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Linking urbanization, human capital, and the ecological footprint in G7 countries: An empirical analysis

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ABSTRACT

The G7 countries are facing the challenges of high urbanization, growing ecological footprint, and decreasing biocapacity. In these countries, urban areas are the center of economic activities and resource consumption. On this note, current study examines the effect of urbanization and human capital on the ecological footprint in G7 countries. The study uses advanced panel data estimators, such as CUP-FM and CUP-BC on data from 1971 to 2014. The findings reveal that urbanization increases the ecological footprint, whereas human capital reduces it. The reliability of long-run estimates is also examined by using CO_2 emissions as a proxy of environmental impact. The results of causality test disclose unidirectional causality from human capital and urbanization to the ecological footprint. However, the causality between urbanization, human capital, and economic growth is bi-directional. Moreover, energy consumption, economic growth, and import increase environmental degradation, while export and foreign direct investment reduce environmental degradation. Finally, detailed policy options are proposed to combat environmental challenges of G7 countries.

1. Introduction

Human demands for energy, water, fiber, timber, infrastructure, and others exert ecological pressure, which in turn leads to climate change, pollution, loss of biodiversity, and land erosion. The ecological footprint (EF) measures the area of productive land and ocean required to support human demand for natural resources and to sequester the wastes generated by human activities (Wackernagel et al., 2002). EF is a tool to track the impact of anthropogenic activities on the ecosystem in terms of six categories of land: cropland, fishing ground, grazing land, forests (timber and fuelwood), forests required to absorb CO_2 emissions (Carbon footprint), and build-up land (infrastructure footprint) (Ewing et al., 2010). Human demand for ecological assets has already exceeded than their productivity (biocapacity), resulting in a situation of overshoot, which indicates that the usage of the planet's resources is higher than its ability to regenerate the resources. It takes more than one and a half year to regenerate the resources which we consume in a year (Ahmed & Wang, 2019). The increasing gap between EF and biocapacity lessens earth's productive capacity resulting in climate change, food shortage, and loss of biodiversity (Rashid et al., 2018).

Meanwhile, people move to urban areas because of better employment, health, and education opportunities. Urbanization is based on economic and social modernization. It is characterized by rural to urban migration and the transformation of rural regions into urban areas (Poumanyvong & Kaneko, 2010). The world's population has gone through a tremendous transition, and currently, more than half of the inhabitants reside in urban areas. Furthermore, 66 percent of the population is projected to be urbanized in 2050; more precisely, nearly 2.5 billion more people will be added to the urban population (World Urbanization Prospects, 2014). The urbanization process increases the population of cities which already possess limited resources. Consequently, the demand for energy, food, transportation, water, housing, commercial buildings, electric appliances, and public utilities, etc. increases which leads to climate change, pollution, over-extraction, and depletion of resources (Ahmed, Wang, & Ali, 2019; Wang, Ahmed,

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Zhang, Wang, & Wang, 2019). Despite the contribution to economic development, innovation, and knowledge, urbanization spreads emissions, negatively impacts local food production (Berry, 1978; Winoto & Schultink, 1996) decreases soil fertility (Ali, Bakhsh, & Yasin, 2019) generates enormous waste, increases deforestation, and environmental degradation (Ali et al., 2019). Urban residents consume almost 75 percent of natural resources (Adams & Klobodu, 2017; UNEP, 2012), more than 66 percent of the world's total energy, and generate about 70 percent of total greenhouse gas (GHG) emissions (UN-Habitat, 2016).

In spite of growing literature on environmental degradation and climate change caused by human activities, environmental issues are growing. It increases the need to go beyond conventional thinking and consider other aspects, such as education and awareness, to control environmental deterioration. Human capital based on education and return to education may influence environmental quality as previous studies report a link between education, environmental awareness, and pro-environment behavior. For instance, Chankrajang and Muttarak (2017) suggest that human capital influences individuals' behavior to use renewable energy products. Also, the role of education cannot be denied in understanding the causes of global climate change and its severe consequences (UNESCO, 2010). Zen, Noor, and Yusuf, (2014) illustrate positive effects of education on recycling activities. Desha, Robinson, and Sproul, (2015) conclude that education influences individuals' preference in following environmental regulations, and Godoy, Groff, and O'Neill, (1998) suggest that education reduces deforestation. Bano, Zhao, Ahmad, Wang, and Liu, (2018) indicate that human capital plays a critical role in reducing CO_2 emissions by promoting energy efficiency. Recently, Ahmed and Wang (2019) suggest that the development of human capital can play a significant role in reducing EF.

Against this background, sustainable urbanization has become a focus of researchers. Many scholars have analyzed the relationship between urbanization and the environment with varying results. For instance, Charfeddine (2017), Sheng and Guo (2016), Al-Mulali, Ozturk, and Lean, (2015), Zhang, Yi, and Li, (2015), and Poumanyvong and Kaneko (2010) argue that urbanization stimulates environmental degradation by increasing energy consumption. On the contrary, some scholars suggest that urbanization reduces environmental degradation by providing the avenues for innovation, resource efficiency, and green technology (Charfeddine & Ben Khediri, 2016; Charfeddine & Mrabet, 2017). The diverse findings clearly indicate that the impact of urbanization depends upon urban population management, urbanization level, and other factors. In addition, CO_2 emissions are used as a proxy for environmental degradation in the majority of the previous studies, which only captures a portion of ecological problems associated with energy consumption (Al-Mulali & Ozturk, 2015). Thus, current study tends to investigate the impact of urbanization and human capital on EF in G7 countries.

We have chosen G7 countries for our study due to several reasons. The G7 (the United States, Canada, the United Kingdom (UK), Germany, Italy, France, and Japan) are highly developed economies of the world characterized by a high level of urbanization, massive trade volume, and skilled human capital. The average urbanization level of G7 countries is 75.59 percent, which is higher as compared to the global urbanization level of 54 percent. In G7 countries, Japan is the most urbanized country with 93 percent of the population in the urban areas, followed by the United Kingdom (82 percent), Canada (82 percent), the United States (81 percent), France (79 percent), Germany (75 percent), and Italy (69 percent). These countries contribute 46 percent to global GDP and consume 23 percent of the world's total produced energy (M. E. Bildirici & Gökmenoğlu, 2017). The G7 countries are attributed with high EF, and 5 of the member nations (the United States, Japan, the United Kingdom, Germany, and France) are included in the list of top 10 countries with the highest EF (Ewing et al., 2010). Moreover, all of the G7 countries except Canada, are in a state of ecological deficit, which indicates a higher demand for natural resources than their productivity. More precisely, G7 nations do not have enough ecological assets within their territory to support the demand of their population.

The study's contribution lies in several points, for instance, as per our knowledge, none of the previous studies has examined the influence of urbanization and human capital on the environment in the context of G7 countries. The literature on urbanization lacks consensus, which clearly shows that urbanization has both positive and negative aspects, and the net effect is difficult to determine without proper examination (Ahmed, Wang, & Ali, 2019). Moreover, urbanization can affect the environment in several ways, and CO_2 emissions only represent environmental degradation related to energy consumption. Hence, this study contributes to the existing literature in numerous ways. First, we examine the linkage between urbanization and the environment in the sample countries. Second, unlike the majority of previous studies, we use EF as a measure of environmental impact. This is because EF discloses the effect of anthropogenic activities on the environment in terms of air, water, and soil, and it is believed to be a comprehensive indicator of environmental damage (Ahmed & Wang, 2019; Charfeddine & Mrabet, 2017). Third, we have also included human capital (based on schooling years and return to education) in our model since environmental issues are anthropogenic, and education may play an important role in improving the environmental quality. Lastly, we have employed some of the advanced econometrics techniques (CUP-FM and CUP-BC methods), which generate robust estimates in the presence of cross-sectional dependence, serial correlation, and endogeneity.

The outline of the remaining article is as follows. Section 2 covers the review of past literature. Section 3 discusses data, theoretical background, and model, and section 4 presents methodology. The results are discussed in section 5, and section 6 concludes this work with some policy recommendations.

2. Literature review

EF is a comprehensive and universally comparable environmental indicator to measure the ecological consequences of human demands, and many recent studies have preferred it over CO_2 emissions (Ahmed & Wang, 2019; Baloch, Zhang, Iqbal, & Iqbal, 2019; Charfeddine & Mrabet, 2017; Danish, Hassan, Baloch, Mehmood, & Zhang, 2019; Rudolph & Figge, 2017; Uddin, Salahuddin, Alam, & Gow, 2017). Many scholars have analyzed the relationship between urbanization and the environment without any literary consensus. In the first group, many scholars explore urbanization and emissions nexus. For instance, Al-Mulali et al. (2015) reveal a positive influence of urbanization on emission using FMOL methodology for 23 European Countries. Likewise, several other country-specific and panel studies report that urbanization upsurges energy demand and emissions (Adams & Klobodu, 2017; Ding & Li, 2017; Liddle, Lung, & Liddle, 2010; Liddle, 2014; Lin & Du, 2015; Salahuddin, Ali, Vink, & Gow, 2018; Shahbaz, Loganathan, Sbia, & Afza, 2015; Sodri & Garniwa, 2016; Wang, Wu, Zeng, & Wu, 2016).

Conversely, Hossain (2011) suggests that the role of urbanization varies across countries. Urbanization positively impacts CO_2 emissions in some countries while reduces emissions in others. Likewise, Behera and Dash (2017) report mixed effects of urbanization on CO_2 emissions in SSEA countries. The findings reveal a positive role of urbanization in environmental degradation in middle and high-income countries, while no significant role in low-income countries. Using time-series data and the ARDL approach, Danish, Zhang, Wang, and Wang, (2017) find a negative contribution of urbanization in CO_2 emissions for Pakistan.

Sadorsky (2014) discloses an insignificant effect of urbanization on emissions for 16 emerging countries. The author argues that estimation techniques influence the effect of urbanization on emissions. In a provincial study, Wang et al. (2016) find substantial variations in the impact of urbanization across Chinese provinces. Using the STIRPAT model and panel data of 99 nations, Poumanyvong and Kaneko (2010) argue that the effect of urbanization on energy consumption and emissions varies across the level of development. Urbanization decreases energy consumption in lower-income countries, whereas it stimulates energy consumption in high and middle-income countries. Moreover, urbanization increases CO_2 emissions, but the magnitude of this effect is higher in middle-income countries. Similarly, Li and Lin (2015) analyze the influence of urbanization on energy and emissions using panel data of 73 nations and dividing countries based on income level. The authors report remarkable variations in results and conclude that the effect of urbanization depends upon the development level as well as the urbanization level of a country.

In the second group, some scholars have controlled urbanization while analyzing the determinants of EF. For instance, Al-Mulali and Ozturk (2015) have found that energy consumption, urbanization, and trade openness increases EF in 14 MENA countries. Charfeddine and Mrabet (2017) reinvestigate the causes of environmental deterioration in the MENA region, and the results of FMOLS and DOLS indicate a negative influence of urbanization on EF. The authors argue that urbanization negatively impacts EF because of economies of scale, improved service sector, use of green technologies, and better waste management in the urban region. Conversely, Charfeddine (2017) discloses that urbanization and trade openness stimulate EF in Qatar; however, these variables do not affect emissions. Further, they find a U-shaped linkage between GDP and EF, while an EKC between GDP and CO_2 emissions. In our opinion, this is because EF is more comprehensive indicators, and it captures both the direct and indirect effects of human consumption. Indeed, Qatar has a very high level of urbanization, but the net effect of urbanization depends on urban population management.

Besides, some researchers examine the non-linear relationship between urbanization and the environment. For example, Martínez-Zarzoso and Maruotti (2011) investigate the non-linear effect of urbanization on emissions in developing countries. The findings authorize an inverted U-shaped link between emissions and urbanization except for middle-income countries. Likewise, Bekhet and Othman (2017) for Malaysia, Ahmed, Wang, and Ali (2019) for Indonesia, and Zhang, Yu, and Chen, (2017) for a panel of 144 countries report a similar relationship. However, Shahbaz, Loganathan, Muzaffar, Ahmed, and Ali Jabran, (2016) and Shahbaz, Chaudhary, and Ozturk, (2017) could not confirm an inverted U-shaped relationship.

Though it is imperative to determine the effect of urbanization on the environment, the direction of causality is also very important for formulating policies. Interestingly, previous studies report various findings including bidirectional, unidirectional, and absence of causality between urbanization and emissions (Al-mulali, Binti Che Sab, & Fereidouni, 2012; Al-Mulali, Fereidouni, Lee, & Sab, 2013; Danish et al., 2017; Shahbaz, Loganathan et al., 2015; Wang, Fang, Guan, Pang, & Ma, 2014; Wang, Li, & Fang, 2017). The causality from urbanization to emissions implies that emissions may be reduced through a reduction in the level of urbanization. However, other causality findings incite authorities to look for energy efficiency, increasing awareness, and the use of green technology to improve the environment. Moreover, the direction of causality between urbanization and income, and between energy and income is also essential to design appropriate policies.

Summing up, previous literature concerning the role of urbanization in environmental degradation lacks consensus. The result of urbanization may depend upon the urban population management, urbanization as well as income level. It is also noteworthy that the majority of the previous studies have used CO_2 emissions as a dependent variable to analyze urbanization-environment nexus. Also, most of the panel studies have employed FMOLS and DOLS techniques, which are not suitable in case of cross-sectional dependence in data. Energy consumption and GDP upsurge environmental degradation in the majority of the previous studies. Moreover, the effect of trade depends upon the scale, composition, and technique effect (Dogan & Seker, 2016). Besides, we expect a positive effect of human capital on environmental quality since education can lead to environmental awareness and pro-environmental practices, and G7 countries possess educated and skilled human capital.

3. Data, theoretical framework, and model

3.1. Data

The study uses data for the period 1971–2014 for G7 countries. The EF of consumption has emerged as a reliable environmental indicator because of its ability to track the consequences of human activities on the environment (Ahmed, Wang, Mahmood, Hafeez, & Ali, 2019; Rudolph & Figge, 2017; Ulucak & Bilgili, 2018). The ecological footprint is computed by adding different productive land-use types[1] (Wada, 1999). We also disaggregate trade into import and export for examining the effect of both components separately since the environmental effect of import and export may not be the same.

The data is amassed from four different databases. The data on the ecological footprint (EF) is gathered from the Global Footprint Network (GFN, 2018). The data on urbanization, energy consumption, trade openness, and economic growth are collected from the World Bank database. The data on human capital are collected from the Penn World Table, version 9 (Feenstra, Inklaar, & Timmer, 2015). The Penn World Table measures human capital by combining and comparing the famous datasets of (Cohen & Leker, 2014) and (Barro & Lee, 2013) for schooling years, while Mincer equation estimates are used for rate of returns on education. Recently, Human Capital Index has emerged as a comprehensive and reliable measure for human capital, and many recent studies have preferred it over the other measures of human capital (Ahmed & Wang, 2019; Danish, Hassan et al., 2019; Ulucak & Bilgili, 2018). The data on CO_2 emissions are collected from the International Energy Agency (IEA). The time frame of this research is based on the availability of data for variables under study. GDP and energy consumption are transformed into the logarithm form. Further details regarding the variables under study and their measurements are provided in Table 1.

3.2. Theoretical framework and model

The environmental aspects of urbanization are studied in the context of three famous theories, e.g., the ecological modernization (EMT), compact city, and urban transition theories. The EMT states that the urbanization process transforms the societies and generates environmental problems which are connected with the level of development. The precedence to income at the cost of the environment during the low and middle level of development causes ecological problems. However, the increase in income diverts the focus of people towards a clean environment. Therefore, the increase in innovation, green technology use, and environment-friendly regulations help in controlling environmental degradation (Mol & Spaargaren, 2000; Poumanyvong & Kaneko, 2010).

The compact city theory emphasizes on developing compact cities with high population density, efficient public transportation, and concentration of facilities in a small area. The development of compact cities reduces energy consumption in transportation, housing, and other sectors, which in turn mitigates emissions (Adams & Klobodu, 2017; Sadorsky, 2014). Similarly, the urban transition theory links environmental degradation with the level of income. The theory states that environmental pressure is merely a cause of rising income levels, which can eventually be reduced through government interventions (Bekhet &

[1] Cropland provides different vegetables, grains, and non-edible products for human as well as animal feed crops (exclusive of grasses). Pasture land provides grasses to animals. Forest land provides different products, for instance timber (furniture and building material), pulp chip (paper production), etc. CO2-sink Land is the land where trees sequester carbon dioxide. Degraded Land is the area occupied by human infrastructure (the previously eco-productive land). Aquatic area or fishing ground includes freshwater and ocean that produce seafood. For more detail computation, see Appendix 1.

Table 1
Data Sources and Variables.

Variables	Symbol	Measure	Data Source
Ecological Footprint	EF	Per capita ecological footprint of Consumption.	Global Footprint Network
CO_2 Emissions	C	CO_2 emissions (Tonnes per capita)	IEA
Gross Domestic Product	GDP	Per capita GDP (constant 2010 US $)	World Development Indicators (WDI)
Energy Consumption	ENG	Energy consumption is expressed in per capita kg of oil equivalent.	WDI
Urbanization	URB	Urban population as a percentage of total population.	WDI
Human Capital	HUC	Human capital index, based on years of schooling and return to education.	Penn World Tables, version 9.0
Import	IP	Import of goods and services as a percentage of the gross domestic product.	WDI
Export	EP	Export of goods and services as a percentage of the gross domestic product.	WDI
Foreign Direct Investment	FD	Foreign Direct Investment (Net Inflows as a percentage of GDP)	WDI
Countries		Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States (7 countries).	

Othman, 2017; McGranahan, Jacobi, Songsore, Surjadi, & Kjellén, 2001). Based on the above discussion, the study's econometric model is adapted from (Danish & Wang, 2019) by including human capital, import, and export and can be expressed in the following equation.

$$(EF)_{it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 ENG_{it} + \beta_3 URB_{it} + \beta_4 HUC_{it} + \beta_5 IP_{it} + \beta_6 EX_{it} + \mu_{it} \quad (1)$$

Where i represents country, β_1 to β_6 symbolize estimated coefficients, and μ and t denote error term and time, respectively. EF indicates the per capita EF of consumption. GDP denotes per capita gross domestic product, and ENG is per capita energy consumption. URB indicates urbanization (urban population as a percentage of the total population), IP signifies import of goods and services (percentage of GDP), and EP is export of goods and services (percentage of GDP). HUC is the human capital represented by the Human Capital Index, which is based on years of schooling and return to education.

We replaced the components of trade (import and export) with foreign direct investment (net inflows as a percentage of GDP) in model 2.

$$(EF)_{it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 ENG_{it} + \beta_3 URB_{it} + \beta_4 HUC_{it} + \beta_5 FD_{it} + \mu_{it} \quad (2)$$

The estimation of model 2 will enable us to investigate the reliability of results as well as the presence of the pollution haven hypothesis in G7 countries. Foreign investors can employ traditional production techniques and dirty technology, which in turn may deteriorate the environment. However, in developed countries, foreign investment may promote energy-efficient technology, particularly in the presence of stringent environmental laws resulting in an environmental improvement (Shahbaz, Nasreen, Abbas, & Anis, 2015). Apart from this, we used CO_2 emissions (tonnes per capita) as the dependent variable and re-estimated both models for robustness check, and to probe the impact of each regressor on emissions for better policy implications. The following models are estimated using CO_2 emissions as the dependent variable.

$$(C)_{it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 ENG_{it} + \beta_3 URB_{it} + \beta_4 HUC_{it} + \beta_5 IP_{it} + \beta_6 EX_{it} + \mu_{it} \quad (3)$$

$$(C)_{it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 ENG_{it} + \beta_3 URB_{it} + \beta_4 HUC_{it} + \beta_5 FD_{it} + \mu_{it} \quad (4)$$

The relationship between EF and urbanization will help in understanding the ecological consequences of the urban population. Previous studies have considered urbanization as an important determinant of the environment with both positive and negative results. Al-Mulali and Ozturk (2015) ague that energy consumption and trade openness increase the ecological footprint, while Uddin et al. (2017) illustrate a negative relationship between trade and EF. Apart from this, we have included human capital as an explanatory variable because education increases environmental awareness and promotes pro-environmental activities (Ahmed & Wang, 2019; Mills & Schleich, 2012; Zen et al., 2014).

4. Econometric methodology

In order to examine the relationship between our variables, we use panel cointegration analysis because our dataset has large T and small N and traditional methods, such as fixed effect and random effect models are suitable for the panel data with large N and small T (Zoundi, 2017).

4.1. Cross-sectional dependence test

The aim of the study is to explore the effect of urbanization and human capital on EF in G7 countries. Since these countries are highly interlinked; therefore, we have conducted cross-sectional dependence tests before further analysis. The results indicate the presence of cross-sectional dependence in our data. Next, we employ several conventional and second-generation unit root tests.

4.2. Unit root analysis

Before investigating the cointegration between our variables, it is essential to determine the unit root properties of variables. The application of unit root tests is vital to avoid spurious regression. In this study, we employ 5 unit root methods, namely LLC of Levin, Lin, and Chu, (2002), Fisher-ADF, Fisher-PP, CIPS, and CADF. The LLC test is the extension of the following Augmented Dickey-Fuller specification.

$$\Delta y_{it} = \varphi_i y_{it-1} + \sum_{l=1}^{k} \theta_{il} \Delta y_{i,t-1} + \gamma_i c_{it} + \mu_{it} \quad (5)$$

Where C_{it} indicates exogenous variables, for instance, fixed effect and time trend, k refers to the lag order, μ_{it} denotes error terms, and φ is the autoregressive coefficient, which is fixed against cross-sections. The null hypothesis that each individual time series is non-stationary is checked against the alternative hypothesis of stationary. This test is not reliable because it assumes cross-sectional independence and homogeneity in the panel.

We have also employed fisher-ADF and PP unit root tests, which are based on the assumption of different unit root process for individual cross-sections. Fisher-ADF and PP unit root tests have a null and alternative hypothesis similar to that of LLC; however, these tests allow heterogeneity and generate reliable results.

Finally, we use newly developed Pesaran (2007) CIPS and CADF tests, which account for cross-sectional dependence and heterogeneity in panel data. The CADF unit root test is based on the following regression.

$$\Delta x_{it} = a_i + \rho_i x_{it-1} + c_i \bar{x}_{t-1} + \sum_{j=0}^{n} d_{ij} \Delta \bar{x}_{it-1} + \sum_{j=0}^{n} \beta_{ij} \Delta x_{it-1} + \varepsilon_{it} \quad (6)$$

Where x_{it} denotes a variable under observation, α represents individual intercept, $\mathcal{E}_{it}$ is the error term, $\bar{x}$ refers to the average for all the observations (N) at time t, and n is the lag order. The null hypothesis, i.e.

all individuals in the panel data series have a unit root is tested against the alternative hypothesis of at least one individual is stationary. The CIPS static can be obtained by taking the cross-sectional average of t_i (N, T).

$$CIPS = \frac{1}{N}\sum_{i=1}^{N} t_i(N,\ T) \tag{7}$$

In this equation, t_i (N, T) takes the t-statistic of ρ_i from Eq. 6. The CIPS test is very popular in the recent literature because of its ability to account for cross-sectional dependence as well as heterogeneity.

4.3. Cointegration tests

In this study, we employ Pedroni (1999) and Westerlund (2007) cointegration tests to analyze the presence of a long-run equilibrium relationship between the variables under investigation. The Pedroni cointegration test is extensively used in environmental studies. This test is based on seven statistics, including four panel and three group-based statistics. The panel based statistics are known as within dimension tests, which include, panel-v, rho, PP, and ADF statistics. The group based statistics are termed as between dimension including group-rho, ADF, and PP. These group and panel based tests are based on the residuals of the following model.

$$Y_{it} = c_i + \vartheta_i t + \sum_{j=1}^{m} r_{ji}X_{jit} + \varepsilon_{it} \tag{8}$$

Where y indicates the dependent variable (EF in our case), and X represents the independent variables. The dependent and independent variables are assumed to be integrated at 1(1). Further, ci and ϑi denote individual intercept and trend, while m, i, and t are the number of predictors, cross-sections, and the time period, respectively. This test is built on the null of no-cointegration, and this hypothesis is the same for both within dimension and between dimension statistics; however, the alternative hypothesis of cointegration is specified as a homogeneous alternative for the former and heterogeneous alternative for the latter.

Next, we apply the Westerlund (2007) ECM Panel Cointegration test, which produces consistent outcomes in the presence of cross-sectional dependence. This test is composed of two group mean statistics (G_t, G_a) as well as two pooled panel statistics (P_t, P_a). All four statistics of Westerlund (2007) are derived from the following error correction model.

$$\Delta x_{it} = \sigma'_i d_t + \delta_i\,(x_{it-1} - \beta'_i y_{it-1}) + \sum_{j=1}^{k_i} \delta_{ij}\Delta x_{it-j} + \sum_{j=-q_i}^{k_i} \gamma_{ij}\Delta y_{it-j} + \varepsilon_{it} \tag{9}$$

Where cross-sections are indicated by N (i = 1,………,N), T (t = 1, ……,T) denotes number of observations. Furthermore, k_i and q_i are used for lags and leads, and d_t refers to the deterministic component. The group mean statistics (G_t, G_a) are based on the alternative hypothesis that all cross-sections are cointegrated. The pooled panel statistics (P_t, P_a) test that as a minimum one cross-section is cointegrated. These four statistics allow heterogeneous specifications for short and long-run coefficients of the ECM model. The P-values generated by Westerlund (2007) cointegration test are based on a bootstrap process which uses the sieve-sampling scheme to reduce the distortion caused by the asymptotic normal distribution. The robust P-values are insensitive to cross-sectional dependence.

4.4. Panel long-run estimates

Several panel data techniques are available to understand the relationship between variables. For instance, the traditional methods, such as the GMM, fixed effect, and random effect models. The fixed effect and random effect models are not reliable in case of endogeneity and serial correlation, while the GMM technique overcomes the issue of endogeneity and serial correlation (Ito, 2017). However, these traditional methods provide spurious results for panel data with small N and large T (as in our case). Moreover, they fail to counter the problem of cross-sectional dependence. The Dynamic Seemingly Unrelated Cointegrating Regressions technique used in the recent literature generates consistent results in case of cross-sectional dependence. However, it does not solve the issue of serial correlation and endogeneity. The PMG method is widely used for the long-run analysis, but it also fails to provide reliable findings in case of cross-sectional dependence. The Mean Group (MG) estimator developed by Pesaran and Smith (1995) and the Augmented Mean Group method proposed by Bond and Eberhardt (2013) generate reliable estimates for data with relatively large sample size. However, these methods are not reliable in the presence of serial correlation and endogeneity.

Keeping in view the above discussion, current study employ continuously-updated fully modified (CUP-FM) and continuously-updated bias corrected (CUP-BC) estimators proposed by Bai, Kao, and Ng, (2009) following some recent studies (Ulucak & Bilgili, 2018; Zafar, Shahbaz, Hou, & Sinha, 2018). These methods are preferred over other estimation techniques because of their ability to generate reliable results even in the presence of autocorrelation, endogeneity, and cross-sectional dependence. The estimates of CUP-BC and CUP-FM are not affected by the fractional integration and the presence of exogenous predictors. In addition, these methods are reliable for small sample sizes, and produce consistent results even if endogeneity does not exist. In addition, we employed heterogeneous FMOLS to verify the results of CUP-BC and CUP-FM following Fang and Chang (2016). The application of the standard OLS method on non-stationary data can produce inconsistent results. Therefore, it is suitable to apply FMOLS to overcome such inconsistency (Behera & Dash, 2017). The FMOLS estimator overcomes possible serial correlation and endogeneity issues by following a non-parametric approach.

4.5. Panel causality test

Next, we use the panel Granger causality test developed by Dumitrescu and Hurlin (2012) to check the direction of causality between our variables. We prefer this causality approach because it provides consistent results in case of cross-sectional dependence, and has no restriction of $T > N$. This test has the null hypothesis of no causality in any of the cross-sections, which is also known as a Homogeneous Non-Causality (HNC) assumption. The HNC is tested against the alternative of the Heterogeneous Non-Causality hypothesis, which indicates the presence of at least one causal relationship in the panel.

5. Results and discussion

This study investigates the relationship between urbanization, human capital, and EF for a panel of G7 countries. Descriptive statistics presented in Table 2 reveal the average ecological footprint of 6.63, which is far higher than the global average of 2.8 gha per capita, and the maximum value reaches 11.11 gha per capita.

Likewise, the average urbanization level is 75.59 percent against the global average of 54 percent, and the maximum value reaches 93 percent. The average GDP per capita 33,898 constant 2010 US $ indicates the high development level of G7 countries. The results of the Pearson correlation in Table 3 show positive correlation of EF with GDP, import, energy, and FDI, while negative correlation with human capital and export. The correlation of CO_2 emissions with energy consumption is positive and strong, while the correlation between CO_2 emissions and FDI is very weak.

In recent literature, the estimation of cross-sectional dependence (CD) has become the key focus. The inability to control CD can produce biased results. Therefore, we analyzed the presence of CD using the Breusch-Pagan LM and Pesaran Scaled LM test. The results in Table 4

Table 2
Descriptive Statistics.

Statistics	EF	C	GDP	ENG	URB	HUC	IP	EP	FD
Mean	6.6301	11.0009	33898.98	4711.52	75.5908	3.1510	21.2202	21.3376	1.2929
Median	5.7686	9.2265	34310.69	3954.81	75.9090	3.1824	21.9141	21.7709	0.7684
Std.Deviation	1.9012	4.6834	8212.23	1977.50	4.9655	0.3939	7.9130	8.6680	1.7094
Maximum	11.1126	22.1340	50782.52	8441.18	93.0210	3.7342	39.9295	45.9825	12.7175
Minimum	4.1546	4.3070	17890.32	1949.14	64.7500	2.0857	5.1827	5.3918	0.7251

(Panel data for the period = 1971–2014 (44 years), observations = 308).

disclose the existence of CD in our data.

Moving forward, we employ several unit root tests and report the results in Table 5. All the variables have a unit root at the level. However, the null hypothesis of non-stationary is rejected at the first difference under all unit root methods. Therefore, these findings indicate that our variables are integrated at 1(1), and hence, the possibility of a cointegration relationship exists.

Next, we use the Pedroni (1999) and Westerlund (2007) cointegration tests. The outcomes of the Pedroni cointegration test in Table 6 show that the associated p-values of four statistics (out of seven) are less than 0.05 in model 1. This confirms the presence of cointegration. Regarding the results of models 2, 3, and 4, most of the significant statistics imply that the variables under study are cointegrated in all models.

Similarly, the results of the Westerlund test in Table 7 confirm a long-run equilibrium relationship between the variables under study. The null hypothesis, based on associated p-values, has been rejected for G_t and P_t statistics for all models at 1 % significance level. The results of both tests strongly confirm the existence of cointegration between variables of interest.

We further apply CUP-FM and CUP-BC methods to estimate the long-run impact of our independent variables on EF in model 1. The findings of CUP-FM and CUP-BC are presented in Table 8. Interestingly, the relationship between urbanization and EF is positive and significant in model 1. The outcomes depict that a 1 percent increase in URB increases EF by 0.58 and 0.61 percent under CUP-FM and CUP-BC methods, respectively. It implies that urbanization positively influences the ecological footprint in G7 countries. The positive relationship between urbanization and EF can be supported on the ground that the average urbanization level of G7 countries is 75.59 percent, and urban areas with high urban population density are associated with higher consumption related environmental challenges (Jorgenson & Clark, 2009). The high-income urban residents of G7 countries require transportation, food, water, and accommodation. The growing demands for natural resources cause excessive exploitation of natural resources, for example, overfishing, higher energy consumption (for transportation, heating, refrigeration), and deforestation associated with urban expansion. Consequently, urbanization in G7 countries stimulates EF. Our results oppose the ecological modernization theory and the findings of those researchers who argue that the high urbanization level has a favorable impact on the environment (Charfeddine & Ben Khediri, 2016; Charfeddine & Mrabet, 2017; Martínez-Zarzoso & Maruotti, 2011). However, our results are in consistence with the findings of (Al-Mulali & Ozturk, 2015) for MENA countries, and (Charfeddine, 2017) for Qatar.

The coefficient of per capita GDP is positive and significant under CUP-FM and CUP-BC as well. A 1 percent increase in GDP increases EF by 0.18 and 0.19 percent under CUP-FM and CUP-BC methods, respectively. These findings support the argument that an increase in income level raises human demands, resource consumption, and associated environmental degradation. Similar results have been reported in the previous literature concerning the relationship between GDP and EF (Jorgenson & Clark, 2009; Rudolph & Figge, 2017; Uddin et al., 2017). Regarding energy consumption and ecological footprint, we again find evidence of positive association. This shows that a 1 percent rise in ENG upsurges EF by 0.26 (CUP-FM) and 0.24 percent (CUP-BC). These results are conceivable because carbon footprint constitutes a significant portion of EF. Moreover, there is an agreement in the literature that energy consumption degrades the environment. This relationship is consistent with the outcomes of previous studies (Ahmed, Wang, Mahmood et al., 2019; Charfeddine & Mrabet, 2017). This finding also corroborates with Bildirici (2017), who suggests that energy consumption deteriorates the environment in G7 countries.

Further, the coefficient of import is positive, and the coefficient of export is negative. A 1 percent increase in IP stimulates EF by 0.034 % under both methods, while a similar increase of 1 percent in EP mitigates EF by 0.006 (CUP-FM) and 0.010 percent (CUP-BC). These findings show that export reduces EF, while import increases EF. The positive role of trade in reducing environmental degradation is corroborated with the composition and technique effects of trade that improve the environment in developed countries (Dinda, 2004). The positive effect of export can be due to the innovation and application of clean technologies in the production of export-oriented goods, which in turn improve energy efficiency and reduce environmental degradation. Another reason could be the stringent environmental regulations in these developed countries that transfer their dirty technology to developing countries with weak environmental laws and structure of consumption remain unchanged. Thus, developed countries are taking advantage of technique effect of trade that helps in controlling the industrial wastes and substitutions between resources. For example, the use of flue-gas desulphurization equipment in Germany, nuclear energy in France, and both nuclear energy and flue-gas desulphurization

Table 3
Pearson Correlation.

	EF	C	GDP	ENG	URB	HUC	IP	EP	FD
EF	1								
C	0.9300	1							
GDP	0.1788	0.1697	1						
ENG	0.9272	0.8857	0.4140	1					
URB	0.2215	0.2994	0.5017	0.4225	1				
HUC	−0.4173	0.5484	0.7070	0.5943	0.6798	1			
IP	0.1373	−0.1563	0.2288	−0.0137	0.0235	0.1627	1		
EP	−0.1810	−0.1803	0.2243	−0.0343	−0.0136	0.1365	0.9665	1	
FD	0.1268	0.0821	0.3367	0.1901	0.2398	0.3383	0.4727	0.4219	1

Table 4
Cross-Sectional Dependence.

	EF	C	GDP	ENG	URB	HUC	IP	EP	FD
Breusch-Pagan LM	164.4964^{a}	307.7321^{a}	329.0643^{a}	170.5765^{a}	260.5021^{a}	432.3532^{a}	84.6486^{a}	73.8783^{a}	118.2070^{a}
	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
Pesaran Scaled LM	22.1419^{a}	44.2437^{a}	47.5353^{a}	23.0801^{a}	36.9559^{a}	63.4731^{a}	9.8212^{a}	8.1593^{a}	14.9993^{a}
	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]

Note: ^{a} shows significance level of 1 percent.

Table 5
Unit Root Tests.

	LLC		ADF		PP		CIPS		CADF	
Variables	Level	First Difference	Level	First Difference	Level	First Difference	Level	First Difference	Level	First Difference
EF	0.90527	−12.2617*	16.5995	160.719***	17.2622	171.740***	−2.367	−6.297***	−2.018	−4.925***
	[0.8166]	[0.0000]	[0.2781]	[0.0000]	[0.2425]	[0.0000]				
C	3.32465	−7.53962	9.35299	93.7312***	10.2667	157.99***	−1.828	−6.283***	−1.532	−4.638***
	0.9996	[0.0000]	0.8078	[0.0000]	0.7424	[0.0000]				
GDP	0.84046	−11.9915***	7.60869	109.528***	3.66165	196.465***	−2.320	−4.872***	−2.564	−3.842***
	[0.7997]	[0.0000]	[0.9087]	[0.0000]	[0.9972]	[0.0000]				
ENG	2.20436	−14.9022***	11.2238	165.324***	9.97969	171.031***	−2.705	−5.911***	−2.489	−4.407***
	[0.9863]	[0.0000]	[0.6684]	[0.0000]	[0.7637]	[0.0000]				
URB	1.30454	−2.00113**	16.8183	22.6199***	8.503737	34.4926***	−2.155	−2.850***	−2.583	−2.850**
	[0.9040]	[0.0227]	[0.2660]	[0.0667]	[0.8613]	[0.0017]				
HUC	0.12163	−4.08679***	10.1263	36.8442***	19.3906	40.6870***	−2.611	−5.705***	−2.611	−3.413***
	[0.5484]	[0.0000]	[0.7529]	[0.0008]	[0.1506]	[0.0002]				
IP	−0.44144	−10.1256***	14.8711	107.610***	18.4339	229.429***	−2.449	−5.511***	−2.406	−4.654***
	0.3294	[0.0000]	0.3870	[0.0000]	0.1877	[0.0000]				
EP	−0.03287	−8.05622*** [0.0000]	14.7078	85.6286***	11.6372	140.895***	−2.103	−4.333***	−2.616	−3.994***
	0.4869		0.3984	[0.0000]	0.6354	[0.0000]				
FD	0.42501	−14.7402***	8.30072	210.104***	9.56297	293.37***	−2.491	−4.989***	−2.008	−6.204***
	0.6646	[0.0000]	0.8731	[0.0000]	0.9108	[0.0000]				

P-values are provided in the brackets.
* Indicates 10 % level of significance.
** Indicates 5 % level of significance.
*** Indicates 1 % level of significance.

Table 6
Pedroni Test for Cointegration.

Common AR coefficients (within-dimension)	Model 1		Model 2		Model 3		Model 4	
	Statistics	Weighted Statistics	Statistics	Weighted Statistics	Statistics	Weighted Statistics	Statistics	Weighted Statistics
Panel v-Statistic	−1.0436	−1.0212	−0.9569	−0.9933	1.9230^{b}	1.1758^{a}	2.1788^{b}	1.8808^{b}
	[0.8517]	[0.8464]	[0.8307]	[0.8397]	[0.0272]	[0.0098]	[0.0147]	[0.0300]
Panel rho-Statistic	0.5329	0.2178	0.7096	0.2687	0.6272	0.0476	0.1760	−0.0175
	[0.7030]	[0.5862]	[0.761]	[0.6059]	[0.7348]	[0.5190]	[0.5699]	[0.4930]
Panel PP-Statistic	−2.9816^{a}	−3.9458^{a}	−3.0046^{a}	−4.5914^{a}	−1.8481^{b}	−2.4693^{a}	−2.1257^{b}	−2.4396^{a}
	[0.0014]	[0.0000]	[0.0013]	[0.0000]	[0.0323]	[0.0068]	[0.0168]	[0.0074]
Panel ADF-Statistic	−1.7392^{b}	−3.2012^{a}	−1.8470^{b}	−3.4872^{a}	−1.7852^{b}	−2.3765^{a}	−1.6610^{b}	−2.2743^{b}
	[0.041]	[0.0007]	[0.0324]	[0.0002]	[0.0371]	[0.0087]	[0.0484]	[0.0115]
Individual AR coefficients (between-dimension)								
Group rho-Statistic	1.1488		1.3153		0.6611		0.2423	
	[0.8747]		[0.9058]		[0.7457]		[0.5985]	
Group PP-Statistic	−3.6304^{a}		−4.6902^{a}		−2.4303^{a}		−2.9942^{a}	
	[0.0001]		[0.0000]		[0.0075]		[0.0014]	
Group ADF-Statistic	−2.5211^{a}		−2.8416^{a}		−2.6672^{a}		−3.2124^{a}	
	[0.0058]		[0.0022]		[0.0038]		[0.0007]	

Note: ^{b} and ^{a} show significance at 5 %, and 1 %, respectively.
Individual intercept and individual trend are selected to calculate the results.

equipment in Japan significantly reduced some greenhouse gases. Therefore, developed countries specialized in less energy-intensive production, use resources efficiently in production, and also export services, which exhibit negative effect of export on EF. Conversely, the positive effect of import on EF can be the result of high energy imports by G7 countries. Some of the G7 countries fulfill most of their energy needs by imports, for instance, Japan (93 percent), Italy (76 percent), Germany (61 percent), and France (44 percent). The plausible reason could be that G7 countries mostly relies on energy imports due to limited natural resources, as countries with limited natural resource are dependent to fossil fuel (Danish, Baloch, Mahmood, & Zhang, 2019), and that increases environmental damage. Moreover, coal import is

Table 7
Westerlund (2007) Cointegration Tests.

	G_t*	G_a	P_t*	P_a
Model-1	−3.354*** (0.000)	2.157 (0.935)	−2.205** (0.010)	−0.937 (0.755)
Model-2	−2.959*** (0.003)	1.962 (0.780)	−2.494** (0.015)	−0.852 (0.62)
Model-3	−3.033 *** (0.003)	1.672 (0.750)	−2.274** (0.018)	−0.584 (0.545)
Model-4	−1.398* (0.070)	1.677 (0.643)	−1.590* (0.092)	−1.010 (0.568)

*, **, and *** show significance at 10 %, 5 %, and 1 %, respectively.
Z-value are reported (robust p-value are in brackets).

higher in some developed countries because of its cheap price (Pié, Fabregat-Aibar, & Saez, 2018), which could be another reason that import increases EF in G7 countries.

Finally, the relationship between HUC and EF is negative, which implies that human capital reduces environmental degradation. A 1 percent increase in HUC reduces EF by 0.06 and 0.07 percent under CUP-FM and CUP-BC, respectively. Positive role of human capital in reducing EF in G7 countries can be linked with skilled labor and education that enhance environmental awareness and pro-environmental practices. Environmental awareness and knowledge regarding the environment influence environmental quality by promoting a sustainable lifestyle. This result is also supported by previous studies that report a stimulating influence of education on pro-environmental activities, such as water-saving, energy conservation, and recycling (Bano et al., 2018; Ulucak & Bilgili, 2018).

We re-examine the relationship between our variables by replacing import and export with foreign direct investment in model 2. The results of model 2 correspond with the results of Model 1. All variables stimulate EF except human capital, which mitigates EF. In model 2, foreign direct investment also reduces EF. A 1 percent increase in FD reduces EF by 0.009 under CUP-FM and 0.021 percent under CUP-BC. This result is consistent with that of Solarin and Al-Mulali (2018), who conclude that the pollution haven hypothesis does not exist in developed countries, and foreign direct investment mitigates environmental degradation in such countries. In developed countries, there are strict environmental laws that prohibit foreign investment inflows in dirty technology; therefore, foreign investment in G7 countries is mostly environment-friendly, which supports the halo hypothesis. This outcome is also consistent with Shahbaz, Nasreen et al. (2015), who argue that foreign investors in high-income countries employ advanced technology and efficient management practices that promote clean environment.

Table 9
Heterogeneous FMOLS Robustness of Results.

	Dependent Variable Ecological Footprint (EF)		Dependent Variable CO_2 Emissions (C)	
Variables	Model 1	Model 2	Model 3	Model 4
GDP	7.9993*** [9.9516]	5.5928*** [8.0686]	8.7601*** [7.8374]	7.9416*** [6.2713]
ENG	8.6360*** [12.3805]	8.7006*** [9.3822]	18.9412*** [19.5276]	19.3537*** [17.5395]
URB	0.1339*** [9.0484]	0.1200*** [6.3877]	0.2661*** [12.9270]	0.3287*** [14.7137]
HUC	−5.9251* [-12.2073]	−8.0974*** [-12.6427]	−7.8567*** [-11.6409]	−6.8746*** [-9.0263]
IP	0.0459*** [5.0467]	——	0.04995*** [3.9461]	——
EP	−0.0602*** [-7.6037]	——	−0.0351*** [-3.1896]	——
FD	——	−0.0273*** [-3.056]]	———	−0.0681* [-1.7284]

Note:
*, and *** denote significance at 10 % and 1 % level, respectively.
SBC optimum lag length 1 is used to compute the results under heterogeneous FMOLS.
T-statistics are reported in brackets.

After exploring the impact of regressors on EF, we estimate both models with CO_2 emissions as dependent variable to assure consistency of results. The estimation of both models with CO_2 emissions will enable us to suggest more specific policies, particularly in the presence of any variation in results. The estimates of Model 3 and Model 4 indicate that urbanization, GDP, energy consumption, and import increase CO_2 emissions, while human capital and export reduce CO_2 emissions. These findings are consistent with the previous results. Further, we estimate all four models using heterogeneous FMOLS, and the results are given in Table 9. The outcomes of FMOLS are consistent with the estimates of CUP-FM and CUP-BC methods. These consistent results indicate that the findings of this study are reliable and can be used for policy implications.

After analyzing the long-run relationship, we apply the Dumitrescu

Table 8
Long-run Results.

	Dependent Variable Ecological Footprint (EF)				Dependent Variable CO_2 Emissions (C)			
Variables	Model 1		Model 2		Model 3		Model 4	
	CUP-FM	CUP-BC	CUP-FM	CUP-BC	CUP-FM	CUP-BC	CUP-FM	CUP-BC
GDP	0.1824*** [4.2693]	0.1994*** [4.4400]	0.1940**** [3.4422]	0.2008*** [3.5311]	0.1891*** [21.6049]	0.1671*** [24.6805]	0.2352*** [31.4120]	0.1956*** [30.8623]
ENG	0.2615*** [8.0217]	0.2425*** [7.1244]	0.2767**** [6.5093]	0.25099*** [6.0555]	0.1328*** [23.6414]	0.0525*** [12.8008]	0.5937*** [13.6749]	0.3162*** [8.2445]
URB	0.5868*** [13.5887]	0.6143*** [13.6024]	0.6044*** [10.7239]	0.6190*** [10.8253]	0.1432*** [19.9439]	0.1158*** [20.0551]	0.7423*** [13.6178]	0.7205*** [14.0841]
HUC	−0.0688* [-2.2034]	−0.0717* [-2.1999]	−0.0587*** [-3.4416]	−0.05372*** [-3.3017]	−0.0106** [-2.4940]	−0.0308** [-8.3100]	−0.0195*** [-6.0598]	−0.0368*** [-10.9865]
IP	0.0341*** [10.3825]	0.0344*** [10.0658]	——	——	0.0186* [2.2393]	0.01585*** [3.6331]	——	——
EP	−0.0064*** [-3.1071]	−0.0101*** [-3.2579]	——	——	−0.0209*** [-3.6720]	−0.0149*** [-3.2318]	——	——
FD	——	——	−0.0099** [-2.5720]	−0.0211** [-2.5929]	——	——	−0.0179*** [-4.4527]	−0.0060 [-1.6071]

Note:
*, **, and *** denote significance at 10 %, 5 % and 1 % level, respectively.
T-statistics are reported in brackets.

Table 10
DH Panel Causality.

Dependent variables							
	EF	GDP	ENG	URB	HUC	IP	EP
EF	——	4.0348***	4.7379***	4.1827**	5.8378***	13.4894***	8.12082***
		[0.0000]	[0.0019]	[0.0145]	[0.0000]	[0.0000]	[0.000]
GDP	1.6388	——	3.0017	3.8380**	4.8099***	6.4231***	4.5858***
	[0.3169]		[0.2943]	[0.0416]	[0.0014]	[0.0000]	[0.0035]
ENG	5.3513***	3.1792	——	7.8976***	5.3760***	15.7143***	12.7010*
	[0.0001]	[0.2082]		[0.000]	[0.0001]	[0.0000]	[0.0000]
URB	3.2677	7.4311**	2.0683	———	7.6801***	2.4110	2.0357
	[0.1728]	[0.0000]	[0.7423]		[0.000]	[0.7258]	[0.9261]
HUC	2.9320	5.2288***	2.9920	4.8182***	——	3.2288	3.1676
	[0.3338]	[0.0002]	[0.2996]	[0.0014]		[0.1878]	[0.1728]
IP	3.6111*	3.3947	2.8487	9.0018***	3.2678	——	2.2429
	[0.0769]	[0.1302]	[0.3854]	[0.0000]	[0.2078]		[0.3571]
EP	2.3459	2.1018	2.2813	9.0018***	3.2589	2.8341	——
	[0.7843]	[0.9883]	[0.8435]	[0.0000]	[0.3021]	[0.3950]	

Notes: ***, **, and * show the significance level of 1, 5, and 10 percent, respectively.
W-stats are reported along with p-values in brackets.

and Hurlin short-run panel causality method to determine the causality between variables. The results in Table 10 reveal that urbanization Granger cause EF, energy consumption, export, and import without any feedback. The bidirectional causal relationship between urbanization and human capital suggests that educated human capital prefers to reside in the cities. Also, better educational and training institutes in urban areas increase human capital development. The bi-directional causality between urbanization and GDP shows that urbanization stimulates economic development, whereas an increase in the level of income influences rural to urban migration for better living standards. Therefore, reduction in urbanization can hamper the economic development in the G7 countries.

Further, the results confirm unidirectional causality from GDP to EF, this finding consistent with the long-run estimates implies that G7 countries achieve economic development at the cost of the environment. The bi-directional relationship between energy consumption and EF infers that energy consumption influences EF resulting in environmental degradation. This high environmental degradation incites policymakers to limit the use of energy that results in a feedback effect. We have not found the causal association between GDP and energy use. This confirmation of the neutrality hypothesis implies that energy conservation will not retard the economic growth in G7 countries.

Human capital Granger cause EF and energy consumption, whereas the relationship between human capital and GDP supports the feedback hypothesis. This indicates that human capital stimulates environmental quality and boost economic development. Moreover, the rise in income level increases investment in human capital. Next, we find that export (EP) Granger cause EF, GDP, and energy use, while bidirectional causality exists between import (IP) and EF. This bidirectional causality indicates that import induces EF, while the high level of EF and low biocapacity in G7 countries increase the reliance on imports to fulfill the needs of their population. Finally, the results show that import (IP) Granger cause GDP and energy consumption.

Our finding of the feedback effect between urbanization and economic growth is in line with Charfeddine (2017). The uni-directional causality between urbanization and EF is similar to the results of Al-Mulali and Ozturk (2015). The feedback effect between the ecological footprint and energy consumption is consistent with Charfeddine and Mrabet (2017). Lastly, the finding of the neutrality hypothesis between energy and economic growth is supported by Dogan (2015) for Turkey, Payne (2009) for the US, Lee (2006) for Sweden, Germany, and the UK, and Ahmed and Wang (2019) for India.

6. Conclusion and policies

We examine the influence of urbanization and human capital on EF in G7 countries over the period 1971-2014. The results of CUP-FM and CUP-BC indicate that urbanization increases EF, while human capital decreases EF. Further, per capita GDP, import, and energy increase EF, whereas export and FDI reduce EF. The consistency of the long-run results is also confirmed through an alternate measure, i.e. CO_2 emissions as a proxy of environmental degradation. The findings of the causality test reveal bidirectional causal relationship between urbanization, economic growth, and human capital. Also, we find the evidence of unidirectional causality running from urbanization to EF and energy consumption, and from human capital to energy consumption and EF.

These results indicate that urbanization degrades the environment, but the feedback effect between GDP and urbanization implies that reducing or slowing down urbanization can adversely impact GDP. On the other hand, the evidence of neutrality hypothesis highlights the possibility of energy conservation policies. Hence, these findings along with the negative relationship between EF and human capital suggest the need for launching various environmental awareness programs in urban areas. Also, energy-efficient electric home appliances and solar energy should be promoted in the residential sector. Urban transportation should be converted to green transportation through the introduction of smart technology and energy-efficient hybrid vehicles. The urban population can be motivated to adopt a sustainable lifestyle that helps in pro-environmental activities, including water-saving, energy-saving, usage of renewable energy instruments, recycling, consuming eco-friendly food, and use public transportation. Policies should be devised to encourage the adoption of green technology to curb pollution caused by urban industries. Electronic and print media can be used for effective ecological awareness campaigns. The inclusion of environmental sustainability contents in the education syllabus can promote the sustainable use of resources at individual level. National, as well as international environment institutions, should be supported and encouraged to target different businesses for promoting energy efficiency and sustainable use of resources.

G7 countries should further design environmental regulations to restrict dirty imports and dependence on fossil fuel sources should be reduced by investing more in energy efficiency and renewable energy projects. More innovation in renewable energy technologies would be more feasible for reducing the adverse impact of energy consumption on EF. Both government and business enterprises should participate in technological innovation in the energy sector. Finally, environmental education and current policy practices of education should continue to enjoy the fruits of sustainable development.

This research has some limitations as it investigates the effect of human capital measured by the Human Capital Index, which only considers education and return to education. Future studies can also expand this work by incorporating other dimensions such as job experience and health. Moreover, disaggregate studies to examine the relationship between urban population density and EF at the city and province-level would be useful for more specific policies. Present study also discloses different environmental impacts of exports and imports, which presents a vital research gap for future studies to examine the effect of each element of imports and exports on EF.

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