Revisiting the relationship between Remittances and CO2 emissions by applying a novel Dynamic Simulated ARDL: Empirical evidence from G-20 Economies.

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Abstract

The current study looks at the causes of carbon dioxide (CO₂) emissions by considering the implications of Remittances in the presence of economic growth, financial development, and energy consumption in the case of selected four G-20 economies over the period 1990–2019. This study first uses the Dynamic Simulated ARDL model to stimulate, estimate, and plot to predict graphs of negative and positive changes occurring in the variables automatically as well as their short- and long-run relationships. Results of the ARDL bounds-test confirm a long-term relationship among CO₂ emissions, remittances, financial development, economic growth and energy consumption. The results of a novel dynamic simulated ARDL disclosed that the financial development is completely connected to CO₂ emissions in Mexico and India in long run. On the other hand, results confirm that there is a positive relationship between remittances and CO₂ emissions in case Australia, Germany, and India, but only have an insignificant relationship with CO₂ emissions in case of Mexico. The result further disclosed that Renewable energy exerts a significant impact on CO₂ in Australia, Mexico, India and Germany in the long run while remittances wield a significant impact on CO₂ emissions in Australia, Mexico, India. Moreover, the findings concluded that GDP has significant nexus with CO₂ in the long-run in case of Australia, Mexico and Germany. This study opens up new visions for the economies of G-20 countries to sustain financial and economic growth by protecting the environment from pollution through its efficient national environmental policy, fiscal policy, and monetary policy.

1. Introduction

Foreign remittances are the most stable form of international financial inflow as compared to other financial aids. It brings many benefits to low and middle-level income economies. It is suggested that migration and remittances play a significant role in reducing extreme poverty and improving per capita income (Pradhan, Upadhyay, and Upadhyaya 2008, Guha 2013). No doubt that additional disposable income gained through foreign remittances helps families to invest in land, seeds, livestock and to get better education as well as health care but on the other side, remittance has also an adverse spillover on the economic growth of the recipient country as it reduces the intention of people to work in the home country because they fulfill their needs by receiving foreign remittances. One another negative effect is that the inflow of remittance indirectly leads to Carbon Dioxide (CO₂) emission, which causes environmental degradation. To consider the harmful effect of carbon emission, the Paris Agreement is signed in the year 2016, by major carbon-emitting nations. This agreement aims to elaborate the alarming threat of change in global climate and to stabilize the adverse effect of greenhouse gas concentrations by applying vibrant features. So, on one side, remittance inflow helps the nations in reducing the poverty ratio but on the other side, it leads the nation toward environmental degradation (Brown et al. 2020). Many research studies confirmed that remittances improve financial development by providing funds available for credit, specifically to small and medium enterprises, that usually face trouble in collecting capital for investment purposes. By facilitating the creation of new business setups and/or expansion of the existing businesses, foreign remittances indirectly contribute to an increase in

CO₂ emissions (Başarir and Çakir 2015, Farhani and Ozturk 2015, Mugableh 2015, Li, Zhang, and Ma 2015). From the past few years, the issue of climate change and its implications on human life is an important challenge for scientists, policymakers, and world health organizations. Researchers have identified different sources that increase the concentration of greenhouse effect, but Carbon Dioxide (CO₂) emission is the largest source that causes more than 75% of environmental degradation (World Bank 2010). There is growing literature on the linkage among the financial development, energy consumption, trade openness, income level, and foreign direct investment (FDI), but very diminutive work has been done about the effect of foreign remittances on carbon dioxide emission (see literature cited by; (Hossain 2012)). Most of the literature has explored the link between economic growth and environmental degradation with the help of the Environmental Kuznets Curve (EKC) hypothesis introduced by (Grossman and Krueger 1995). They assumed that, as an economy of a country develops, it increases economic inequality up to a certain level and then decreases slowly in the form of an inverted U-shaped curve. This occurs because, at the initial stage of economic development, countries don't focus on environmental pollution. However, after improving human welfare and per capita income, environmental degradation decreases significantly, while economic growth continues to rise (Shafik 1994, Orubu and Omotor 2011). Numerous research studies are still inconclusive or provide a mixed consensus about the relationship between financial sector development and CO₂ emission. While some studies concluded that financial development is a crucial source of environmental degradation by emitting more CO₂ (Li, Zhang, and Ma 2015, Başarir and Çakir 2015, Tamazian and Rao 2010). On the other hand, the findings of few studies negate the positive relation of financial development with that of CO₂ emission by supporting the negative relationship between financial development and CO₂ emanations (Tamazian, Chousa, and Vadlamannati 2009, Shahbaz et al. 2013). Based on a theoretical perspective, foreign aid is likely to increase energy consumption and Carbon emission in both ways, directly and indirectly. In case of direct effect, implementation of aid-induced projects leads to higher demand of energy usage, while the indirect effect may follow when foreign aid improve education level, infrastructure and, household income which improve aggregate demand and production level and finally results in greater energy consumption, which leads to more CO₂ emissions, although the environmental Kuznets curve (EKC) hypothesis might hold (Ozturk and Acaravci 2013). This paper is examining the impact of remittance, economic growth, renewable energy, and financial development variables on Carbon emission by using a novel technique known as a dynamic simulated ARDL model. For this purpose, annual time series data is collected from the period of 1990 to 2019 of four selected G-20 countries i.e., Mexico, Australia, Germany, and India. A motivation for selecting G-20 countries is because these countries release CO₂ gas more than four-time of collectively released by the remaining countries all over the world. According to a European Union report cited by (Erdoğan et al. 2020) G-20 countries has produced 91% of worldwide CO₂ gas in 1970 and this figure dropped to 83% in 2017, which supports the argument that these countries are doing efforts to minimize the emission of CO₂. In the majority of G-20 countries, these emissions are no longer growing. While the global CO₂ emission increase by 56% from 1970 to 2017. Within the G-20 member countries, Australia, Saudi Arabia, Canada and the United States stand for the highest per capita energy-related CO₂ emissions. Japan, South Korea, and Saudi Arabia are still showing an increase in CO₂

emission over the period of five years 2008-2013. On the other hand, South Africa and Argentina show the decline in per capita Carbon emissions, as with the EU and its big member states Italy, France, Germany, and the UK. While India, Indonesia, and Brazil have the lowest per capita energy-related CO₂ emissions among all the G-20 countries, although recently there is a slightly increasing trend in India and Brazil. While China per capita emissions are currently above the G-20 average, which is 38%. China has the highest growth rate between 2008 and 2013.

Our study is comprehensive and contributes to the existing literature in several ways. Thus, this research study considered to fill the gap in present literature by taking foreign remittances as a potent measuring tool for economic growth and financial development and tries to observe its indirect role on Carbon emission. Firstly, this study attempts to identify the nexus between foreign remittances and Carbon emission in the four selected G-20 countries namely Mexico, Australia, Germany, and India. The reason behind choosing these countries is that these countries vigorously develop their biofuel industries (Xu, Zhong, and Qiao 2020). Secondly, this study performs a novel approach known as Dynamic Simulated ARDL to explore the relationship between remittance, economic growth, renewable energy, and financial development and their impacts on CO₂ emission. in four selected G-20 countries. This unique model “dynamic simulated ARDL” is recognized by (Jordan and Philips 2018a). This model estimates, and plots to predict graphs of (+ive and - ive) change that occurs in the variables automatically along with their short-run and long-run relationship. Although, the classical ARDL model which is recommended by (Pesaran, Shin, and Smith 2001) can help us in identifying only short-run and long-run relationships. Lastly, we employ a novel technique Dynamic Simulated ARDL for every country separately.

The remaining of the paper is synthesized as follows. Section 2 of the paper consists of a past literature review. Section 3 represents the research methodology and data collection process. Section 4 describes the estimation, algorithms, parameter settings, and model configuration. While conclusion, policy recommendations, and limitations of the study are mentioned in section 5.

2. Literature Review

There is a wide literature about financial development, economic growth, and Carbon emission. Many researchers have concluded their studies in different ways. Some of them argue that economic growth and financial development increase the level of CO₂ emission while many of them support the negative as well as inverted U-shaped link (Grossman and Krueger 1995, Aslan, Apergis, and Yildirim 2014, Aslan, Apergis, and Topcu 2014, Tamazian, Chousa, and Vadlamannati 2009, Sadorsky 2011, Omri et al. 2015, Mahalik and Mallick 2014, Shahbaz, Haouas, and Van Hoang 2019, Le and Bao 2020). According to (Zhang and Cheng 2009), previous literature shows three types of arguments about energy consumption, environmental pollution, and countries' economic growth. The first school of thought is concerned with the connection between economic growth and environmental pollution, which is strongly associated with the validity of the EKC hypothesis. While the second school of thought is concerned with the consumption of energy and its output. These nexuses recommend that economic development and its output may be determined jointly as economic growth is not possible without the use of energy. High

economic development needs more consumption of energy (Halicioglu 2009). The third school of thought has a mixed approach of the above two techniques, which observed the dynamic connection of economic growth, energy consumption, and environmental pollution. The studies of (Soytas and Sari 2009, Soytaş, Sari, and Ewing 2007, Apergis and Payne 2009, Halicioglu 2009) studied the relationships among economic growth, financial development, energy consumption, and CO₂ emission.

2.1. Remittances and CO₂ emission

Remittances boost households' consumption levels and enable them to invest in luxury items they might not have been able to afford otherwise, such as new vehicles and other home equipment. However, as investment and consumption of goods expand, fuel combustion and energy consumption increase, resulting in increased carbon emissions. So, it is found in past literature that an increase in remittance indirectly boosts the emission of CO₂. According to (Ahmad et al. 2019) remittances positively affect CO₂ emission through a five stages interaction mechanism. They argue that the inflow of foreign remittances increases personal income which increases the consumption level of the people due to which aggregate demand also increases. And to fulfill the additional demand, we need more production which ultimately leads to a rise in the emission of CO₂. Similarly, (De and Ratha 2012) analyze the link between remittance and household income. They conclude that remittance inflow significantly increases the income level of the household, which also increases the consumption level of the recipient. According to Corsepius (1989) and Tucker (2011), an increase in the aggregate demand also increases industrial production which helps in the improvement of financial development. (Brown et al. 2020) concluded that remittances defiantly help people in reducing the poverty level but at the same time increase in remittances indirectly creates environmental pollution. Studies by (Farhani and Ozturk 2015, Mugableh 2015, Li, Zhang, and Ma 2015) show that the inflow of remittances supports small and new businesses as emerging firms face difficulty in securing capital from financial institutions. Therefore such type of firms raises their capital through remittances. (Das, McFarlane, and Jung 2019) conclude that foreign remittances contribute to the rise in economic growth (GDP per Capita), and an increase in economic growth significantly increases carbon dioxide emission. (Ahmad et al. 2019) analyze the asymmetric relation between remittances and carbon emission both in the long-run and short-run. They conclude that carbon emission decrease with negative shocks in remittances and rises with positive shocks as it influences the consumption and saving level of the recipient country, which creates financial demand, and both contribute to the rise in carbon emission. According to (Neog and Yadava 2020) the negative shocks in foreign remittances are more persistent as compared to positive shocks. They found that the inflow of foreign remittances and financial development in India creates environmental pollution through the use of more energy. On the other hand, (Sharma, Bhattarai, and Ahmed 2019) analyze the impact of foreign aid, economic growth, and remittance on carbon emission in Nepal. Their empirical results show that an increase in foreign aid and remittances reduce the emission of carbon in the long run. Because more remittance inflow and financial aid enable the household to use energy-efficient appliances in their home which are mostly dependent on renewable energy sources and emit low carbon. (RAHMAN, CAI, and AHMAD 2019) measure the influence of FDI, remittances inflow, and energy usage on carbon emission in the context of

six Asian countries (India, Pakistan, China, Bangladesh, Philippines, and Sri Lanka). They conclude that the effect of remittance on CO emission varies from country to country as they found a significant and positive impact of foreign remittances on carbon emission for Pakistan, Bangladesh, Philippines, and Sri Lanka in the long run. However, this relationship is significant and positive only for Pakistan, Philippines, and Sri Lanka in the short run. They discovered no correlation between remittances and CO₂ emissions in China or India.

2.2. Economic Growth and CO₂

(Ahmed, Uddin, and Sohag 2016) found a causal relationship between economic development and CO₂ emissions throughout the year 1980 to 2010. Long-term, they find a substantial bidirectional relationship between CO₂ emissions and economic development in Europe. According to them, the most effective way to reduce CO₂ emissions without harming economic development is through technical innovation. Economically developed countries employ sophisticated technology for manufacturing, which leads to a decrease in carbon emissions, according to Dinda (2018). Chinese researchers have examined the relationship between technological advances in the energy industry and CO₂ emissions from 1995 to 2012 (Jin et al. 2017). There is an inverted U-shape relationship between per capita income and CO₂ emissions in their analysis, which confirms the EKC hypotheses. Technological advancements in the energy industry lead to a reduction in CO₂ emissions with hysteresis, according to the researchers' findings. In a study conducted by Salman, Long and coworkers (2019), panel data analysis was used to evaluate the link between economic development and carbon emissions in different industrialized and developing nations from 1990 to 2016. They conclude that energy use increases CO₂ emissions in both developed and developing countries.

2.3. Renewable energy consumption and CO₂

According to (Mardani et al. 2018), the adaptive neuro-fuzzy inference model was used to assess the impact of economic development and energy consumption on carbon emissions for G-20 nations from 1963 to 2016. Economic growth and energy consumption were identified as the major contributors to G-20 countries' carbon emissions. In 2017, G-20 countries accounted for 83 percent of global CO₂ emissions. From 1992 to 2014 the G-20 nations were also analyzed by (Li, Hu, et al., 2021), who utilized the Common Correlated Effect Mean Group and Augmented Mean Group methods. It was concluded that non-renewable energy use and economic growth both contribute to CO₂ emissions in G20 countries. These nations' carbon emissions have been boosted by foreign direct investment and urbanization, on the other side. Their causation test revealed a bidirectional relationship between carbon emissions and economic development, carbon emissions and energy consumption, and carbon emissions and urbanization. Economic development, biofuel energy use, and carbon emissions were linked in a sample of G-20 countries between 2001 and 2017. The environmental Kuznets curve (EKC) between economic growth and CO₂ emissions was proven using a completely modified ordinary least squares regression. However, the use of biofuel energy has a considerable negative impact on carbon emissions in these chosen nations, according to the study. Using the three-stage least squares technique (Adewuyi and Awodumi 2017), they analyzed the relationship between economic growth, biomass energy use, and CO₂

emissions in West African nations from 1980 to 2010 Only five African states (The Gambia, Burkina Faso, Nigeria, Mali, and Togo) showed a substantial correlation between biomass use, GDP, and CO₂ emissions, whereas the remaining African nations showed only a moderate correlation. (1980-2015) (Awodumi and Adewuyi 2020) studied the impact of nonrenewable energy use on economic development and CO₂ emissions in Africa's main oil-producing states Non-renewable energy consumption (natural gas and petroleum) had an uneven influence on economic development and carbon emissions per capita in all nations except Algeria. To evaluate the relationship between economic development, carbon emissions, and energy consumption in South Korea from 1991 to 2011, (Park and Hong 2013) performed basic regression analysis utilizing the Markov switching model. Even though the relationship between economic growth and CO₂ emissions in South Korea is unpredictable, they found a statistically significant relationship between economic growth and energy consumption, which includes coal in the industrial sector, petroleum products in the transportation and industrial sectors, as well as LNG in both the residential and commercial sectors of South Korea. From 1968 to 2014, Saudi Arabia's economic development and energy consumption were analyzed (Mahmood et al. 2020). Long-term and short-term economic growth and energy use both contribute significantly to high CO₂ emissions. As a result, economic growth and energy use have societal consequences in the form of environmental degradation. Although the study's emphasis was only on Saudi Arabia, the findings should be regarded with caution. There is a connection between carbon dioxide emissions and economic development and energy usage (Saidi and Hammami, 2015). Carbon emissions are considerably and adversely associated with economic growth, but the energy consumption is highly and favorably correlated with it. Salahuddin and Gow (2014) examined the link between economic growth, energy consumption, and greenhouse gas emissions in Gulf nations (Salahuddin and Gow 2014). Energy consumption promotes economic growth and CO₂ emissions in the long run as well as the short term, they observed. (Saboori, Sulaiman, and Mohd 2012) analyze the link between energy consumption, CO₂ emissions, and economic growth in Southeast Asia from 1971 to 2009. (Waheed, Sarwar, and Wei 2019) identify a positive and substantial connection between carbon emissions and energy consumption, both on the short and long-term time scales. Energy consumption and economic development in single and multi-country situations from 1970 to 2019. As a result, the evaluation focused mostly on the country's environment, the study's methodologies, and statistical modeling, as well as its empirical conclusion. Conclusion: While carbon emissions are not directly linked to economic growth, high energy consumption is a key factor in high CO₂ emissions in industrialized countries. Because not all developed nations were included in this study, the conclusions cannot be generalized.

2.4. Financial development and CO₂

Financial development and carbon dioxide emissions have been studied by several scholars in different nations. However, according to (Pata 2018) the usage of renewable energy including hydropower, solar energy, and biomass as well as alternative energy consumption did not affect carbon emissions. In Turkey, economic expansion, financial development, and urbanization are the leading causes of carbon emissions, according to this study. By using several econometric approaches such as the ARDL, FMOLS, and Canonical Co-integrating Regression (CCR) models, (Isiksal, Samour, and Resatoglu 2019) examined

the impact of the banking sector's development on carbon emissions in Turkey from 1980 to 2014. However, they discovered that the rise in real interest rates causes a drop in carbon emissions because high real interest rates raise the cost of capital or make credit more difficult to get. This paper uses panel co-integration, the unit root test, and ARDL analysis to test the relationship between energy consumption in six Sub-Saharan African nations from 1980 to 2014. However, they found a one-way causality between energy consumption and environmental degradation over a long period of time, despite the bidirectional causation in the short term. In addition, they found a long-term, unidirectional causal relationship between pollution and foreign direct investment. There is also a bidirectional causal relationship between energy consumption, CO₂ emissions, and economic progress in Middle Eastern countries (Al-Mulali and Che Sab 2018). In accordance with (Ahmad et al. 2019), studies such as ((Zhang 2011), (Saboori, Sulaiman, and Mohd 2012), (Ozturk and Acaravci 2013), (Boutabba 2014), (Li, Zhang, and Ma 2015), (Jamel and Maktouf 2017) found that financial development increases carbon emissions significantly and positively, whereas other studies such as (Saidi and Mbarek 2017, Al-Mulali, Tang, and Ozturk 2015, Shao et al. 2018, Xing, Jiang, and Ma 2017) found a significant and adverse association between financial development and carbon emission.

2.5. Concluding Literature

Foreign remittance is one of the major sources of economic development. It is clear that remittance does not directly affect the emission of CO₂, but it is a five stages interaction mechanism (FSIM) through which the inflow of remittances plays an important role in CO₂.

Stage 1: Remittance's inflows and household income

There is a significant association between remittances and household income. Migrant people send money to their home countries to financially support their families, which leads to an increase in the personal income of the recipient country.

Stage 2: Effect of Household income on Consumption and Savings

Consumption and saving power of people increase with the increase in household income. As household divide their income into two parts, i.e., consumption, and saving. Everyone earns money to consume goods and services so that it makes their life comfortable. The second part of income is saving. People feel threats and insecurity of jobs in less developed countries, therefore they save some amount of their income in banks for securing their future. When people are able to earn more, they spent a large amount of their income in satisfaction of their needs and wants as well as they also save their earnings for the future.

Stage 3: Increase in consumption and saving leads to increase in aggregate demand and bank savings.

Economic growth is dependent on consumption and saving level. Aggregate demand may only increase when consumption increases, which is linked with the income level of individuals. Some rational individual scarifies their current consumption for future benefits and save their surplus income in banks

account. So, an increase in consumption and saving level leads to an increase in aggregate demand and bank savings of people.

Stage 4: Increase in aggregate demand and bank saving leads to increase in industrial production and financial sector development.

Financial sector development and advancement in industrial production are closely interlinked. Financial institutions provide loans to entrepreneurs, through which they extend their business or establish a new plant to fulfill the aggregate demand of customers.

Stage 5: Increase in both industrial production and financial sector development leads toward more CO₂ emission.

Industrial production is considered one of the important sources of CO₂ emission. Industries use oil, coal and natural gas, etc. as a source of energy in the production process, and all these sources of energy result in the emission of more CO₂. By concluding the overall discussion, the inflow of remittances indirectly increases the emission of CO₂ gas, which causes environmental pollution.

3. Data And Methodology

This research study attempts to analyze the influence of remittance, economic growth, renewable energy and financial development variables on CO₂ emission performing a novel dynamic simulated ARDL model for annual time series data ranging from 1990 to 2019 in four selected G-20 countries. Although the goal of this research is to investigate the nexus for the G-20 countries, only four countries are chosen depending on the accessibility of the data. We identify the effect of remittance, economic growth, RE and financial development variables on CO₂ emission in four selected G-20 countries namely Australia, Mexico, Germany, and India. The reason behind choosing these countries is because these countries vigorously develop their biofuel industries (Xu, et al., 2020). For data collection, we gathered data from the official website of the World Bank and Federal Reserve Bank. In this research, CO₂ emission is the dependent variable which is computed as metric tons per capita, whereas explanatory variables are renewable energy that is computed as a percentage of total final energy consumption, FDI is calculated as % of GDP, a proxy for economic growth as it is operationalized as GDP, the proxy used for Financial development is Domestic credit to the private sector as a percentage of GDP (Gadanecz and Jayaram 2008), and Remittance is measured as a % of GDP.

Table 1
Measurement of variables

Symbols	Variables	Type	Unit of Measurement	Source
CO2	Carbon dioxide	DV	Metric tons per capita	WDI
RE	Renewable Energy	IV	% of total final energy consumption	WDI
REM	Remittance	IV	%	WDI
FD	Financial Development	IV	Domestic credit to the private sector as a % of GDP	WDI
GDP	Gross domestic product	IV	Gross domestic product	WDI

3.1. Specifications of the Model and Methodology

Traditionally, the nexus between remittances and CO2 emissions have been studied using conventional time-series approaches such as cointegration analysis with an auto-distributive lag model (ARDL), followed by error correction (EC) modeling and Granger causality. However, the ARDL model developed by (Pesaran, Shin, and Smith 2001) can only evaluate the variables' long- and short-run correlations. As a result, they are insufficient to resolve the issues associated with studying long- and short-run diverse model specifications. The current study, which was expanded in another work as an extension of the new dynamic simulated ARDL model, is capable of stimulating, estimating, and robotically plotting forecasts of counterfactual changes in one regressor and their effect on the regress, while maintaining the remaining independent variables constant. This modeling technique is used in this case. The uniqueness of this research is based on a small number of contributions. To begin, for the first time, remittances were examined as a driver of CO2 emissions in selected G-20 countries. Second, we used the innovative dynamic simulated ARDL model developed lately by (Jordan and Philips 2018a) (Jordan and Philips 2018b). This unique dynamic simulated ARDL model is used to examine the effect of regressors on the dependent variable. Unit root tests were used to determine the variables' order of integration and stationarity. Among all variables, only a few are integrated at the I(0) level, while others are integrated at the I(1) level, allowing for the development of a unique dynamic simulated ARDL model suited for this study. The ADF (Dickey and Fuller 1979) tests were also conducted before employing a dynamic simulated ARDL and confirmed mixed results of the stationarity of variables which is a pre-condition of Dynamic Simulated ARDL. The connections of the variables were tested with the following equation.

The association can be expressed in the following manner,

$$CO_2 = f(FD, RE, GDP, REM)$$

1

In regression form,

$$Y(\text{CO}_2) = \alpha + \beta_1(\text{FD}) + \beta_2(\text{RE}) + \beta_3(\text{GDP}) + \beta_4(\text{REM}) + \epsilon_t(2)$$

Where $\beta_1, \beta_2, \beta_3, \beta_4$ indicate coefficients of the model and ϵ_t is the residual. Apart from this, the RE represents renewable energy consumption, FD represents Financial Development, REM represents Remittance, GDP is the gross domestic product and CO2 means carbon dioxide.

It is essential to check the stationarity of every single time series before performing cointegration tests because, in the case of non-stationary variables found, spurious regression maybe happen. Furthermore, one of the assumptions of the bounds testing approach is that no single variable is united of order two and all the variables should have a mixed order of integration. Therefore, ADF and KPSS tests are carried out. The general equations for KPSS and ADF tests are written as follow,

$$x_t = r_t + \beta_t + \epsilon_1$$

3

This breaks up a series into three parts i.e., a random walk r_t , a deterministic trend β_t , and a stationary error ϵ_1 , with the regression equation.

$$\Delta x_t = \alpha + \phi x_{t-1} + \gamma_t + \sum_{i=1}^m \delta \Delta x_{t-i} + \epsilon_t(4)$$

Where Δ indicates difference operator; α shows intercept; t tells a time index; ϕ exhibits coefficient presenting process root i.e., concentrate on testing; γ_t is the coefficient on a time trend; m signifies the number of lags of the autoregressive model and ϵ_t is a random error.

3.2. ARDL Bounds test

Bounds test is carried out by the dynamic simulated ARDL approach to explore the long-run nexus amongst variables. The ARDL bound test to cointegration was conducted to identify the long-run association amongst the variables in this study. The equation for the model is written as under,

$$\Delta \text{CO}_2 = \beta_0 + \sum_{i=0}^u \beta_1 \Delta(\text{CO}_2)_{t-1} + \sum_{i=1}^t \beta_2 \Delta(\text{GDP})_{t-1} + \sum_{i=0}^u \beta_3 \Delta(\text{RE})_{t-1} + \sum_{i=0}^v \beta_4 \Delta(\text{FD})_{t-1} + \sum_{i=0}^j \beta_5 \Delta(\text{REM})_{t-1} + \phi_1(\text{FD})_{t-1} + \phi_2(\text{RE})_{t-1} + \phi_3(\text{GDP})_{t-1} + \phi_4(\text{REM})_{t-1} + \epsilon_t(5)$$

Where the symbol Δ shows the first difference term, RE means renewable energy consumption, FD represents Financial Development, REM means Remittance, GDP is the gross domestic product and CO2 means carbon dioxide. $t - 1$ indicates the first lag, that we consider in this study. In the aforementioned equation, ϕ is estimated for variables' long-run nexus. The null hypotheses and alternative hypotheses for the ARDL bound test are written as under,

$$H_0: \phi_1 = \phi_2 = \phi_3 = \phi_4 = 0$$

$$H_1: \phi_1 \neq \phi_2 \neq \phi_3 \neq \phi_4 \neq 0$$

The analyzed results of F-statistics confirm either to reject or accept the null hypothesis. In case, if the F-statistic values are more than the value of upper bounds then there will be a long-run nexus between the variables of the study while in case of the F-statistic values are smaller than the value of lower bounds then there will be no long association between variables (Pesaran, Shin, and Smith 2001). On the other hand, if the values fall between the value of upper and lower bounds then the decision will be indecisive. The model's stability is evaluated using CUSUM and CUSUMS Q (Brown, Durbin, and Evans 1975). The model's stability was determined using the cumulative sum control chart (CUSUM) and the cumulative sum control chart of squares (CUSUMS Q).

3.3. ARDL Model

The ARDL approach has numerous benefits over other time series models (Pesaran, Shin, and Smith 2001) (Pesaran, Shin, and Smith 1999). The classical ARDL method can be performed for data of a short period (Haug 2002). This method was introduced to identify the long-run nexus among different types of variables. Different kind of co-integration techniques has been carried out by many scholars from the literature of past and present studies. Some co-integration techniques of (Phillips and Hansen 1990); (Johansen and Juselius 1990); (Engle and Granger 1987) have some weaknesses like these methods do not have estimation about the structural breaks and order of integration for variables is not distinctive. That's why we have a preference to select the most suitable method of ARDL bounds test for this purpose as compared with the abovementioned techniques. This kind of methodology includes various benefits and is beneficial in the case of variables that have cointegration at $I(0)$ level, or at the level of first difference $I(1)$. This modeling methodology is employed here.

3.4. Dynamic Simulated ARDL model

The Dynamic-simulated ARDL model was developed by (Jordan and Philips 2018a). The new dynamic ARDL model is meant to overcome the weaknesses of the prior ARDL model to assess various model specifications at both long and short distances. The new dynamic simulated ARDL model has the potential to stimulate, estimate, and mechanically plan the forecasts of counterfactual changes in a single regressor and its effect on regressions whilst maintaining the remaining independent variables, according to (Sarkodie and Strezov 2019); Khan and coll. (2019a); (Jordan and Philips 2018a)., and Khan et al., (2019b). This unique model can routinely estimate, stimulate and trace the charts and the short-term and long-term links between negative and positive factors. Although (Pesaran, Shin, and Smith 2001) created an ARDL model, it is able to estimate only long- and short-term connections between variables. All the parameters of the research are stationary and have a mixed integration order $I(0)$ and $I(1)$, which enables a single dynamically simulated ARDL model to be utilized. The timeliness of the variables in this study meets the requirements for constructing a unique simulated dynamic ARDL model. The counterfeit alterations in regressors and their effects on regression have been revealed in this research. The equation for a new dynamic ARDL error correction is drawn from previous work (e.g. Khan et al. 2019a; (Sarkodie and Strezov 2019); (Jordan and Philips 2018a) and Khan et al. 2019b)

4. Estimation And Discussion

Table 2
Descriptive Statistics

	Variables	Mean	Std. Dev.	Min.	Max.
Australia	CO2	16.63	0.920373	15.12797	18.20018
	REM	0.2136	0.179769	0.118009	0.763848
	RE	8.071942	0.769816	6.680426	9.278198
	Fin Devp	102.3017	27.85915	60.23745	142.4232
	GDP	1.989350	1.536057	-3.764578	4.345641
Mexico	CO2	4.066278	0.209414	3.630864	4.455658
	REM	1.844391	0.719809	0.780924	3.075317
	RE	11.09045	1.613753	8.964824	14.41330
	Fin Devp	22.83850	6.613886	12.87772	36.57343
	GDP	2.556073	2.923293	-6.291231	6.846852
Germany	CO2	9.911090	0.709145	8.797642	11.62265
	REM	0.293903	0.104722	0.171187	0.464153
	RE	6.288987	3.802502	1.988633	14.20625
	Fin Devp	93.60872	10.51059	77.45453	112.4173
	GDP	1.624146	2.062344	-5.693836	5.255006
India	CO2	1.139804	0.323534	0.709001	1.817783
	REM	2.686943	0.859136	0.742647	4.168610
	RE	48.35925	6.697632	36.02122	58.65286
	Fin Devp	37.72058	12.06305	22.51077	52.38571
	GDP	6.237351	1.906986	1.056831	8.845756

The summary statistics of the included series is given in Table 2. We used annual data from 1990 to 2019 for the G-20's top four remittance-receiving economies, namely Australia, Mexico, Germany, and India. Our sample size is proportional to the number of countries and variables included. We chose these nations because they are major CO2 emissions, receivers of remittances and FDI, and energy users. The data comes from the World Development Indicators (World Bank). Table 2 reports some common statistics of the data utilized in the analyses. The mean value of CO2 for Australia is highest among the selected countries and lowest for India comparatively. The mean of GDP and Remittances for India are the highest values against other countries. The average values of Fin Devp and RE are the highest for Australia and India respectively.

Table 3
Unit Root Tests

	Variables	Level	1st Difference	Conclusion
Australia	CO2	-4.138072*		I(0)
	REM	-3.945161*		I(0)
	RE	-1.976786	-5.422637*	I(1)
	Fin Devp	-1.497253	-2.978142*	I(1)
	GDP	-4.131741*		I(0)
Mexico	CO2	-5.370239*		I(0)
	REM	-4.114195*		I(0)
	RE	-2.189608	-7.089111*	I(1)
	Fin Devp	0.308812	-3.275674*	I(1)
	GDP	-5.847163*		I(0)
Germany	CO2	-9.494821*		I(0)
	REM	-6.91523*		I(0)
	RE	-1.412846	-5.302135*	I(1)
	Fin Devp	-0.882342	-4.874146*	I(1)
	GDP	-6.221989*		I(0)
India	CO2	-4.932366*		I(0)
	REM	-5.364875*		
	RE	-2.065820	-6.426908*	I(0)
	Fin Devp	-1.095910	-4.313544*	I(1)
	GDP	-4.560454*		I(0)

The unit root test output is depicted in Table 3. The variables of the research must be stationary and integrated at mixed order I(0) or I(1) before executing a novel dynamic simulated ARDL model. To investigate the order of integration of variables with statistical analysis, the Augmented Dickey-Fuller (ADF) and KPSS unit root tests were employed. Table 2 shows the results of the two stationarity tests. For example, renewable energy consumption and financial development are nonstationary at the level of all four G-20 countries: Australia, Germany, and India. However, they become stationary at the first difference in the data. Four G-20 countries have stable levels for three of the variables, namely GDP, Remittances, and Carbon Dioxide Emissions. Due to this, we may use Dynamic Simulated ARDL to estimate selected four nations in our study. As a consequence, all variables utilized in this study have mixed results of

stationary and integrated at a mixed order of $I(0)$ and $I(1)$, which shows that a novel dynamic ARDL model may be implemented.

Table 4
Bounds Tests

PESARAN, SHIN, AND SMITH (2001) COINTEGRATION TEST			
Country	F-statistic	K	Conclusion
Australia	6.182	4	Cointegrated
Mexico	7.662	4	Cointegrated
Germany	9.505	4	Cointegrated
India	39.166	4	Cointegrated
Pesaran et al. (2001) Critical Value Bounds			
Significance	I(0) Bounds	I(1) Bounds	
10%	2.75	3.99	
5%	3.35	4.77	
1%	4.77	6.12	

Table 4 reports the findings of a long-term co-integrating association between remittances, energy consumption, GDP, financial development, and CO₂. The computed value of F-statistic for Australia is 6.182, which is higher than the upper bound value; therefore, the alternative hypothesis is accepted. The computed value of F-statistics for India, Germany, and Mexico are 39.166, 9.505, and 7.662, respectively, which are all higher than the upper bound of 6.12. Hence, H_0 is rejected at the 1% significance level.

Table 5
Dynamic Simulated ARDL Short-term and Long-term Results

Variables	Australia	Mexico	Germany	India
Cons	13.432955 (0.000495)	4.120774 (0.000382)	9.743640 (0.000221)	3.6005750 (0.000776)
ΔCO_2	-0.513948 (0.000821)	-0.896286 (0.000110)	-0.979006 (0.000052)	-0.9658469 (0.000102)
ΔRE	0.147488 (0.303701)	0.085080 (0.001673)	0.057017 (0.145542)	0.0004637 (0.0322)
RE	0.457065 (0.000552)	0.045973 (0.016888)	0.207723 (0.000486)	0.0487933 (0.000154)
$\Delta\text{Fin Devp}$	0.045255 (0.102512)	0.018741 (0.045197)	0.005646 (0.711151)	-0.0066639 (0.371)
Fin Devp	0.006115 (0.144637)	0.015897 (0.000321)	0.005888 (0.137211)	0.002792 (0.04894)
REM	2.321573 (0.000593)	0.200404 (0.000558)	2.176225 (0.125470)	0.0336498 (0.04182)
GDP	0.042347 (0.048268)	0.014357 (0.007691)	0.050635 (0.016557)	0.0026752 (0.680)

Table 5 illustrates the factors' long- and short-run effects on carbon emissions, with mixed findings in the four countries. In the long term, there is a positive and substantial relationship between energy consumption and CO₂ emissions in each nation, and these relationships are significant at the 1% level for Australia, Mexico, and Germany, but are significant at the 5% level for India. (Zhu et al. 2016), (Sapkota and Bastola 2017), and Neequaye and Oladi (2017) all corroborate these findings (2015). In contrast, the data suggest that in the long run, financial development is completely connected to CO₂ emissions in Mexico and India. According to the empirical findings, global financial expansion has the potential to raise Co₂, and this result holds for rising markets such as Mexico and India. However, the empirical findings revealed that there is no discernible effect of financial development on carbon emissions in industrialized nations such as Australia and Germany. These findings corroborate the findings of previous studies (Turkekul, 2016, Yasmin, 2017, Apergis, N, 2018). This means that as a country's development level increases, the "beneficial effect" of financial growth on carbon emissions will progressively be countered by the "disadvantageous effect." We can see from the long-term coefficient that a 1% increase in financial development increases CO₂ emissions by 0.015897% in the instance of

Mexico at the 5% significance level. Additionally, the long-term coefficients for India are determined to be 0.002792 at the 5% level of significance. On the other hand, results confirm that there is a positive relationship between remittances and CO2 emissions in case Australia, Germany, and India, but only a negligible relationship in Mexico. According to several experts, a sizable proportion of immigrants travel overseas, particularly from India to the Gulf nations, and bring their earnings home. However, because the majority of earnings are not distributed through traditional channels such as banks, financial development is harmed. Additionally, many migrants are temporary employees overseas, and the profits they send home are saved and subsequently invested when they return home. This investment results in economic growth, which increases individual per capita income and can result in increased energy demand, which can have a negative impact on the environment. According to the long-term coefficient, a one percent rise in remittances would raise CO2 emissions in Australia by 2.321573 percent at the 1% significance level. Additionally, at the 5% level of significance, the long-term coefficients for Germany and India are determined to be 2.176225 percent and 0.0336498 percent, respectively. Additionally, the data suggest that GDP has a large and beneficial influence on CO2 emissions in Australia, Mexico, and Germany, but has a negligible effect on CO2 emissions in India. This means that after a particular level of GDP is reached, more GDP growth may be achieved at the expense of environmental deterioration. A country's industrialization will result in increasing pollution. As increased output and consumption result in increased environmental harm, economic expansion will have a detrimental effect on the environment (Everet, Ishwaran, Anssaloni, & Rubin, 2010). This makes sense, as increased income levels will result in the pursuit of a more manufacturing-based economy. If there are no effective and appealing laws requiring companies to reduce pollution via the use of environmentally friendly manufacturing techniques and processes, the existence of these industries will eventually result in significant environmental damage. (Grossman and Krueger 1995); Khan et al. (2019a); and Miikayilov et al., (2018) all explored the same outcomes.

The results report that lagged dependent variable is positively correlated to CO2 emissions in all four G-20 countries. This denotes that the current 13.432955% rise in CO2 emissions is connected with a 1% rise in CO2 emissions in the previous period in the case of Australia. Furthermore, in the short term, renewable energy consumption has a statistically significant positive effect on the release of CO2 in case of Mexico and India but has an insignificant association with CO2 in Australia and Germany. Though, in the short run, the nexus of financial development with carbon emissions indicates a significant and positive only in the cases of Mexico. A 1% increase in financial development will raise carbon emissions by 0.018741% in Mexico but have insignificant nexus with CO2 in case of Australia, Germany, and India in the short term.

"Dynamic Simulated ARDL Model" was developed by (Jordan and Philips 2018a). To overcome the limitations of the prior ARDL model for assessing long and short-run varied model specifications, the new dynamic ARDL model was developed. (Jordan and Philips 2018a) as well as (Sarkodie and Strezov 2019) claim that the novel dynamically-simulated ADL model has the ability to stimulate and assess counterfactual changes in one regressor as well as their influence on the regression while keeping the remaining independent variables fixed. Dynamically simulating and simulating graphs with the ARDL model has the basic benefit of being highly good at these tasks. As a result of these functions, it is

possible to anticipate (both positive and negative) changes in the explanatory and dependent variables. Although the ARDL model proposed by Pesaran et al. (2001). When exploring the real link between explanatory variables and the response variable, dynamic ARDL graphs are often utilized. The dynamic ARDL simulations spontaneously plot the forecasts of actual explanatory variable change and its impacts on the response variable whereas holding other regressors constant. The influence of explanatory variables, which are renewable energy consumption, Financial Development, Remittance, gross domestic product on CO2 emissions is forecasted to increase and decrease by 10%.

Figure 1 shows a 10% increase and a decrease in Remittances and its effect on CO2 emissions in Australia. The dots specify the average prediction value, whereas the dark blue to light blue line specifies 75, 90, and 95% confidence interval, respectively.

The impulse response plot in Figure 1 illustrates the connection between remittances and CO2 emissions. The graph depicts the switch to remittances and its effect on CO2. A 10% rise in remittances implies a positive long- and short-term effect on CO2 emissions in Australia; however, a 10% decrease in remittances indicates a positive long- and short-run effect on CO2 emissions in Australia.

Figure 2 shows a 10% increase and a decrease in Remittances and their effect on CO2 emissions in Mexico. The dots specify the average prediction value, whereas the dark blue to light blue line specifies 75, 90, and 95% confidence interval, respectively.

The impulse response plot in Figure 2 was used to inspect the association between remittances and carbon dioxide emissions in Mexico. The Remittances graph indicates that a 10% increase has a positive influence on carbon dioxide emissions in the short and long run in Mexico, whereas a 10% reduction has the opposite effect in the short and long run.

Figure 3 shows a 10% increase and a decrease in Remittances and their effect on CO2 emissions in Germany. The dots specify the average prediction value, whereas the dark blue to light blue line specifies 75, 90, and 95% confidence interval, respectively.

The link between remittances and carbon dioxide emissions in Mexico is depicted in Figure 3. The graph demonstrates that a 10% increase or 10% decrease in the growth of remittances has a favorable effect on CO2 emissions in Germany in the long and short run.

Figure 4 shows a 10% increase and a decrease in Remittances and its effect on CO2 emissions in India. The dots specify the average prediction value, whereas the dark blue to light blue line specifies 75, 90, and 95% confidence interval, respectively.

The relationship between remittances and emissions of carbon dioxide in Mexico is shown in Figure 4. The chart shows that a 10% increase or a 10% decrease in the growth of transfers has a favorable long- and short-term effect on CO2 emissions in India.

Table 6
Diagnostic Tests

Tests	Australia	Mexico	Germany	India
Serial Correlation	0.642	5.705	0.023	1.371
Breusch-Godfrey LM Test	(0.423)	(0.087)	(0.879)	(0.242)
Shapiro-Wilk Test for Normality	0.97	0.98	0.969	0.955
	(0.551)	(0.837)	(0.544)	(0.242)
Ramsey RESET test	0.817	0.914	1.627	0.438
	(0.527)	(0.432)	(0.371)	(0.562)
R-squared	0.5981	0.7331	0.6968	0.9042
Adjusted R-squared	0.4641	0.6442	0.5957	0.8722
Notes: For the J–B test, the null is normality. For the Breusch–Pagan–Godfrey (B–G) test, the null is no serial correlation. For the Arch test, the null is no heteroskedasticity. SC stands for no serial correlation. P-values are presented in parentheses.				

Table 6 summarizes the findings of several statistical diagnostic tests such as the Breush-Godfrey LM, Ramsey RESET, and Shapiro-Wilk tests. All these experiments were performed to assess the reliability of the model. The Breusch Godfrey LM test shows that the model has no serial correlations. The Ramsey RESET test shows that the model is used properly while the Shapiro-Wilk test shows that the calculated residual models are normal.

Stability Test

This test assesses the dynamic stability of the parameters in the calculated models using the cumulative sum of resources (CUSUM), portrayed in Fig. 5. The parameters are constant across all sampling periods in all nations, namely Australia, Mexico, Germany, and India.

5. Conclusions

Research is extensive on the nexus between FDI, energy consumption, openness to trade, growth, and carbon emissions but to date, no study has included remittances to the top G-20 recipient model. Because remittances were shown to boost growth and alleviate poverty by increasing per capita incomes, the ARDL-bound test was utilized to experimentally examine whether remittances can result in CO₂ emissions. The major contribution of the paper is to assess in four G-20 nations the influence of remittances, financial development, renewable energy consumption, and GDP on CO₂ emissions, using an ARDL bound test and dynamic simulated ARDL model. The main goals of this research were to analyze the impact on CO₂ emissions for selected G-20 nations utilizing time-series data from 1990 to 2019, such as financial development, renewable energy consumption, remittances, and economic growth.

Several researchers previously employed basic ARDL in their empirical research. (Pesaran, Shin, and Smith 2001) supported Classical ARDL. To assess long-term and short-term interactions between the variables, this dynamic simulated ARDL model can be employed. This empirical research will improve previous research in the following ways. This is the first research to experimentally evaluate the effects of economic development, remittances of renewable energy, and economic growth on CO2 emissions in four G-20 countries with a new dynamic simulated ARDL model. Second, this new model is able to stimulate, estimate and produce graphs of variable changes (positive and negative) and short-term and long-lasting connections automatically. Third, the study used a Dynamic Simulated ARDL to determine independently the connection between remittances and CO2 emissions for each nation. We ran root unit tests to establish the variables' steadiness and integration sequence. The root test unit determines that all variables are stationary and in the highest order $I(0)$ and I have been integrated (1). The ADF tests were performed to evaluate the linear stochastic trend of the research variables. In all four G-20 nations investigated, the findings of the ARDL test show the presence of a long-term co-integrating nexus between variables. The long-term results demonstrate that the use of renewable energy in all four G20 economies investigated, namely Australia, Mexico, Germany, and India, has a considerable favorable impact on CO2 emissions. Moreover, the statistically significant beneficial impact of consumption of renewable energy on CO2 emissions in Mexico and India has no medium-term influence on CO2 emissions in Australia and Germany. In addition, CO2 emissions increase significantly in the long term when remittances increase in Australia, Mexico, Germany, and India. In comparison, financial development in all four G-20 Member States has a long-term favorable influence on CO2 emissions. In the short term, however, the coefficients of financial development only show a substantially positive relationship with carbon emissions in the case of Mexico. Moreover, our data show that GDP has a major adverse impact in Australia, Mexico, and Germany on CO2 emissions but has a minimal impact on CO2 emissions in India. As a result, we find that the results for four G-20 countries are mixed, due to the variability of economies across economic sectors concerning GDP, remitting, and energy consumption. Our work contributes most significantly by showing that the environmental repercussions of the growth of economic activity can be varied and should be analyzed case by case, requiring further research. The study indicates that developing nations should prioritize the conservation of the environment while pursuing development objectives such as the consumption of renewable energy, GDP growth, financial development, and remittances.

5.1. Policy Implications

Our results have several important policy implications. The research's key policy implications are that economies should pursue a diversity of economic courses and that policymakers should consider these variables since remittances can be used for financial development, which helps cut CO2 emissions. Remittances should be sent via established channels and used to stimulate economic growth, as they are in India and Mexico, where they do not contribute to environmental degradation. While energy is vital to the economy, countries must shift away from oil and fossil fuels in favor of renewable energy and liquefied natural gas, as energy is a significant cause of pollution. As a result, these governments and

politicians should establish an innovative renewable energy policy that incorporates a carbon price and a subsidy for renewable energy. Additionally, the government should encourage the banking sector to offer more favorable terms on domestic loans to industrialists, investors, and other commercial businesses, thereby boosting the adoption of innovative environmental technologies.

As a result, governments should prioritize energy and economic policies that promote energy efficiency and economic growth while having no net effect on CO₂ emissions. Additionally, such measures should be implemented without impairing society's energy consumption or economic growth. For example, climate finance has been accepted at the global level as one of the necessary activities to address the environmental consequences of CO₂ emissions. This entails investing in clean, climate-friendly technologies that stimulate economic growth. Renewable energy is a component of such an endeavor. Future research should therefore include raising awareness of and encouraging investment in various renewable energy sources. This will provide clean energy sources for commercial and personal consumption in both developed and emerging nations. As a result, any damage to the environment is minimized, and nations' economic growth is constrained. Although previous research indicates that financial development can help cut CO₂ emissions in a variety of states, our findings indicate the contrary. In the instance of four G-20 economies that we studied, the positive outcome of financial development on CO₂ emissions may indicate that businesses choose to grow production via financing rather than develop energy-saving technologies. This element should cause policymakers to express concern about the environmental consequences of financial development. They should strike a balance between financial development and CO₂ emissions, taking into account the country's unique circumstances, and devise long-term strategies to promote both the financial industry and environmental conservation. As a result, governments should devote greater resources to fostering technical advancement in the industrial sector, such as providing loans for investments that result in lower carbon-emitting products and financing renewable energy projects. In general, industrialized countries have well-established industrial systems, which encourage firms to invest in technological innovation but not in scale development, while financial sectors prefer to fund environmental protection projects in response to government-enforced environmental restrictions. These factors could effectively negate the "beneficial effect" of financial progress. As a result, policymakers in industrialized countries will face less environmental pressure as they plan the development of the financial sector, allowing them to focus on the resource allocation function and growth effect of financial development.

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Figures

Figure 1

The Impulse Response Plot for Remittances and CO2 emissions.

Figure 2

The Impulse Response Plot for Remittances and CO2 emissions.

Figure 3

The Impulse Response Plot for Remittances and CO2 emissions.

Figure 4

The Impulse Response Plot for Remittances and CO2 emissions.

Figure 5