller (CADF) test introduced by Pesaran (2007). While testing the stationarity property, we consider an autoregressive AR (1) process across countries in panel data.

$$z_{it} = q_i z_{it} - 1 + y_{it}\partial_i + \varepsilon_{it} \qquad \text{eq-8}$$

Where, i denotes time period, y_{it} shows the exogenous variable (includes individual trends and fixed effects), q_i shows the autoregressive coefficients and ε_{it} denotes the error term, assumed to be mutually independent idiosyncratic disturbance. When $q_i = 1$, z_i has the unit root problem. Further, there might be panel heterogeneity, when dealing with panel data techniques. It is assumed that the variations between cross-sectional units are captured by fixed effects, some individual variability among cross-sections may still exist (due to differences in industrial, energy system and economic structures), and if it is not taken into consideration, it may lead toward biased outcomes. Therefore, the cointegration among the variables will be explored by using the panel cointegration method by Westerlund and Edgerton (2008). This cointegration technique generates samples via LM bootstrap cointegration approach and constructs two statistics. The significance of this approach is due to its null hypothesis that implies long run cointegration existence among variables and addresses state of heterogeneity in modeled variables. The test statistics reported by this test are given by:

$$LM_{\varphi}(i) = T\hat{\varphi}_i(\hat{r}_i/\hat{\sigma}_i) \quad \text{eq-9}$$

$$LM_{\tau}(i) = \hat{\varphi}_i/SE(\hat{\varphi}_i) \quad \text{eq-10}$$

Here, $\hat{\varphi}_i$ is the approximation of φ_i against standard error $\hat{\sigma}_i$, and $\hat{r}^2{}_i$ is the estimated long run variance of m_{it}, $\varphi_i(L) = 1 - \sum_{i,j} \varphi_{ij} L^j$ is a scalar polynomial with lag length L, and ρ_i is the vector of factor loading parameters. These statistics account for the structural breaks in the form of level shifts and regime shifts.[2]

3.4. Robustness check

In addition, the study further applied the system GMM approach and FGLS technique on our three baseline models (Arellano & Bover, 1995). The system GMM approach is employed as forward difference instrumental variables, to avoid endogeneity and reverse causality problems. FMOLS and DOLS cointegration techniques are applied for robustness check, so as to ensure that our findings are valid and not spurious. Details of the estimation procedures are explicated in Appendix 3.

4. Empirical Results and Discussion

In pursuit of finding the association between energy consumption and its possible determinants in the NICs, we have carried out the empirical estimation, and as the first steppingstone of the analytical process, we have assessed how the cross-sections of the data are dependent on each other. With this purpose, we have employed Pesaran (2004) cross-section dependence test, and the test outcomes are described in Table 3 indicate the presence of cross-sectional dependence in the data. This validates the applicability of the second-generation unit root test.

[2] Level shift is the change in the nominal value of the data at a particular time, whereas Regime shift is a persistent change in the data.

<<Insert Table 3>>

Before going for estimating the long-run coefficients, we need to assess the order of integration of the variables, by checking their stationarity properties. In doing so, we have employed cross-sectional Im-Pesaran-Shin, (2002) (CIPS unit root test) and cross-sectionally augmented Dickey and Fuller (CADF) tests by Pesaran (2007). For both the tests, the model parameters found to be having the unit root at the level, and the unit-roots are removed at the first difference. Therefore, it can be concluded that the variables are first order integrated and hence validating the application of cointegration test.

<<Insert Table 4>>

Once we found the evidence for the integrating property of the model parameters, we can now proceed with the validation of the long-run association among them. In this pursuit, we have conducted the Westerlund and Edgerton (2008) panel cointegration test. The described test results in Table 5 divulge that the model parameters are significantly cointegrated, and the long-run association among the variables is corroborated across the three empirical models. Founded on this piece of evidence, we can proceed for estimating the long-run coefficients of the model parameters.

<<Insert Table 5>>

<<Insert Table 6>>

With a view to estimate the determinants of energy demand across the three estimation models, we have employed the Generalized Method of Moments (GMM) and the estimation outcomes are stated in Table 6. The impact of export diversification on energy consumption is found to be negative and significant. This can have a significant implication towards the sustainable energy future of the NICs, as these countries have been reportedly failed to meet various objectives of SDGs. This is reflected in terms of the association between export diversification and energy consumption, as rise in the export product diversification is found to have catalyzing the growth in energy consumption in the NICs[3]. Here, we need to remember that the values of export product diversification, represented by Theil Index, are negative. As these countries are majorly export-driven, therefore, the dependence on the commercial energy consumption can be assumed, and at the same time, in order to achieve growth, policymakers in these nations might be giving economic growth more preference over the achievement of ecological sustainability. In such a scenario, rise in the export product diversification might result in further rise in energy consumption. This segment of the results can be considered as an extension of the findings of Gozgor and Can (2016b). However, this segment of the results also contradicts the findings of Shahbaz et al. (2019b) in the case of the US.

While saying this, it should be understood that growth in export diversification can be carried out either through economies of scale or economies of scope. In this pursuit, we have analyzed the intensive and extensive margins of export diversification. In Table 6, both the margins have significant and negative impacts on energy consumption. This segment of the results indicates that the production processes followed in the NICs are largely driven by the consumption of commercial energy, and in this pursuit, export-led economic growth in these nations is largely driven by commercial energy. Horizontal or vertical expansion of the export product lines are responsible for increasing the demand of commercial energy, and thereby, defining the problem of sustainable energy implementation in these nations, notwithstanding the SDG objectives. Irrespective of achieving economies of scale or scope, export portfolio is found to be energy-intensive, and this segment of this results fall in the similar lines with the impact of overall export diversification on energy consumption. Literature of energy economics has largely focused on this aspect, whereas the individual constituents of the export diversification index have been largely ignored. Our study contributes to the literature

[3] Values of export product diversification, represented by Theil Index, are negative.

of energy economics by analyzing the impacts of intensive and extensive margins of export diversification on energy consumption.

Now, for the NICs, energy consumption majorly takes place through the consumption of fossil fuel, and in this pursuit, these countries are recognized as crude oil importers. Therefore, any fluctuations in the oil prices would have an inverse direct impact on the energy consumption pattern. In view of this phenomenon, it can be assumed that any rise in crude oil price will eventually decrease the energy consumption in these countries. The results obtained by us in the course of the study indicate this particular phenomenon, and this result is consistent across the empirical models. This segment of the results falls in similar lines with Mensah et al. (2019) for Africa, and extends the finding of Mo et al. (2019) and Lu et al. (2020).

The export-oriented growth in the NICs might be assumed to be driven by industrial development of these nations, which might have a consequential impact on the per capita income and standard of living. This rise in industrial development will also necessitate the rise in commercial energy consumption, and hence, GDP might be considered as one of the drivers of energy consumption in these nations. The positive and significant coefficients of GDP across three empirical models reported in Table 6 show that the rise in GDP might lead to rise in energy consumption in NICs during the study period. Following the seminal work of Kraft and Kraft (1978), this association has been analyzed by researchers for three decades. This segment of our findings falls in the similar lines with Hossain (2011) for the NICs, Gorus and Aydin (2019) for the MENA countries, Zafar et al. (2019) for the APEC countries, and several others. Ozturk (2010) has provided with a detailed survey of literature on this association, while Sinha (2019) has provided a different methodological perspective on this aspect.

While stating about the nature of economic growth in the NICs, we should also consider the rich resource pool of these nations, which also complements the economic growth. The commercial energy consumption is majorly carried out through the consumption of these natural resources, and therefore, the abundance of natural resources in these nations might be direct proportionate to the consumption of commercial energy. Reflection of this association can be visualized in the coefficients of natural resources in Table 6. This segment of the results shows that for the NICs, the abundance of natural resources drives the energy consumption, and this finding falls in the similar lines with Wu et al. (2018), Bekun et al. (2019), Shahbaz et al. (2019a), and several others.

Lastly, when the industrialization sets in, vocational opportunities rise. Due to the consequential demand created in the labor market, people from rural areas start migrating towards the industrialized urban areas. With graduation of time, rise in migrated population in the urban areas increases the energy demand for habitual sustenance. Therefore, it can be inferred that rise in urbanization, in turn, leads towards the rise in energy consumption. The results stated in Table 6 show that the coefficients of urbanization across three models are positive and significant, and this indicates that for the NICs during the study period, rise in rural-urban migration might result in the surge in the energy consumption. This segment of the results falls in similar lines with the findings of Shahbaz and Lean (2012), Bakirtas and Akpolat (2018), and several others.

The models have been analyzed using FGLS tests and the test outcomes are stated in Table 6. Except for the coefficient of oil price, all remaining coefficients are consistent. The results of the FGLS test validate the results obtained in GMM.

To check the robustness of the model estimates, we have conducted the FMOLS and DOLS tests on the three empirical models. The results of this empirical exercise are stated in

Table 7. All the coefficients have demonstrated consistency across the empirical models. This validates the robustness of the results.

<<Insert Table 7>>

5. Implications for policy

By far, we have estimated the impact of export diversification and its components on energy consumption, in the presence of natural resource abundance, crude oil price, urbanization, and economic growth. The results show that the export diversification and its components result in a rise in energy consumption. Except for crude oil price, other moderating parameters also exert the similar impact on energy consumption. These findings might be important from the perspective of sustainable development, as we have already discussed how the results indicate the unsustainable nature of this energy-led export-oriented growth. In view of the negative externalities caused by the energy consumption pattern, the existing energy, and the allied economic policies need to be revised for addressing the SDGs. Over the last decade, the researchers in energy, environmental economists and policymakers have been putting forth effort in internalizing these negative externalities, and considering the context of NICs, these policy level revisions might prove to be crucial (Sinha et al., 2017, 2018; Zafar et al., 2019).

As a whole, these results provide significant insights regarding the sustainable energy future of the NICs. While these countries are characterized by export-led economic growth, the export portfolio is majorly developed by utilizing commercial energy, which is derived from fossil fuel and other natural resources. This elevation in economic growth is creating several vocational opportunities, leading to the rural-urban migration. Along with the rise in pressure on urban infrastructure, this rise in urbanization is also resulting in a further increase in the energy demand. Now, in such a situation, the existing energy generation infrastructure might not be enough to cater to this rising demand for energy, and this might have further negative consequences. First, dependence on natural resources for energy generation might bring about faster depletion of natural resources, and thereby, these countries might resort to importing of fossil fuel sources, which will have a negative impact on their trade balance. Second, the dependence of natural resources and price of imported crude oil might make the commercial energy costlier with the graduation of time. Third, rise in energy prices might escalate the cost of production, and thereby, diminishing the competitiveness of the export portfolio. Fourth, the consumption of fossil fuel in the process of energy generation will have negative environmental consequences. Policymakers might consider these aspects, so that the negative externalities caused by the energy-led growth can be internalized in the growth trajectory, without slowing down the pace of growth.

While saying this, a few caveats need to be remembered. They are discussed in the sequential manner:

1. It should not be overlooked that the dependence on the commercial fossil fuel-based energy consumption has led the NICs to the export competitiveness in the global market. Therefore, while designing the new energy and other economic policies, the policymakers should take care about not to harm the economic growth pattern, and this internalization of the negative externalities can be carried out in a phase-wise manner.
2. As the urbanization rate will rise with the rise in the growth in industrialization, the total demand for energy will rise in the coming years, and the existing energy generation infrastructure might not be capable enough to cater to that level of demand.
3. Moreover, the rise in the demand for the goods produced in these nations will also drive the demand for energy. If these nations keep on relying on the traditional fossil fuel sources for generating commercial energy, then these nations might encounter energy security issues, along with the deterioration in environmental quality. In such a situation,

these nations should gradually shift towards renewable energy sources for energy generation.

4. However, as renewable energy implementation is costly, this shift might have a negative consequence on the cost of production, and thereby, diminishing the competitiveness of the export and harming the economic growth. So, this shift needs to be carried out in a phase-wise manner (Roy and Singh, 2017; Roy et al., 2018). Following are the sequential phases:
    a. In the initial phase, the low-cost renewable energy solutions can be provided to the households, and the high-end renewable energy solutions can be provided to the industries. For both cases, these solutions can be provided by the government at a pro-rata rate. Based on the capacity of the solution, interest income can be imposed, which may also vary according to the level of income of the household or net revenue of the firm.
    b. In so doing, for covering the short-run economic losses, the government might gradually decrease the subsidies on the fossil fuel-based energy, increase the import duties on crude oil, and channelize the incremental subsidy earning towards the renewable energy solutions. It will not only make the renewable energy solutions affordable but also will discourage the industries and households to consume fossil fuel-based energy and encourage renewable energy implementation.

6. Concluding remarks

This article examined the impact of export product diversification on the rising energy demand of 10 NICs. To test the primary narrative of paper, the study applied Westerlund and Edgerton (2008) cointegration, FGLS regression, system GMM, FMOLS, and DOLS techniques for three model specifications (for three indicators of export diversification). To summarize, the present study highlights innovative conclusions based on the association between export diversification, extensive margin, intensive margin, natural resources and oil prices. Firstly, the paper demonstrates that export product diversification, extensive margin, and intensive margin help to reduce overall energy demand. Notably, this finding is line with sustainable development goals for emerging countries, inferring that more products in export basket and improvement in trading relations might help to reduce energy demand, which in turn can assist in achieving cleaner environment objectives. Secondly, the empirical results indicate that oil prices shocks lead to reduction in energy demand, while increase in natural resources positively affect the overall energy demand in NICs. Lastly, the study observed positive association between energy demand and economic growth, which validates the growth hypothesis for the case of NICs. The empirical finding suggests that economic progress of emerging economies is dependent on energy sources, and the NICs might ponder upon finding alternative energy sources, which can also help to achieve several objectives of the SDGs.

During the initial stages of implementation, the renewable energy solutions might be imported from developed nations. Henceforth, the government should encourage the domestic capacity building for the research and development towards the discovery of alternate energy solutions. At the same time, the industries also focus on enhancing the energy efficiency of the production processes and reducing the level of pollution being created by those processes. The financial institutions might be directed by the policymakers to introduce discriminative credit policy based on the level of negative environmental externalities caused by the firms. This will also force the firms to implement cleaner technologies.

While carrying out these exercises, the policymakers should not disregard the role of environmental awareness among the citizens. In this pursuit, the policymakers should stress on people-public-private partnerships to (a) protect the environment, (b) enhance environmental awareness among citizens, and (c) increase green and sustainable vocational opportunities. These approaches being taken up by the citizens will help the policymakers to define and enforce the rights to use of public goods, protect the natural resource pool, and inculcate the energy-efficient habits at the household level. All these actions will lead these nations to address the issues regarding (a) inexpensive and clean energy for everyone (SDG objective 7), (b) fostering innovation for industrial infrastructure (SDG objective 9), (c) improving the environmental quality (SDG objective 13), and (d) bringing sustainability in the consumption pattern (SDG objective 12) (UNDP, 2017). While addressing these issues, the policymakers will be largely ensuring the sustainability of economic growth (SDG objective 8) and making the industrial cities sustainable (SDG objective 11) (UNDP, 2017).

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Figure and Tables:

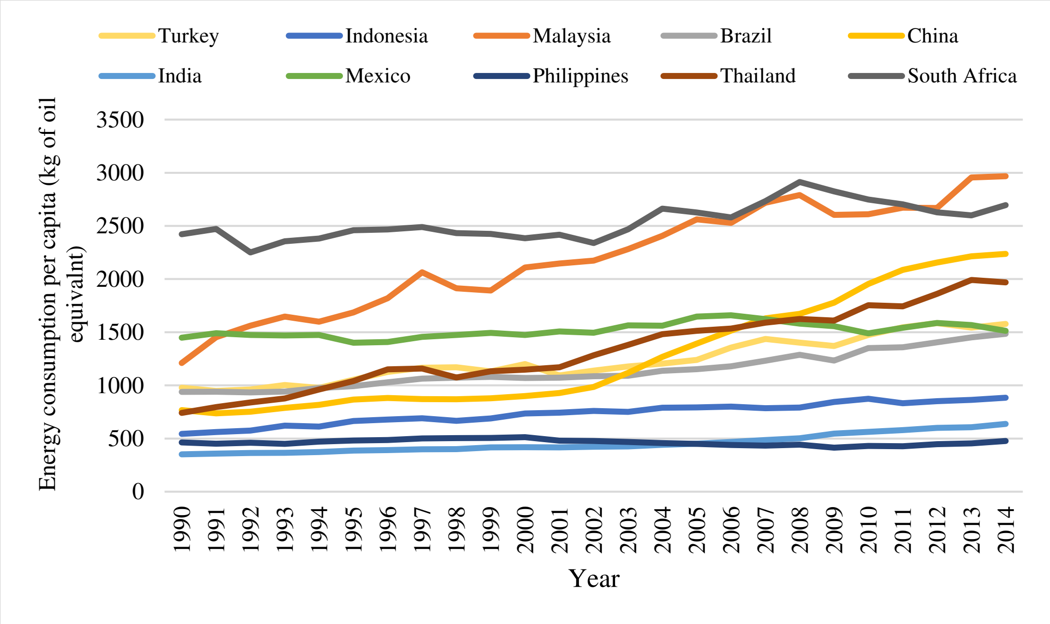

Figure 1: Trends in Energy Consumption per capita of NICs   Source: Authors tabulation

Table 1 (a): Energy Consumption, exports and GDP figures of NICs in 2014

Country	Energy consumption per capita (kg of oil equivalent)	Exports of goods and services (constant 2010 US $, Values in millions)	GDP per capita (constant 2010 US $)
Brazil	1495	225,098	11951
China	2237	2,342,293	6097
Indonesia	884	150,366	3693
India	637	317,545	1640
Mexico	1562	396,882	9839
Malaysia	3003	234,135	10524
Philippines	474	61,810	2496
South Africa	2695	92,590	7583
Thailand	1969	227,573	5589
Turkey	1651	157,610	13277

The table presents the figures for the period 2013 to 2014, based on availability of data for 10 newly industrialized countries.

Source: World Bank (2019)

Table 1 (b): Summary of Literature

Authors	Period	Countries	Methods	Results
Bentzen and Engsted (1993)	1948–1990	United States	Cointegration technique	Oil→EC
Gately and Huntington (2002)	1971–1997	96 countries	Structural model	EG↔EC
Altinay and Karagol (2004)	1950–2000	Turkey	Granger causality	EG≠EC
Paul and Bhattacharya (2004)	1950–1996	India	ECM	EG←EC
Shiu and Lam (2004)	1971–2000	China	ECM	EG→EC
Yoo and Kim (2006)	1971–2002	Indonesia	Granger causality	EG→EC
Ang (2008)	1971–1999	Malaysia	VECM model	EG→EC
Soytas and Sari (2009)	1960–2000	Turkey	Toda-Yamamoto test	EG≠EC
Huntington (2010)	1997–2006	United States	Decomposition	Oil→EC
Hossain (2011)	1971–2007	NICs	Panel cointegration & Granger causality	EG→EC URB→EC
Sohag et al. (2015)	1985–2012	Malaysia	ARDL bound test	EG→EC
Saidi and Mbarek (2016)	1990–2018	9 developed countries	Panel DOLS and FMOLS	EG≠EC
Destek (2016)	1971–2011	NICs	ARDL bound test	REC↔EG
Wang et al. (2016)	1990–2012	China	Granger causality	EG↔EC
Bakirtas and Akpolat (2018)	1971–2014	Emerging countries	Bivariate and tri-variate panel Granger causality	EG→EC URB→EC
Mrabet et al. (2019)	1980–2014	developed and emerging countries	Augmented Mean Groups (AMG)	Urbanization →Non-REC
Shahbaz et al. (2019b)	1975–2016	United States	Autoregressive-distributed lag (ARDL)	Diver↔EC
Samargandi (2019)	1990–2016	OPEC countries	Panel ARDL	REC→EC GDP→EC
lv et al. (2019)	2005–2016	China	Spatial panel data techniques	EG→EC
Bekun et al. (2019)	1960–2016	South Africa	Pesaran et al. (2001) bounds test	EG←EC

Notes: EG denotes economic growth, EC means energy consumption and URB shows urbanization, NREC reflects non-renewable energy, Diver shows the export diversification. ← , → represents unidirectional, ↔ is bidirectional, whereas, ≠ presents no relationship.

Table 2 (a): Data and Variables specification

Variables	Specification	Data Source	Status
Energy Consumption	Energy consumption per person (kg of oil equivalent per capita)	World Bank	Dependent Variable
Export diversification	Export quality measures across different aggregation levels of export products	IMF	
Extensive Margin	Quality of trading relationship	IMF	Independent Variables
Intensive Margin	The actual trade in trading relationship	IMF	
Oil Price	Oil price is taken in Dollars per barrel as per brunt standard	BP Statistical Review	
GDP	GDP is taken as per capita constant 2010 US $	World Bank	Control Variables
Natural Resource	Natural resources (oil, natural gas, mineral, forest and coal rents as a share of GDP	World Bank	
Urbanization	urban population as the share within the total population	World Bank	

Export diversification index provides three measures for exports of new products into new markets; Export diversification, Extensive Margin and Intensive Margin.

Table 2 (b): Summary statistics and pairwise Correlation

	Descriptive statistics					Correlation
Variables	Obs	Mean	Std. Dev.	Min	Max	Energy Consumption
Energy consumption	440	6.648	0.560	5.591	7.995	1
Export diversification	440	2.474	0.631	1.680	4.840	-0.2431*
Extensive Margin	440	0.289	0.242	0.000	1.060	-0.4981*
Intensive Margin	440	2.185	0.520	1.300	3.850	-0.0627
Oil	440	3.887	0.586	2.606	4.798	0.1039*
GDP	440	7.922	1.035	5.471	9.496	0.7370*
Natural resources	440	5.804	6.531	0.123	37.570	0.0816
Urbanization	440	47.764	18.437	17.184	85.433	0.6981*

*The pairwise correlation statistics are obtained at significance level of 5%.

Table 3: Results of Cross-Section Dependence test

Variable	*Test statistic*	*Variable*	*Test statistic*
Energy Consumption	21.40[a]	Oil Price	44.50[a]
Export Diversification	7.44[a]	GDP	37.10[a]
Extensive Margin	25.80[a]	Natural Resource	17.97[a]
Intensive Margin	3.86[a]	Urbanization	40.66[a]

a is significant value at 1% level.

Table 4: Results of Second-Generation Unit Root test

Test	*Variable*	*Level*	*First Difference*
CIPS	Energy Consumption	-1.826	-5.534[a]
	Export Diversification	-2.206	-5.373[a]
	Extensive Margin	-2.212	-5.260[a]
	Intensive Margin	-2.229	-5.333[a]
	Oil Price	-2.091	-6.169[a]
	GDP	-1.730	-5.043[a]
	Natural Resource	-1.417	-6.154[a]
	Urbanization	-1.781	-5.364[a]
CADF	Energy Consumption	-1.575	-3.624[a]
	Export Diversification	-2.119	-4.476[a]
	Extensive Margin	-1.734	-3.927[a]
	Intensive Margin	-1.667	-4.001[a]
	Oil Price	-2.012	-5.311[a]
	GDP	-1.798	-3.969[a]
	Natural Resource	-2.175	-5.716[a]
	Urbanization	-1.599	-3.746[a]

a is significant value at 1% level.

Table 5: Findings for Westerlund and Edgerton (2008) cointegration test

		No Shift Statistic	*Level Shift Statistic*	*Regime Shift Statistic*
Model 1	LM_{τ}	-13.974[a]	-9.409[a]	-8.583[a]
	LM_{ϕ}	-24.974[a]	-15.446[a]	-14.153[a]
Model 2	LM_{τ}	-12.985[a]	-7.482[a]	-3.039[a]
	LM_{ϕ}	-22.295[a]	-11.450[a]	-6.572[a]
Model 3	LM_{τ}	-18.664[a]	-2.134[a]	-4.473[a]
	LM_{ϕ}	-28.865[a]	-3.726[a]	-6.544[a]

Notes: Models are applied with a maximum number of 5 factors, a is significant value at 1% level.

Table 6: Empirical estimates with system GMM and FGLS regressions

	SGMM			FGLS regressions		
Variables	Model-1	Model-2	Model-3	Model-1	Model-2	Model-3
Export Diversification	-0.2313[a] (-33.80)	-	-	-0.2295[a] (-7.77)	-	-
Extensive Margin	-	-0.7083[a] (-44.530)	-	-	-0.6498[a] (-9.22)	-
Intensive Margin	-	-	-0.2206[a] (-23.81)	-	-	-0.2246[a] (-5.40)
Oil Price	-0.0472[a] (7.150)	-0.0339[a] (-5.570)	-0.0489[a] (-7.42)	-0.0441 (-1.52)	-0.0300 (-1.06)	-0.0469 (-1.56)
GDP	0.3090[a] (37.490)	0.2557[a] (33.53)	0.3190[a] (38.52)	0.3108[a] (8.57)	0.2616[a] (7.37)	0.3209[a] (8.50)
Natural Resources	0.0230[a] (33.480)	0.0097[a] (16.910)	0.0236[a] (30.92)	0.0217[a] (7.53)	0.0081[a] (3.15)	0.0229 (6.83)
Urbanization	0.0060[a] (13.310)	0.0067[a] (16.250)	0.0064[a] (14.34)	0.0059[a] (2.95)	0.0066 (3.42)	0.006 [a] (3.08)
Constant	4.5048 (82.58)	4.5556 (91.07)	4.3162 (80.06)	4.4879 (18.73)	4.492 (19.36)	4.312 (17.56)
AR (1)/ Autocorrelation	0.572	0.539	0.544	No	No	No
AR (2)/Homoscedastic panels	0.981	0.947	0.986	Yes	Yes	Yes
Number of Instruments	425	425	425			
Year effects	yes	Yes	Yes	Yes	Yes	Yes

Note: a show the significance level at 1%. Z-statistic values are shown in parentheses. AR1 & AR2 are p-values for Arellano–Bond test for first-order serial autocorrelation & Arellano–Bond test for second-order serial autocorrelation. In SGMM and FGLS regressions country fixed effects and year fixed effects are considered in all specifications.

Table 7: Long-run estimates using FMOLS and DOLS techniques

	FMOLS			DOLS		
Variables	Model-1	Model-2	Model-3	Model-1	Model-2	Model-3
Export Diversification	-0.3104[b] (-2.050)	-	-	-0.2354[a] (-3.3400)	-	-
Extensive Margin	-	-0.6860[a] (-3.180)	-	-	-0.6609[a] (-3.700)	-
Intensive Margin	-	-	-0.3094[b] (-2.410)	-	-	-0.2380[b] (-1.850)
Oil Price	-0.2486[c] (-1.670)	-0.0693 (-0.800)	-0.0835 (-0.900)	-0.0725 (-0.880)	-0.0491 (-0.570)	-0.0858 (-0.790)
GDP	0.2767 (1.490)	0.2182[b] (2.010)	0.3146[a] (2.700)	0.3070[a] (3.670)	0.2596[a] (2.970)	0.3176[a] (2.860)
Natural Resources	0.0363[b] (2.380)	0.0122 (1.550)	0.0313[a] (3.030)	0.0243[a] (3.570)	0.0097 (1.500)	0.0259[b] (2.530)
Urbanization	0.0066 (0.640)	0.0080 (1.350)	0.0055 (0.870)	0.0062 (1.350)	0.0070 (1.470)	0.0065 (1.080)
Constant	5.7510 (4.690)	4.9234 (6.960)	4.6899 (6.200)	4.6189 (7.960)	4.5644 (7.600)	4.5001 (5.900)
R^2	0.28	0.30	0.28	0.65	0.66	0.62
Newey-west Bandwidth	24.36	27.40	23.31	5.95	7.07	11.58
Number of observations	440	440	440	440	440	440

Note: a show the significance level at 1%, b denotes significance at 5% and C shows significance at 10%. Z-statistic values are shown in parentheses.

Appendix 1A: Correlation matrix considering Export Diversification

	Energy Consumption	Export Diversification	Oil Price	GDP	Natural Resource	Urbanization
Energy Consumption	1.0000					
Export Diversification	-0.4976	1.0000				
Oil Price	-0.3033	0.1495	1.0000			
GDP	0.8002	-0.2668	-0.0786	1.0000		
Natural Resource	0.1384	-0.3314	0.3332	-0.0862	1.0000	
Urbanization	0.7093	-0.2220	-0.1306	0.9196	-0.0982	1.0000

Appendix 1B: Correlation matrix considering Extensive Margin

	Energy Consumption	Extensive Margin	Oil Price	GDP	Natural Resource	Urbanization
Energy Consumption	1.0000					
Extensive Margin	-0.4976	1.0000				
Oil Price	0.1672	-0.0586	1.0000			
GDP	0.8002	-0.2668	0.1517	1.0000		
Natural Resource	0.1384	-0.3314	0.2901	-0.0862	1.0000	
Urbanization	0.7093	-0.2220	0.1435	0.9196	-0.0982	1.0000

Appendix 1C: Correlation matrix considering Intensive Margin

	Energy Consumption	Intensive Margin	Oil Price	GDP	Natural Resource	Urbanization
Energy Consumption	1.0000					
Intensive Margin	-0.1055	1.0000				
Oil Price	0.1672	0.0855	1.0000			
GDP	0.8002	0.0355	0.1517	1.0000		
Natural Resource	0.1384	0.4235	0.2901	-0.0862	1.0000	
Urbanization	0.7093	-0.0389	0.1435	0.9196	-0.0982	1.0000

Appendix 2: Multicolinearity statistics

Variables	Before transformation		After transformation	
	VIF	Tolerance	VIF	Tolerance
Energy Consumption	5.78	0.1732	1.00	1.0000
Export Diversification	30.30	0.0330	1.00	1.0000
Extensive Margin	3.87	0.2585	1.00	1.0000
Intensive Margin	28.27	0.0354	1.00	1.0000
Oil Price	1.16	0.8592	1.00	1.0000
GDP	12.22	0.0818	1.00	1.0000
Natural Resource	1.96	0.5092	1.00	1.0000
Urbanization	7.02	0.1424	1.00	1.0000

Appendix 3: Description of empirical procedures

System Generalized Method of Moments

The Generalized method of moments (GMM) was initially developed by Hansen in 1982. The GMM technique is considered suitable for panel data, when the number of moment conditions is smaller than number of parameters to estimate. In general, the GMM is a working procedure to estimate the equations with endogenous regressors in panel data and unobserved heterogeneity. In such a condition, the random effects, or fixed effects estimator is not considered suitable for a finite time period and huge observations of cross-section. In the economics literature, the typical dimension of panel data is to have little time period and large cross-sections, while the GMM estimator is considered suitable for consistent estimations. The GMM estimator was introduced by Arellano and Bond, (1991). The GMM estimator uses the lag levels of variables as instruments for endogenous differences. We apply the system GMM estimator with forward differenced equations, by considering the lags of instrumental variables which is helpful to avoid endogeneity and reverse causality issues (Muhammad, 2019; Shahzad et al., 2020).

$$g_n(\varphi) = \frac{1}{n}\sum_{t=1}^{n} g(w_t, \varphi) = \frac{1}{n}\sum_{t=1}^{n} x_t(y_t - z_t'\varphi) \begin{pmatrix} \frac{1}{n}\sum_{t=1}^{n} x_{1t}(y - z_t'\varphi) \\ : \\ \frac{1}{n}\sum_{t=1}^{n} k_t(y - z_t'\varphi) \end{pmatrix}$$

$$T_{xy} - T_{xy}\varphi = 0$$

In above equation, $T_{xy} = n^{-1}\sum_{t=1}^{n} X_t Y_t$ and $T_{xz} = n^{-1}\sum_{t=1}^{n} X_t Z_t'$ are the sample moments for GMM. If $L = K$ (φ_0) is just identified and T_{xz} is invertible than the GMM estimator of φ_0 is

$$\varphi = T^{-1}{}_{xy} T_{xz}$$

Here, the GMM estimator is known as indirect least square estimator. If $K > L$ then there may not be any solution to estimate GMM equation. In such a case, the idea is to find φ that makes $T_{xy} - T_{xz}\varphi$ as close to zero as possible. To do this, the weight matrix is added and the GMM estimator of φ is defined as:

$$\varphi(w) = \min_{\varphi}(J)(\varphi w)$$

Feasible Generalized Least Square

Feasible Generalized least square (FGLS) is a common estimator, where the cross-sectional covariances are typically considered parametrically in the econometric models. The utilization of FGLS estimator offer few advantages over other panel data techniques. First, the FGLS avoids any autocorrelation and heteroscedasticity in the panel data models. Second, the FGLS estimator is considered as most reliable in panel data when time period is more than number of entities (T>N) (Reed and Ye, 2011; Zhang and Nian, 2013). The sample data in this study is 27 years with 10 countries (T>N), which mentions that FGLS is reliable technique. Finally, the FGLS estimator avoids variable biasness issues. The mentioned advantages of FGLS motivate us to consider the FGLS estimator as potential technique for empirical analysis (Li and Lin, 2015). The FGLS estimator estimates the models under the assumption that all aspects of models are specified. These assumptions include that the disturbances have different variances for all panels. Under these assumptions, the FGLS estimator is considered asymptotically efficient.

$$\beta_{fgls} = (X'\Omega^{-1}X)^{-1}X'\Omega y \qquad (1)$$

By incorporating the dependent and explanatory variables with logs the FGLS estimator can be presented as.

$$\log(u^2) = \alpha_0 + \delta_1 x_1 + \delta_2 x_2 + ... + \delta_k x_k + \varepsilon \qquad (2)$$

Fully Modified and Dynamic Ordinary Least Squares

Pedroni, (2000) introduced the fully modified ordinary least squares (FMOLS) as a valid technique to check the long-run relationships between variables. As the FMOLS estimations report unbiased outcomes of long-run elasticities, consistent t-statistics and standard errors are reported in case of any endogenous regressors. Further, the dynamic ordinary least squares (DOLS) estimation technology is also considered important to examine the long-run relationships between variables for estimating the cointegration vector. While, the DOLS regressions utilize the future and past figures of the differenced regressors as additional explanatory factors (Wong et al., 2013).

In this study, we use the FMOLS and DOLS methods as a robustness check of our main findings. The main advantage of using the FMOLS framework is to check the efficiency during the presence of mixed order of integration of related variables in the cointegration framework. For instance, the FMOLS and DOLS techniques can be performed if one of the variable is stationary at first difference I(I) or variables are cointegrated at level I(0) and first difference with leads (p) and lags (-p) of first difference. The FMOLS and DOLS methods consider two constrains; endogeneity and sample biasness etc. (Alam and Murad, 2020). The FMOLS estimator allows first stage residuals to be heterogeneous with the long-term coefficients. Our findings of FMOLS and DOLS are sensible and in line with the theoretical viewpoint.

The panel FMOLS estimator for the coefficient β of panel can be presented as;

$$\beta_{nt}-\beta=\left(\sum_{i=1}^{n} w_{22i}^{-2}\sum_{t=1}^{t}(x_{it}-x_{it})^2\right)^{-1}\sum_{t=1}^{T}(x_{it}-x_i)w_{11i}^{-1}w_{22i}^{-1}\left(\sum_{t=1}^{t}(x_{it}-x_{it})\mu_{it}^{*}-T\lambda_i\right)$$

In above equation the standard error μ_{it} is presented as

$$\mu_{it}^{*} = \mu_{it} - \frac{w_{21i}}{w_{22i}} \Delta x_{it}, \gamma \equiv T_{21i} + \Omega_{21i} - \frac{w_{21i}}{w_{22i}} (T_{21i} + \Omega_{21i})$$

In above equation, the w_i is lower triangular decomposition of Ω_i as defined in above equation. Hence, under the assumption of convergence the estimator β_{nt} converges to the true value of $T\sqrt{N}$ and it can be distributed as;

$$T\sqrt{N}(\beta_{nt} - \beta) \rightarrow n(0, v)$$

Where, the v is defined as: $v =_{6}^{2if\ x_i = y_i = 0}$ and here the $T \rightarrow \infty$ and $n \rightarrow \infty$.

Hence, the FMOLS estimator is considered unbiased for the standard case without intercepts as well as the fixed effects model with heterogeneous intercepts.

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