Integrated Analysis of CO2 Emission Intensity, Bilateral FDI, and Institutional Quality Nexus: Case Study of G20 Countries

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Integrated Analysis of CO_2 Emission Intensity, Bilateral FDI, and Institutional Quality Nexus: Case Study of G20 Countries

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Abstract

A clean natural environment is a primary concern of contemporary lives, business investments, and governments. However, there is a lack of knowledge of how countries can achieve high investment across borders and better institutional quality while protecting the environment. Thus the current paper explores the effect of bilateral FDI, institutional quality, and CO_2 emission intensity on each other for 19 selected G20 countries over the 2009-2017 periods. This paper estimates the three equations that jointly address the endogeneity problem by employing both static and dynamic simultaneous econometrics techniques with a panel dataset. The empirical results confirm that bilateral FDI reduces CO_2 emission intensity and strengthens the institutional quality in G20. The results also support a positive and significant effect of institutional quality on bilateral inward FDI and CO_2 emission intensity. This paper confirms a positive and considerable feedback effect of CO_2 emission intensity on institutional quality. Further, this study establishes a triplex relationship between these three factors and consolidates vital policy insights to achieve sustainable growth concerning the nexus among environment quality-FDI-institution quality for G20 economies.

Keywords: CO_2 emission intensity, Bilateral FDI, Institutional quality, Panel data, Simultaneous techniques, G20 countries

JEL Classification Q53, Q56, F21, F23, Q28, E02

1. Introduction

The increasing level of CO_2 emission is a pertinent issue and is widely discussed in different policy frameworks. According to Intergovernmental Panel on Climate Change (2014), CO_2 emission is a significant anthropocentric contributor to environmental degradation, which has reached approximately 1^0 C and resulted in extreme weather events, rising sea levels, and melting of Arctic sea ice. This will lead to long-term and irreversible changes such as destruction of the ecosystem, increased ocean acidity, extreme weather events like more frequent and severe natural disasters. All together causes severe negative economic and social impacts such as increased poverty, inequalities with high food insecurity, and ill worsening peoples' safety and health directly affecting humans' lives (United Nations 2019). Therefore, an increase in CO_2 emission is a hazard and a premier concern of every economy globally. The majority of CO_2 emission comes from industrialization and fossil fuel combustion; those are consistent components of economic growth and development (Sabir et al. 2020). At the same time, industrialization is the base for any investment and economic growth and development. However, years ago, economists proposed an 'inverted U' shaped relationship between economic growth and environmental quality, commonly known as the environmental Kuznets curve (EKC) (Grossman and Krueger 1991). The well-investigated EKC hypothesis has different distinguished mechanisms by which investment from foreign sources like foreign direct investment (FDI) can affect the environmental quality.

Nevertheless, inward FDI has many contributions, such as employment creation, productivity enhancement, diffusion of technologies, human capital formation, and internationalization and economic integration (Sabir et al. 2020). However, the policymakers believed that the host countries need to improve their institutional quality performances to attract more FDI inflows (Ullah and Khan 2017). In addition, Bokpin (2017) has explained that better institutional quality characterized by stable governance, well-developed democracy, and control of a country's corruption is necessary for an economy to accrue more FDI inflows. However, FDI is not free from the negative consequences of environmental quality (Opoku and Boachie 2020), and thus the FDI-environment quality nexus remain under surveillance for all countries. On the one hand, researchers argued that FDI leads to sustainable economic growth with cleaner and advanced technologies in host countries (Abdouli et al. 2018). On the contrary, studies claimed that FDI harms environment quality and causes CO_2 emission through polluting industries (Omri et al. 2014; Shahbaz et al. 2015). This argument mainly supports that FDI contributes to economic prosperity with the additional cost of environmental degradation.

In this line, studies highlighted that the polluting multinational firms invest in countries with inadequate and less stringent environmental regulations or economies with poor institutional qualities (Sabir et al. 2020). From this, it can be assessed that the polluting multinational firms invest in countries with inadequate and less stable regulations. Therefore, this puts a strong rationale for institutional quality in protecting the environmental quality from the polluting units. Thus, developed institutional quality is not only helped to attract more FDI inflows but also restrict the polluting firms from entering the host countries' environment (Dang 2019; Mahjabeen et al. 2020). However, few studies have addressed such nexus among FDI-institution-environment and attempted to examine such a multiplex relationship among these three variables (Dang 2019; Sabir et al. 2020). They argued that a better institutional quality could boost environment-friendly FDI and set the host countries' environmental quality. Thus, it becomes imperative to examine the bidirectional and the triplex relationship among environmental quality, bilateral FDI, and institutional quality, which are more or less ignored in the existing studies. Therefore, this study attempts to examine this nexus among CO_2 emission intensity-bilateral FDI-institutional quality in the case of selected G20 economies.

Our paper has the following objectives: (1) to verify the "pollution halo" or "pollution haven" hypothesis for bilateral FDI on CO_2 emission intensity and the existence of the reverse effect of CO_2 emission intensity on bilateral FDI. (2) To explore whether the institutional quality will increase or decrease CO_2 emission intensity and verify the reverse impact of CO_2 emission intensity on institutional quality. (3) To examine the role of institutional quality on FDI and know the feedback effect of FDI on institutional quality. (4) To empirically explore the trilateral relationship among CO_2 emission intensity, bilateral FDI, and institutional quality in a simultaneous framework.

The novelties of this study are sevenfold. First, it investigates the simultaneous nexus among FDI-institution-environment. Second, we use bilateral FDI data and include other host and source countries' bilateral characteristic variables. Third, instead of taking only the developing or the developed countries, this paper considers a mixed group of countries (G20) to present the heterogeneity and balanced picture of the world. Fourth, we used a comprehensive coverage dataset for 19 selected G20 countries, considering host and source countries with 342-panel pairs from 2009 to 2017. We use the IMF's newly available bilateral FDI data. Fifth, this analysis remained safe from the omission biased after controlling the significant macroeconomic variables. Sixth, we covered a wide range of institutional quality indicators following Kunčič (2014) for our empirical estimation. Finally, this study minimizes the gap concerning econometric modeling using static and dynamic system models such as seemingly unrelated regression, three-stage least square, and generalized method of moments. According to empirical analysis, our research put forward some specific policy implications for reducing CO_2 emission and achieving more FDI inflows with better institutional qualities in selected G20 countries.

The rest of this study is organized as follows. In section 2, a structured review and hypotheses are provided. In section 3, the data, variables, and methods are explained. In section 4, the empirical results and discussion are described. Section 5 presents the conclusion, and policy implications are described in section 6.

2. Literature Review

This section considers four-part links between environment quality, bilateral FDI, and institutional quality of existing literature.

2.1. Environmental quality and FDI

The theoretical literature on environment-FDI nexus is better explained with four different hypotheses: the Porter Hypothesis (PH, henceforth), the Pollution Haven Hypothesis (PHH, henceforth), the Race-to-Bottom Hypothesis (RTB, henceforth), and the Pollution Halo Hypothesis (PHHH, henceforth). The Porter hypothesis states that FDI comes with new and advanced technology and can improve the host countries' environmental quality (Porter and Van der Linde 1995). Therefore, with new and greener technologies, investors use less energy-intensive capital and cause fewer emissions (Mielnik and Goldemberg 2002). In contrast, the literature on PHH started by Pething (1976) explains that the pollution-intensive production units migrate from more stringent environmental regulation (developed/North) countries to less stringent regulated (developing/south) countries to minimize the cost of adhering to these regulations. Copeland and Taylor (1994) have mentioned that the flight of polluted industries using FDI towards growing economies provides economic opportunities but brings environmental hazards in the long run. This hypothesis also gives a branch to another hypothesis called 'race to the bottom' in developing countries. That allows polluting units from developed nations to developing countries and brings global pressure on the environment (Rudolph and Figge 2017). Contrary to the PHH and the RTB hypotheses, the PHHH hypothesis argues that FDI in developing countries improves economic development and provides green and advanced technologies, thus improving environmental quality (Zarsky 1999). The argument lies that FDI is coming from developed economies, then it is more eco-friendly with greener technologies. Thus FDI not only generates economic growth but also improves the host countries' environment quality. Clubbing all the theoretical arguments on environmental quality-FDI nexus, two approaches can be well addressed. First, FDI has a negative relationship with environmental quality. The second approach argues a positive relationship between FDI and environment quality.

The existing empirical literature of FDI-environment quality nexus has examined a positive and significant relationship between FDI and CO_2 emission. It supports the PHH hypothesis for developed countries (like Kuwait, Turkey), for many developing and growing countries (like Mexico, Brazil, India, and China), and for a set of Asian developing countries (Acharyya 2009; Jun et al. 2018; Salahuddin et al. 2018; Khan and Ozturk 2020). In contrast, recent studies highlighted that FDI and environmental quality have a positive association. This supports the PHHH and the PH hypothesis for different developed and developing countries like Malaysia, and China, 30 OECD countries, MINT groups, and a set of Sub-Sharan African countries (Pazienza 2015; Acheampong et al. 2019; Balsalobre-Lorente et al. 2019). In addition, considering a different set of countries, Shahbaz et al. (2015) and Marques and Cantano (2020) highlighted that the PHH exists only for low and middle-income countries and is rejected for high-income countries. However, there are minimal studies available on the reverse effect of environmental quality on FDI. According to Walter and Ugelow (1979), environmental quality significantly affects the international capital moment. In this regard, the contemporary literature evidence that the environment is an essential input factor of production, and thus the environment has a significant effect on socio-economic activities (Pao and Tsai 2011; Azam 2016). However, Haug and Ucal (2019) denied any significant relationship between FDI and environmental quality and argued that FDI variation could not explain environmental regulations.

2.2. Environmental quality and Institutional quality

The theoretical base for environmental quality-institutional quality nexus is well explained in two critical theories: the environmental governance theory (EGT) and the ecological modernization theory (EMT). The EGT theory is applied to determine the crucial factors influencing environmental outcomes and their objectives (Baron and Lyon 2012). This theory helps institutions to mitigate environmental externalities. Thus the EGT theory argues that governance of an economy is the fundamental factor to create efficient environment management and helps to improve the environment quality (Armitage et al. 2012). Second, the EMT theory emphasizes the relationship between environmental deterioration and social, political, and institutional changes (Mol and Spaargaren 2000). Unlike EGT, EMT systematically analyzes how economic, political, and social forces interact with one other in providing environmental goods and services (Lemprière 2016).

In this regard, a good number of empirical literature have demonstrated the relationship between institutional quality and quality of the environment and gained various researchers' attention. Different economists have used specific institutional quality indicators (for example, democracy, political globalization, and control of countries' corruption) in case of the EU, G20, BRICS, and OECD countries (Paramati et al. 2017; Wang et al. 2018). They highlighted a negative relationship between institutional quality and environmental degradation and concluded that better institutional quality improves better environmental quality. In contrast, Scruggs and Rivera (2008) have mentioned that democracy and political freedom have no significant role in better environmental quality. However, with different institutional indicators, the outcomes are forced to remain contradictory and lead to an insufficient solution. Therefore, it is wise to take composite indicators of institutional quality instead of single indicators to keep studies from remaining inconclusive as institutional quality components usually interact (Wu 2017). The relationship between institutional quality indices and CO_2 emissions has drawn much attention to overcome this limitation. Using a bunch of institutional parameters from World Development Indicators (WDI), International Country Risk Guide (ICRG), and Freedom Index dataset, existing studies examined in several cross country studies (for instance, BRICS, MENA, EMDEs, and many different sets of developing countries). They found that institutional quality has a significant role in improving the environmental quality (Wu 2017; Ali et al. 2019; Danish et al. 2019; Azam et al. 2020; Le and Ozturk 2020; Omri and Mabrouk 2020). These studies' findings commonly support that an influential institution can improve environmental quality in developed and developing economies. In contrast, Armenien and Mengaki (2019) highlighted no significant effect of institutional quality changes on CO_2 emission in 67 high-income and upper-middle-income countries. However, there is hardly any study available that measures the role of environmental quality to determine the host countries' institutional quality.

2.3. FDI and Institutional quality

A growing body of literature has examined MNCs' location decisions through the institutional lens and explains two theories supporting institutional quality have a significant role in determining FDI inflows. According to Dunning (1980), a multinational corporation (MNCs) enters host countries to capture ownership, location, and internalization advantages. This is also known as the eclectic paradigm or the OLI model. After Dunning, the institutional economist North (1990) has pioneered the theory of 'institution' and set the rules of games those MNCs should follow in their own experience and optimal resource allocation. In return, host countries' government must improve their institution to lower the transaction costs to encourage foreign investors. In addition to these two theories in recent times, Westney (1993) has explored the feedback effect of FDI on the host country's institutional quality. The study revealed that MNCs significantly improve the host countries' organizational patterns through subsidiaries. In summary, it can be assumed that the theoretical view highlighted that better institutions are positively related to FDI inflows, and more FDI can improve the host countries' institutional quality.

The empirical literature on these theoretical arguments emphasizes the effects of different institutional dimensions (like property rights protection, control of corruption, democracy, government stability, civil liberty, and political rights) on inward FDI. It revealed that foreign investors are incredibly motivated by the host country's institutions (Aziz 2018; Ibrahim et al. 2020). However, recent studies revealed that the coefficients of control of corruption, government effectiveness, political stability, the rule of law, and the voice and accountability significantly attract FDI inflows in developed countries but do not impact FDI inflows in developing countries substantially (Peres et al. 2018; Sabir et al. 2019). At the same time, recent literature constructed the composite institutional indicators considering its importance to examine the diversified influence of institutional indicators on inward FDI (Moon 2019). In this regard, a set of empirical literature have examined the FDI-institutional quality indices nexus for a group of developing regions (Kurul and Yatra 2017; Ullah and Khan 2017). They put a similar conclusion that better institutional quality can significantly attract more FDI inflows in those regions. In contrast, Kandil (2009) revealed that institutional quality is not significant in attracting FDI inflows. On the other side, some recent studies have explored the positive role of FDI inflows on institutional quality and revealed that FDI inflow could stimulate host countries' institutional quality improvement (Fukumi and Nishijima 2010; Huynh 2020; Huynh et al. 2020).

On the other hand, this detailed literature is mainly based on unidirectional FDI inflows, and the number of studies exploring the nexus from bilateral FDI stock is minor. Thus, these studies mostly neglect the host and source approach to deal with the destination's FDI and institutional quality nexus. To emphasize this importance, Daude and Stein (2007) and Kunčič and Jaklič (2014) used bilateral FDI stocks from OECD countries worldwide and suggested that institutions greatly influence FDI stocks. In recent times, Mishra and Jena (2019) also found that a composite institutional index plays a vital role in attracting FDI in major Asian countries. However, hardly any study examines FDI-institutional quality nexus with bilateral FDI and composite institutional quality index in G20.

2.4. Environmental quality, FDI, and Institutional quality

Two common concepts can establish theoretical connections on the trilateral relationship between FDI, institutional quality, and environmental quality: environmental governance theory and the pollution haven hypothesis. These theories mainly argue a strong relationship with institutions, open economy, and environmental degradation (Adeola 2000). More specifically, Sabir et al. (2020) highlighted that the level of CO_2 emission could be controlled with stringent rules and regulations. The stringent regulations also influence inward FDI and their external effect on the host countries' environmental quality.

Recent studies have highlighted the role of institutional defects and their cruciality while judging the environmental effects of FDI (Tang et al. 2020). Considering this, Wang et al. (2020) mentioned that corruption indirectly leads to pollution by lowering the existing standards, enabling low-quality FDI inflow, and weakening the FDI spillover effect. Similarly, it is argued that democracy plays a significant role in influencing FDI and natural resources.

Further, good institutional quality is an instrument to reduce the adverse effect of environmental quality on FDI (Asiedu 2013; Dang 2019). Therefore, good governance is an instrument to meet the environmental challenges related to inward FDI (Bokpin 2017). On the contrary, Jorgenson (2009) demonstrated that less-developed countries could not minimize the harmful effects of FDI on the environment even after solid government regulations.

The existing studies have explained the nexus among environment quality, FDI environment quality, and institutional quality. However, the empirical results are mixed (see Table 1.), and the conclusions are elusive. Although the studies already signified the environmental quality and FDI relationship, further investigation on bidirectional relations in the G20 context is less evidenced. Next, concerning the choice of institutional quality indicators, only a few papers have covered a comprehensive coverage of its indicators (see Kunčič 2014), while the study does not have coverage for environmental quality. The next gap lies as hardly any composite institutional index verifies bidirectional effect with bilateral FDI in G20. Finally, as per the best of our knowledge, only one study (Dang 2019) has examined a trilateral linkage between environmental quality, bilateral FDI, and governance indicators. Therefore, to minimize such a massive gap in this FDI-institution-environment relation, we draw a new analysis to reveal the relationship correctly in selected G20 countries. By considering the importance of this nexus, the study follows the following hypotheses:

H_1: There is a bidirectional relationship between bilateral FDI stocks and CO_2 emission intensity.

H_2: There is a bidirectional relationship exist between institutional quality and CO_2 emission intensity.

H_3: There is a bidirectional relationship between bilateral FDI and institutional quality.

H_4: There is a simultaneous relationship exist between environmental quality, bilateral FDI, and institutional quality.

3. Data, Variables, and Methods

This section focuses on the analysis of the data and variables and econometric techniques used in this study.

3.1. Data Description and Data Source

This study examines the impact of CO_2 emissions intensity, bilateral FDI, and institutional quality on each other for 2009-2017 of G20 countries excluding the European Union (EU). Our study employs data of G20 countries as a sample for our estimation because it covers the world's major economies, where G20 comprises major developed economies such as G7 countries and typically the most emerging countries such as BRICS (Yao and Tang 2020). According to the IMF (2017), the economic performance of G20 members together contributed around 90% of the gross world product. They comprise approximately two-thirds of the world's population, and about 80% contribution to world trade. At the same time, the ratio of CO_2 emissions from G20 countries to world CO_2 emissions over decades has remained a significant issue started from 1970 to now (Mardani et al. 2018). However, studies relating to the environmental quality of G20 countries are highly explored but mainly limited to energy-growth-environment linkages (Li et al. 2020; Xu et al. 2020). Simultaneously, hardly any study has covered such a triplet association considering CO_2 emission intensity, bilateral FDI, and institutional quality. However, the EU has not been included in our country selection because it is based on the country-level data, but the EU comprises 28 countries. Another reason is that some countries (such as France, Germany, Italy, and the UK) also stand individually in the G20 groups. Thus, it is better to prevent the EU in our cross-country list (Wang et al. 2018). The survey periods in the econometric models are limited to 2009-2017 because of two reasons. First, the upper limit is restricted to show the importance of the global financial crisis when the G20 responded to several coordinated economic policies and aimed for 'strong, sustainable and balanced growth' at the Pittsburg Summit 2009. The second significant restriction to this period is the availability of IMF data for bilateral FDI. All data are collected from different sources. For more straightforward analysis, variables are transformed into a natural logarithm form, and in the case of variables with zero and negative values, we follow Gujarati (2004) method. Variables used in the empirical estimation with the measurement, definition, source, and expected signs are reported in Table 2. The variables' descriptive statistics of this paper are reported in Table 3.

3.1.2. Dependent variables

Three dependent variables of our empirical estimation are CO_2 emission intensity, bilateral FDI, and institution. The first dependent variable of our estimation is CO_2 emission intensity (CO_2). CO_2 emission is used globally due to its data on the most extended panel among other global and local pollutants to measure the environmental performance. However, as CO_2 is only a byproduct of energy consumption, it becomes viable to take CO_2 intensity (CO_2/energy use) as a better measure of the environment quality of countries than the level of CO_2 emissions or its per capita level (Hosseini and Kaneko 2013). Thus, we take CO_2 intensity measured with CO_2 emissions per energy use to proxy environmental quality.

The second dependent variable we use for our empirical model is bilateral FDI stock (FDI). The advantages of stock rather than flows are: First, it is a better measure of capital ownership as local capital markets finance it. Second, stocks are less volatile than the flows (Kunčič and Jaklič 2014; Kahouli and Maktouf 2015). The bilateral FDI stock depends on the origin country i's characteristics, destination country j's characteristics, and bilateral-specific variables size of the economy and geographical distance. Following a mirror approach, we use an inward bilateral FDI position from the Coordinated Direct Investment Survey (CDIS) database compiled by the IMF for all the 19 countries from a host country perspective.

The third dependent variable of our research is the institutional quality (INST). To ease the comparison of different quality measures of the institution, we followed the approach developed by Kunčič (2014) and normalize the indicators to lie between zero and one, such that a higher number lies higher quality institutions. The institutional quality is measure through 31 formal institutional indicators.[1] As a proxy for the host country's institutional functions, our research employs data from various sources to compute the institutional quality index[2]. The

[1] See Kunčič (2014) better understand formal all Institutional quality indicators (except checks and balances), standardization, computation, and their sources.
[2] See Table 2 for detailed sources.

institutional quality index of this study follows a principal factor analysis and provides a single factor score for each country as such higher values reflect better institutional quality (Kunčič and Jaklič 2014).

3.1.2. Main explanatory variables

1. **Market size.** Studies argue that market size plays an essential role in attracting foreign investors (Aziz 2018) and helps to develop an eco-friendly environment with good institutions (Wang et al. 2018). Thus, following Hargrove et al. (2019), GDP per capita is a proxy for market size ($DGDPPC$).

2. **Distance.** Large parts of the growing empirical literature of FDI location are based on gravity. In its standard specification of bilateral trade flows (in our case, bilateral inward FDI stocks) depends negatively on the distance between them (Daude and Stein 2007). The empirical estimation employs distance ($DISTANCE$) and it is measured with the great circle geographical gap between the countries' capitals.

3. **Financial Development**. Researchers argue that defining financial development is one of the vital pillars of FDI and the better institution of host economies (Donaubauer et al. 2020). In this paper, private credit has been considered a proxy to measure our empirical estimation's financial development(FD).

4. **Trade openness.** The degree of openness is a significant factor in stimulating FDI and the institutional frame of an economy (Aziz 2018). In addition, Hargrove et al. (2019) mentioned trade openness as a significant factor influencing the level of CO_2 emission. Following the previous literature (Essandoh et al. 2020), our study uses total export and import of goods and services as a percentage of GDP ($TRADE$) to measure trade openness.

5. **Natural resource endowment.** Most FDI has invested in countries endowed with natural resources, including oil, natural gas, and minerals. However, a transparent relationship between the institution and natural resources endowment potentially motivates FDI and also determines the level of CO_2 emission intensity (Sabir et al. 2020; Hosseini and Kaneko 2013). Considering its importance, we use natural resource depletion (% of Gross National Income) as a proxy to natural resource endowment ($RESOURCE$).

6. **Inflation.** A high rate of inflation may be costlier for foreign investors with high uncertainties. Thus, it becomes crucial to judge the institutional quality of any country that is responsible for long-term unsustainability concerning price setting and profit expectations (Khan and Hanif 2020). We consider the annual percentage of GDP deflator as a proxy of inflation ($INFL$) in our estimation.

7. **Infrastructure.** A developed infrastructure such as internet services is vital to attract FDI, establish better governance, and improve the environmental quality (Kahouli and Omri 2017). Following Kahouli and Maktouf (2015), our study uses individuals using the internet (% of the population) as a proxy to infrastructure development (INF).

8. **Population.** The size of an economy's population shows the size of the economy and has a more significant influence on foreign direct investment (Kahouli and Maktouf 2015). However, a growing population might cause

more volatile institutions and become the prime cause of the rapid increase of pollution globally (Hargrove et al. 2019). Considering its priority, our paper accounts for the total number of residents in a nation as a proxy to the size of the population (POP).

9. **Human capital.** Human capital is one of the significant bedrock of any country's development and helps to adopt new advanced technologies, provides better experience and skill, and motivates better environment quality (Dong et al. 2019). Following Kahouli and Maktouf (2015), we proxy the tertiary enrollment rate for human capital (HC).

10. **Urbanization.** Urbanization can foster a better environmental performance by tackling the climate change issue as urbanized people are more aware of the environment (Yao et al. 2018). This paper considers the urban population as a percentage of the total population (URB) as a proxy to assess the impact of urbanization on the carbon intensity level.

11. **Other explanatory variables.** We consider three essential variables from a bilateral approach to emphasize both host and source countries' differences and similarities to examine the nexus among environment-FDI-institution. Following Kahouli and Omri (2017), our study considers the difference in GDP per capita ($DGDPPC$), the difference in CO_2 emission intensity (DCO_2), and the difference institutional quality index ($DINST$) as three core control variables in the models.

3.2. Econometric Strategy

This section explains both static and dynamic simultaneous techniques employed in our empirical estimations.

3.2.1. Static models

Three different panel static models, such as random effect (RE), fixed effect (FE), and Hausman-Taylor regressions (HT), are used in this paper. The advantage of the random effect mechanism considers the time series and the dataset's cross-transversal nature (Kahouli and Maktouf 2015). The RE technique accounts for the interception as random variables through common member countries. However, the RE estimates become biased and inconsistent when the specific effects of the models are correlated with some explanatory variables (Kahouli and Omri 2017). Therefore, it is necessary to do the Hausman test to identify the essential bias in the estimations. If the test statistics reject the null hypothesis, the analysis prefers the FE method over the RE. The advantage of the FE estimator lies in that it helps each group member to examine different country-specific intersections (Kahouli and Omri 2017). Still, it becomes unsuitable for time-invariant variables such as distance, a fundamental variable in the bilateral FDI context (Kahouli and Maktouf 2015). To overcome this disadvantage of the FE estimator, we include the HT regression in our static models (Hausman and Taylor 1981). The HT estimates overcome the endogeneity between explanatory variables and allow time-fixed variables and time-varying variables. Some of them may be endogenous in the correlation with the individual effects but exogenous to the error term. Thus it can produce consistent and efficient estimates for the time-invariant variables (Kahouli and Omri 2017).

The three static models follow the following equation form:

$$lnCO_{2\,ijt} = \rho_0 + \rho_1 lnDCO_{2ijt} + \rho_2 lnFDI_{ijt} + \rho_3 lnINST_{ijt} + \rho_4 lnDINST_{ijt} + \rho_5 lnGDPPC_{ijt} + \rho_6 lnDGDPPC_{ijt} + \rho_7 lnPOP_{ijt} + \rho_8 lnTRADE_{ijt} + \rho_9 RESOURCE_{ijt} + \rho_{10} lnINF_{ijt} + \rho_{11} lnHC_{ijt} + \rho_{12} URB_{ijt} + \mu_{ijt} \dots (1)$$

$$lnFDI_{ijt} = \beta_0 + \beta_1 lnINST_{ijt} + \beta_2 lnDINST_{ijt} + \beta_3 lnCO_{2,ijt} + \beta_4 lnDCO_{2ijt} + \beta_5 lnGDPPC_{ijt} + \beta_6 lnDGDPPC_{ijt} + \beta_7 lnPOP_{ijt} + \beta_8 lnFD_{ijt} + \beta_9 lnTRADE_{ijt} + \beta_{10} lnRESOURCE_{ijt} + \beta_{11} lnINFL_{ijt} + \beta_{12} lnINF_{ijt} + \beta_{13} lnDISTANCE_{ijt} + u_{ijt} \dots (2)$$

$$lnINST_{ijt} = \alpha_0 + \alpha_1 lnDINST_{ijt} + \alpha_2 lnFDI_{ijt} + \alpha_3 lnCO_{2ijt} + \alpha_4 lnDCO_{2ijt} + \alpha_5 GDPPC_{ijt} + \alpha_6 lnDGDPPC_{ijt} + \alpha_7 lnPOP_{ijt} + \alpha_8 lnFD_{ijt} + \alpha_9 lnTRADE_{ijt} + \alpha_{10} lnRESOURCE_{ijt} + \alpha_{11} lnINFL_{ijt} + \alpha_{12} lnINF_{ijt} + \epsilon_{ijt} \dots (3)$$

The above equations (1)-(3) are static models. Where i stand for host, j for source, t for time, ρ_0, β_0, and α_0 are constants; ρ, β, and α are coefficients; μ_{ijt}, u_{ijt}, and ϵ_{ijt} are the error terms in equations 1, 2, and 3, respectively.

3.2.2. Simultaneous equations

According to Eqs. (1), (2), and (3), the CO_2 emissions intensity, bilateral FDI, and institutional quality may influence each other; therefore, there may be potential endogeneity caused by the multilateral causality. However, the conventional static estimates cannot be used here as they ignore the endogeneity and may suffer from bias and inefficient estimates (Wooldridge 2016). Therefore, we purpose of using simultaneous equation techniques in the empirical analyses.

3.2.2.1. Simultaneous static equations

The advantage of the seemingly unrelated regression (SUR) model is that it simultaneously evaluates all equations' parameters. Thus, this technique considers each equation's parameters and considers the system; then, other equations are also determined (Kahouli 2018). However, the SUR estimation is based on an assumption of no endogenous regressors and is affected by the error covariance matrix (Zellner and Thell 1962). To avoid this limitation, we use the three stages least square (3SLS) method. The 3SLS technique has the advantage of estimating all the parameters while accounts equations with endogenous regressors. Simultaneously, the 3SLS estimates are more consistent, asymptotically normal, and more efficient than single equation estimates. This research uses this technique to combine multivariate and two-stage regression (Zellner and Thell 1962). Thus, this technique improves equation-by-equation efficiency by considering correlations across equations (Wooldridge 2010).

3.2.2.2. Dynamic simultaneous equations

The three dependent variables are not free from the impacts of their lagged values independently. Thus the dynamic panel equations for our empirical estimations are as follows:

$$lnCO_{2\,ijt} = \rho_0 + \rho_1 lnCO_{2ij,t-1} + \rho_2 lnDCO_{2ijt} + \rho_3 lnFDI_{ijt} + \rho_4 lnINST_{ijt} + \rho_5 lnDINST_{ijt} + \rho_6 lnGDPPC_{ijt} + \rho_7 lnDGDPPC_{ijt} + \rho_8 lnPOP_{ijt} + \rho_9 lnTRADE_{ijt} + \rho_{10} RESOURCE_{ijt} + \rho_{11} lnINF_{ijt} + \rho_{12} lnHC_{ijt} + \rho_{13} URB_{ijt} + \mu_{ijt} \ldots (4)$$

$$lnFDI_{ijt} = \beta_0 + \beta_1 lnFDI_{ij,t-1} + \beta_2 lnINST_{ijt} + \beta_3 lnDINST_{ijt} + \beta_4 lnCO_{2,ijt} + \beta_5 lnDCO_{2ijt} + \beta_6 lnGDPPC_{ijt} + \beta_7 lnDGDPPC_{ijt} + \beta_8 lnPOP_{ijt} + \beta_9 lnFD_{ijt} + \beta_{10} lnTRADE_{ijt} + \beta_{11} lnRESOURCE_{ijt} + \beta_{12} lnINFL_{ijt} + \beta_{13} lnINFR_{ijt} + \beta_{14} lnDISTANCE_{ijt} + u_{ijt} \ldots (5)$$

$$lnINST_{ijt} = \alpha_0 + \alpha_1 lnINST_{ij,t-1} + \alpha_2 lnDINST_{ijt} + \alpha_3 lnFDI_{ijt} + \alpha_4 lnCO_{2ijt} + \alpha_5 lnDCO_{2ijt} + \alpha_6 GDPPC_{ijt} + \alpha_7 lnDGDPPC_{ijt} + \alpha_8 lnPOP_{ijt} + \alpha_9 lnFD_{ijt} + \alpha_{10} lnTRADE_{ijt} + \alpha_{11} lnRESOURCE_{ijt} + \alpha_{12} lnINFL_{ijt} + \alpha_{13} lnINFR_{ijt} + \epsilon_{ijt} \ldots (6)$$

The above Eqs. (4)-(6) are dynamic panel data models. Where, $lnCO_{2ij,t-1}$, $lnFDI_{ij,t-1}$, and $lnINST_{ij,t-1}$ are the 'one lagged' value of our estimation's three dependent variables, i.e., CO_2 emissions intensity, bilateral FDI, and institutional quality. As per our knowledge, hardly any studies based on these three parameters are verified with such estimation considering such delayed variables. However, the introduction of dynamics in the econometric model poses serious problems due to estimators' incompatibility (Baltagi 2008). In such cases, econometric models are likely to have endogeneity problems (Muhammad and Khan 2019). We use the two-step System GMM technique (SGMM) in our estimation to fix the above issues. The SGMM helps to remove the country-pair-specific effect of the error term and the source of the correlation between the latter and lagged dependent variable (Kahouli and Maktouf 2015). This dynamic SGMM technique also overcomes the weak instrument issue is in the difference GMM (Muhammad 2019). Another advantage of this technique tackles the endogeneity issue, the data's spatial characteristics, and generates instruments from explanatory variables (Kahouli 2018). The rationale to select the two-step SGMM lies as it is considered more efficient than the one-step estimator in the case of a large sample (Khan et al. 2019). To validation the instruments of SGMM, two conditions are to be met. First, the absence of second-order autocorrelation (AR_2), and second is the over-identified hypothesis should not fail to reject in the Hansen test, which indicates that the instruments are valid and the model is correctly specified (Roodman 2009).

[Insert Table 2 near here]

[Insert Table 3 near here]

4. Empirical results and discussions

This section reports both static and simultaneous techniques' outcomes that examine the three-way linkage among environment quality, bilateral FDI, and institutional quality among G20 countries.

4.1. Results of the static models

Table 4 demonstrates estimates of the coefficients of static models such as FE and HT for CO_2 emission intensity, bilateral FDI, and institutional quality. However, in panel data, it is not wise to interpret simple regressions. Thus, we employ both FE and RE techniques in our estimation. While choosing between FE and RE, the Hausman test rejects the null and indicates that the FE estimators are preferable to RE coefficients for our analysis; therefore, our interpretation is limited to FE results only, however, all the panel regression results (including the RE and the OLS) are shown in Table S4 (See S4A, S4B and S4C) in the supplementary material. In all static models, coefficients mostly have expected signs, and they are statistically significant. In all three cases, the F-statistics specification is statistically significant at the 1% level.

Model 1 in Table 4 demonstrates the bilateral FDI and institutional quality coefficients on CO_2 emission intensity in G20 countries. The FE and the HT estimators have shown that the bilateral FDI stocks give positive coefficients but do not significantly influence CO_2 emission intensity. The result demonstrates that institutional quality performance has a substantial and antagonistic relationship with CO_2 emission intensity. This result is consistent with the current works' findings (Hargrove et al. 2019). Except for these two significant endogenous variables, FE and HT estimators also explain that the difference in CO_2 emission intensity and the difference in institutional quality performance have a positive and significant impact on CO_2 emission intensity. This shows that both countries' bilateral characteristics also affect the host countries' CO_2 emissions. However, the difference in GDP per capita remains negative and insignificant. Out of the control variables, the result reveals that GDP per capita and inflation rate positively and significantly contribute to increasing CO_2 emission intensity in the host countries. However, other control variables such as natural resource endowment, human capital, and urbanization negatively and significantly affect CO_2 emission intensity. However, the Trade coefficient remains an insignificant factor with a negative sign for the CO_2 emission intensity. The FE coefficient of the population demonstrates a negative and significant impact on CO_2 emission intensity. The distance variable is considered to smoothen the HT model in Model 1; however, it remains insignificant and not affecting our results.

Model 2 presents the static model coefficients of institutional quality and CO_2 emission intensity on bilateral FDI in G20. The FE and the HT estimators demonstrate that the coefficients of CO_2, although negative, do not significantly influence bilateral FDI stock. Both methods' results that institutional quality positively and affect substantially host countries' inward bilateral FDI stock. This result is consistent with earlier results like (Daude and Stein 2007; Aziz 2018). The difference in CO2 emission intensity coefficient has shown a positive and significant influence on bilateral FDI only in the HT model. However, the difference in institutional quality has a negative and significant impact on bilateral FDI in both estimators. The coefficient of the difference GDP per capita has negatively and significantly affected the bilateral FDI. The coefficient of distance reveals a substantial and adverse effect on FDI inflows. This finding is consistent with several gravity literature of bilateral FDI (Daude and Stein 2007). The coefficient of infrastructure shows a positive and significant impact on the bilateral FDI in both techniques. This result is consistent with the existing literature (Kahouli and Maktouf 2015). In addition, the coefficient of the financial development reveals a negative and significant effect on FDI. These results support the existing findings by (Aziz 2018).

Model 3 reveals the static model coefficients of bilateral FDI stock and CO_2 emission intensity on institutional quality. According to the estimator's results, the CO_2 emission intensity and the difference in the CO_2 emission intensity coefficients negatively and significantly impact the host countries' institutional performances. Similarly, the bilateral FDI demonstrates a significant and positive effect on the host countries' institutional performances. Our finding is consistent with recent literature (Huynh 2020).

Similarly, the coefficients of the difference in institutional quality have a positive and significant impact on host countries' institutional performances. In addition, the coefficients of the difference in GDP per capita, natural resources, and inflation rate demonstrate a negative and significant impact on host countries' institutional performances. The coefficient of other explanatory factors such as GDP per capita has a positive and significant impact on host countries' institutional quality. The result is consistent with the existing literature (Kahouli and Omri 2017). The coefficient value of population demonstrates a significant and positive impact on host countries' institutional qualities only in the FE. However, financial development, trade, and infrastructure coefficients remain insignificant to influence the institutional quality.

[Insert Table 4 near here]

4.2. Results of simultaneous techniques

Our main models are the simultaneous estimators verified with three efficient system techniques presented in three models in Table 5. We report only the robust SGMM results and indicate the SUR and the 3SLS results with superscripts and subscripts[3] if they remain significant. The two-step SGMM estimator is validated with the Hansen test and the result of the AR_2 test. The statistics reported by the Hansen test indicate the acceptance of the null hypothesis that the restrictions on the identification are valid. Significantly, our AR_2 results notify us that there is no second-order correlation present in any SGMM estimators.

Model 1 demonstrates the effect of bilateral FDI and institutional quality on CO_2 emission intensity in G20 countries. The coefficient value of bilateral FDI reveals a negative and significant impact on carbon emission levels. This implies that the host countries' inward FDI comes with an environmentally friendly approach and supports the 'halo effect.' This study is consistent with several existing literature (Dang 2019; Sabir et al. 2020). Institutional quality coefficient value signifies a positive and significant effect on environmental degradation. This result implies that improvement in institutional quality deteriorates the environmental quality as a whole. This study is consistent with the empirical results of existing literature (Saidi et al. 2020).

The lagged carbon emission intensity coefficient value shows a significant and positive change in the carbon emission level in the host countries. This implies that the current emission level has a substantial effect on the environmental quality. The significant bilateral country characteristics such as difference institutional quality and difference GDP per capita reveal a negative and significant association with CO_2 emission intensity. This explains that the higher the difference between the host and source countries' institutional performance and their economic size, the lower the host countries' emission level. However, the difference in CO_2 emission intensity positively and

[3] The SUR and the 3SLS results compared to the SGMM results are shown in Table S5 (see S5A, S5B and S5C) in the supplementary material.

significantly influences the host countries' CO_2 emissions. The result also reveals that the coefficient of infrastructure has a significant and negative effect on CO_2 emission levels. This implies that better infrastructure facilities can help to reduce the host countries' CO_2 emission intensity. Human capital's coefficient demonstrates that it is significant but negatively affects carbon emission levels. This implies that education, knowledge, and awareness about the environment can help the economy sustainably (Kahouli 2018). On the other side, urbanization shows a positive and significant impact on increasing CO_2 emission intensity. This finding is consistent with the existing literature by Muhammad et al. (2020). However, the other explanatory variables like GDP per capita, population size, trade openness, and natural resource remain insignificant to influence the host countries' CO_2 emissions.

Model 2 gives the simultaneous estimation coefficients of institutional quality and CO_2 emission intensity impact bilateral FDI in G20 countries. The CO_2 emission intensity reveals a negative and insignificant coefficient in our model. The coefficient of institutional quality indicates a positive and significant impact on inward bilateral FDI stocks. This result is consistent with the existing studies (Aziz 2018). The SGMM coefficient of the lagged value of bilateral FDI shows a positive and significant FDI in the host countries. This implies that existing bilateral FDI can substantially attract more FDI.

Similarly, the different carbon emission intensity coefficient demonstrates a significant and positive impact on bilateral FDI. This implies that a higher gap in the emission level in the two countries can promote more inward FDI into the host destinations. However, the difference in institutional quality coefficient remains negative and significant. This reveals that the similarities in institutional performances are also significant for host countries to pull more bilateral FDI into their destinations. However, the coefficients of the other two bilateral characteristics' variables, such as difference GDP per capita and distance, remain negative and insignificant. Control variables such as GDP per capita, the size of the population, and the infrastructure show a positive and significant effect and signify that the growth in the market size increases host countries' inward FDI. This finding is consistent with the existing literature (Aziz 2018; Kahouli and Maktouf 2015). However, the coefficient of resource endowment and inflation is negative and significant. This implies that the massive potential of natural resources can cost the 'resource curse' issue (Asiedu 2013), and a higher rate of inflation means higher uncertainties for the foreign investors (Aziz 2018). However, the coefficient of trade gives an insignificant value to influence the bilateral FDI in G20 countries.

Model 3 reveals that the coefficient of CO_2 emission intensity reveals a positive and significant effect on institutional quality in G20 countries. This implies that higher emission countries with increased production and energy consumption can boost economic growth and improve institutional performance. This study also remains consistent with the existing literature (Hosseini and Kaneko 2013). The coefficient of the bilateral FDI has a positive and significant effect on institutional quality. This implies that more and more FDI can promote better institutional quality in the host destination. This result is consistent with the existing literature (Huynh 2020; Huynh et al. 2020). Simultaneously, the lagged value of institutional quality reveals a positive and significant effect on institutional quality. The coefficient of the difference in carbon emission intensity and the difference in GDP per capita has a negative and significant impact on institutional quality. This implies that the differences in environmental quality and economic growth among pair countries also influence the host countries' institutional quality. However, the coefficient of the difference in institutional quality remains positive and significant. The other important explanatory variables, such as GDP per capita, demonstrate a positive and significant impact on institutional quality. The coefficients of population, resource endowments, financial development, and inflation reveal a negative and significant effect on the source countries' institutional quality. However, the coefficient value of trade openness and infrastructure remains insignificant to influence the institutional quality in our findings.

[Insert Table 5 near here]

In summary, our empirical results confirm that bilateral FDI improves environmental quality by reducing CO_2 emission intensity in G20. Thus our result supports the existence of the 'halo effect' in our sample countries. Next, our empirical estimation confirms that the institutional quality and CO_2 emission intensity has significantly caused each other in G20. The result also reports a significant bidirectional association between institutional quality and bilateral FDI. Finally, with system estimators' help, our results confirm the final hypothesis of this paper and evidence a simultaneous relationship between CO_2 emission intensity, bilateral FDI, and institutional quality in G20. Our empirical results prioritize a trilateral relationship among CO_2 emission intensity, bilateral FDI, and institutional quality (see Fig. 1). However, our results confirm only a unidirectional positive relationship between FDI and environmental quality in G20. With this, our findings imply significant policy implications to achieve sustainable growth concerning environment-FDI-institution nexus for G20 economies.

[Insert Figure 1 near here]

5. Conclusion

Over the last few years, environmental quality, bilateral FDI, and institutional quality research have been focal topics. However, hardly any study considered the relationship between environmental quality, bilateral inward FDI, and institutions on each other in 19 selected G20 countries during the sample period of 2009-2017. Our research uses a panel of 342 pairs of host and source countries by using three basic panel estimators such as fixed effect, random effect, and Hausman-Taylor estimators to demonstrate a preliminary result of our hypothesis. However, to overcome the limitations of static one equation models, we follow three simultaneous techniques: seeming unrelated regression, three-stage least square, and the system generalized method of moments estimators. The lagged value of three dependent variables in the SGMM reveals a significant agglomeration effect in each case. Our research indicates that bilateral FDI directly influences CO_2 emission intensity, implying that FDI helps the G20 countries to improve environmental quality. The results support that the host countries' institutional quality has positive and significant encouragement to FDI. Simultaneously, the results support that the bilateral FDI also improves host countries' institutional quality in the sample case. The findings reveal that institutional quality and CO_2 emission intensity are simultaneously associated in host countries. The result shows bilateral characteristic variables like distance, the difference in institutional quality, the difference in CO_2 emission intensity, and the difference in per capita GDP play an essential role in determining the source countries' environmental quality, institutional performance, and bilateral FDI stocks. In addition to these, our findings also reveal that other macro-economic variables such as GDP per capita, size of the population, financial development, trade openness, infrastructure, natural resources, inflation, human capital, and urbanization are significant to influence the environment-FDI-institution nexus in selected G20 countries.

Our study has few limitations; first, we have ignored the interaction effect of bilateral FDI and CO_2 emission intensity on institutional quality, bilateral FDI and institutional quality on CO_2 emission intensity, and institutional quality and CO_2 emission intensity on FDI. Second, our study is limited to only select 19 countries of G20 economies. Third, our study is limited to only nine years due to data limitations. Thus we suggest that further research can extend this study taking the interaction effect into the linkage. Studies can be broadened to cover the entire world using various econometric specifications.

6. Policy implication

This study suggests the subsequent policy implications of G20 countries to decrease the environmental degradation and a better economy with improved institutional quality and a large volume of foreign investments. The policymakers should encourage more greener FDI in G20 countries with incentive policies such as tax reductions and more subsidies. This is because it helps to use more advanced technologies and clean energy-efficient technologies to reduce the emission pressure to have a better economy. The government of G20 economies should allow other countries' investment to boost up their institutional reforms to achieve a sustainable economy. However, G20 economies should minimize performance gaps in all three aspects to maximize benefits from FDI while also improving institutions and maintaining a pollution-free environment.

Further, the study suggests policymakers should invest more to provide advanced equipment to extractive units during the extraction of natural resources to curb the negative impact of natural resources on environment quality in sample countries. However, G20 economies should promote urbanization and invest more in human capital to achieve a low level of pollution in their economies. Our research also finds that G20 countries' governments should consider the impact of other macroeconomic factors such as GDP, infrastructure, and population while making any policy framework concerning environment-FDI-institution nexus. Here, economies should emphasize avoiding a trade-off between economic growth and environmental quality by relaxing rules to attract greater FDI inflows, strengthening institutions, and improving environmental quality. Therefore G20 economies have to follow a comprehensive framework to achieve the sustainable goals 2030 with a multidimensional process with high integrity.

Declaration

Ethics approval and consent to participate: The authors declare the provided manuscript with the title “Integrated Analysis of CO_2 Emission Intensity, Bilateral FDI, and Institutional Quality Nexus: Case Study of G20 Countries” has not been published before nor submitted to another journal for the consideration of publication.

Consent for publication: The authors declare that the manuscript does not contain any person’s data in any form (including any individual details, images, or videos).

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Figures

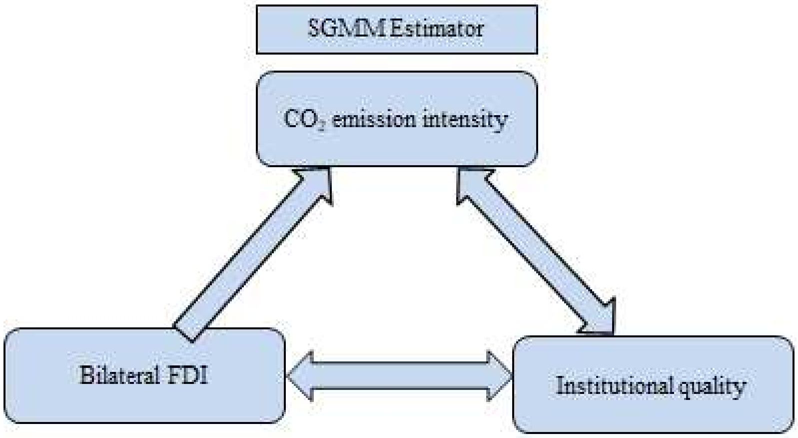

Figure 1

The three-way linkage for selected G20 countries Note: This three-way linkage of the SGMM estimator is consistent with the SUR and the 3SLS results. Source: Authors' calculation

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