Do Energy Consumption and Environmental Quality Enhance Subjective Wellbeing in G20 Countries?

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Abstract

G20 countries are responsible for more than 80% of global energy consumption and the largest emitter of CO_2 in the world. Literature related to the energy consumption-environmental quality-subjective wellbeing nexus is limited and lacks consensus. This paper analyses the impact of energy consumption and environmental quality on subjective wellbeing in G20 countries from 2006 to 2019 using a panel corrected standard error (PCSE) panel model. Cantril life ladder data is used as a proxy of subjective wellbeing. For robustness, the Newey-West standard error model is used. The findings reveal that renewable energy consumption and improved environmental quality, i.e. lesser carbon emissions enhance subjective wellbeing in G20 countries. In contrast, non-renewable energy consumption degrades subjective wellbeing. Moreover, the study also finds a bidirectional causality between renewable energy consumption, non-renewable energy consumption, and economic growth. The policymakers of these countries should encourage renewable energy production and its consumption to reduce carbon emissions for conserving the environment and enhancing their people's subjective wellbeing.

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Abstract

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1. Introduction

According to the United Nations Environment Programme (2020), despite the cut in carbon emissions due to the COVID-19, the world is heading towards a temperature rise above 3°C. The non-CO_2 components of greenhouse gases (GHGs) such as methane (CH_4) and nitrous oxide (N_2O) continued to increase in 2020. Executive Director Inger Andersen of United Nations Environment Programme (UNEP) recently urged for the immediate need of reducing emissions; otherwise, the goal to reach 1.5°C by 2030 will only be a dream (UNEP, 2020). This rise of 3°C in global temperatures could result in catastrophic weather-related events, ozone depletion, and ecosystem degradation, which is a severe threat to humankind.

It is widely evident from the literature that massive energy consumption activities are responsible for the increasing GHG emissions (Hao et al., 2015; Khan et al., 2014; Sarkodie & Strezov, 2019) and climate change (MacKay, 2008). The use of cleaner and sustainable energy in both production and consumption is required to meet long-run energy and climate goals (IEA, 2020). Therefore 37 countries have committed to shift from non-renewable to renewable energy consumption in the Doha Amendment, 2nd commitment period (2013-2020).

G20 countries account for two-thirds of the world population and have more than 80% of energy demand (Rogelj et al., 2016). It is a global body comprising the 20 largest economies, and consumes 95% of the world's coal, more than 70% of its oil and gas, and is responsible for 85% of global investment in renewables (Goldthau, 2017). The G20 comprises Argentina, Australia, Brazil, Canada, China, EU, France, Germany, India, Indonesia, Italy, Japan, Mexico, Russia, Saudi Arabia, South Africa, South Korea, Turkey, UK, and the USA. These countries have experienced energy-led growth and are under continuous pressure for CO_2 mitigations. For overcoming the Paris emissions commitments, these countries have a bulk investment in inventing sustainable energy sources and energy-saving technologies (Qiao et al. 2019). Many G20 countries like Germany, Italy, France, the UK, the United States, Canada and Japan, and the EU have experienced high growth rates in renewable energy production and reduction in fossil fuel consumption.

The purpose of energy consumption in a economy is to improve the wellbeing of humankind. One of the goals of the Sustainable Development Goal (SDGs) is to ensure universal access to affordable, reliable, and modern energy by 2030. These goals reflect the significance of energy services for meeting basic needs and improving wellbeing (Kalt et al., 2019). Indeed, higher energy consumption has reduced drudgery, increased productivity, and provided a comfortable life. Alam et al. (1991) have found a positive association of electricity consumption and physical quality of life (PQLI) with the per capita electrical energy consumption in 112 countries. Residential energy consumption positively contributes to household living standards through lighting, cooking, heating, and cooling and promotes wellbeing (Welsch and Biermann, 2019). In the Nagasaki city of Japan, Liu et al. (2016) have investigated the link between energy consumption and quality of life (QOL). Energy consumption in the form of demand for car trips and public transport trips raises the quality of life. Shobande (2020) has found a positive impact of energy use on infant mortality rate in the panel of 23 African countries. Liu and Matsushina (2019) have used HDI as a proxy of QOL and found that HDI improves with the changes in energy quality in the OECD and non-OECD countries. Better access to energy promotes economic growth and human development together and increases the pace of achieving the target of SDGs (Ouedraogo, 2013). Niu et al. (2013) have found that countries with a higher level of income and higher per capita energy consumption have attained a higher level of human development. Wang (2020) have found a positive link between renewable energy consumption and human development in BRICS countries during 1990-2016. Renewable energy production helps the countries to achieve higher HDI via enhanced economic development (Kazar and Kazar, 2014).

But the higher level of pollution, GHG emissions, and climate change brought by rampant energy consumption have threatened the Subjective Wellbeing (SWB) of people worldwide. SWB is used to measure the wellbeing of people based on subjective evaluations of a person's own lives (Diener, 2000). It includes both positive (happiness), negative emotions (sadness, anxiety, and stress), and life satisfaction. In economics, only the revealed preferences in the form of choices have been given importance rather than the psychological aspect, i.e., self-reported preference (Case and Deaton, 2015). After the emergence of Bhutan's Gross national happiness index (GNH) and the Easterlin Paradox debate, economists have started considering SWB. Stiglitz et al. (2009) have recommended countries to adopt the subjective determinants of wellbeing because it can better understand people's lives beyond income and material consumption. The happiness ranking of G20 countries is presented in Figure 1.

Insert [Figure 1]

Deterioration of environmental quality has adversely affected the mental health and subjective wellbeing of the people. Rehdanz and Maddison (2005) established that weather changes caused by global warming has an adverse effect on people's happiness[1]. Welsch (2006) shows that air pollution has a strong negative impact on subjective wellbeing. Ferrer-i-Carbonell and Gowdy (2007) obtained a negative coefficient for concern about ozone pollution and an individual's wellbeing. In a similar study, Cuñado and Gracia (2013) explored the relationship between air

[1] In this paper, Happiness and life satisfaction (LS) are used interchangeably as a proxy of SWB.

pollution, climate change, and Spanish people's subjective wellbeing. They found that an increase in carbon dioxide, nitrous oxide, and airborne particulate matter (PM) is negatively related to happiness. Similarly, Spanish people are unhappy during high temperatures and high precipitation. Tiwari (2014) indicated that CO_2 emissions have an undesirable impact on happiness. A higher air pollution index significantly reduces hedonic happiness and raises depressive symptoms in Chinese citizens (Zhang et al., 2017; Gu et al., 2020). Song et al. (2020) pointed out the importance of subjective evaluation of pollution; the result of the study reveals that the adverse impact of bad air quality on happiness is more on unhealthy, middle, and old age people. Thus, these people are more willing to pay for protecting the environment. Giovanis and Ozdamar (2018) explored the impact of air quality on mental health. For improving mental health, pensioners in the European countries have a marginal willingness to pay are €221 and €88 per year for one unit decrease in sulphur dioxide and ozone level respectively.

There is a limited literature on the nexus between environmental degradation and SWB. Out of this, few studies have been carried out regarding the relationship between energy consumption and subjective wellbeing. Afia (2019) has found the positive direct and indirect impact of energy consumption on happiness in the sample of 47 countries. Okulicz-Kozaryn and Altman (2020) have concluded that energy consumption is unrelated to happiness in developed economies, while in developing economies, people are happier with less energy consumption. Mazur and Rosa (1974) have found that the industrial nations, which are already sufficient in the energy and electricity consumption, further increase in their per capita energy or electricity consumption, have no impact on happiness. Smil (2003) has found that higher energy has not improved the objective and subjective self-assessment. Longhurst and Hargreaves (2019) have found that emotions like worry, fear, and care determine energy use consumption and its management. Churchill et al. (2020) have examined the effect of fuel poverty on subjective wellbeing (SWB) in Australia and found that an increase in fuel poverty is associated with lower levels of SWB. Fanning and O'Neill (2019) have investigated the relationship between carbon-intensive consumption and wellbeing for 120 countries from 2005-2015. It is found that there is a negative relation between carbon footprint and happiness in non-growing carbon footprint countries while an insignificant relation in growing carbon footprint countries.

Renewable energy and sustainability are interconnected with the SWB. Many Scholars explored the different aspects of sustainability, renewable energy, and SWB. Zhang et al. (2017) have found that renewable natural capital has a positive relationship with subjective wellbeing because of the fear of the extinction of non-renewable natural capital. For the low-income economies, economic factors related to livelihood which are mainly based on non-renewable energy consumption determine the level of SWB. Consequently, people may not perceive renewable energy as an essential determinant of wellbeing. Sarpong et al. (2020) have found a positive relationship between renewable energy consumption and quality of life in eight South African countries from 1995-2017. The wellbeing of the people can be enhanced by reducing global consumption and over-exploitation of natural resources (Sheth et al., 2011). In these studies, the separate impact of both non-renewable energy consumption and renewable energy consumption on SWB is not considered. Up to our best knowledge, G20 countries, which is the 80% energy consumer and the largest emitter of CO_2, are not studied. The existing literature is primarily based on OECD countries, European countries, and BRICS countries.

This paper contributes to the literature in several ways. Firstly, it quantifies the impact of renewable and non-renewable energy consumption and environmental quality on the SWB. Secondly, this is the first attempt to investigate the effect of renewable and non-renewable energy consumption on SWB in G20 countries. Moreover, this study attempts to acknowledge the role of renewable energy on human wellbeing through the channel of SWB in the panel data of 19 countries by using the latest time period, i.e., 2006-2019. Exploring the connection between renewable energy consumption and subjective wellbeing can put forward a new argument for conserving non-renewable energy and boosting renewable energy consumption through diverse energy innovations. The rest of the paper is designed in the following way. Section 2 presents the relationship between subjective wellbeing and energy consumption in G20 countries. Section 3 describes the data sources and methods. Section 4 explains the results and discussion. Lastly, Section 5 deals with the conclusion, policy implications, and limitations of the study.

2. Relationship Between Subjective Wellbeing and Energy Consumption in G20 Countries

This section shows the relationship among SWB, renewable energy consumption (REC), non-renewable energy consumption (NREC), CO_2 emissions, and economic growth in each G20 country by using scatter plot diagrams. To plot these scatter plots, data are averaged from 2006-2019.

The relationship between REC and SWB is presented in Figure 2. The scatter plot depicts the positive relationship between SWB and REC. Canada has the highest level of REC as well as SWB among the sample G20 countries. However, Australia, UK, Mexico, Germany, France, and Saudi Arabia have a high level of happiness (near 7) despite less REC. It might be possible due to the use of energy-efficient technologies.

Insert [Figure 2]

The relationship between NREC and SWB is shown in Figure 3. It shows that among the selected G20 countries, high NREC does not bring a higher level of happiness. This result supports the energy-subjective wellbeing paradox (Okulicz-Kozaryn and Altman, 2020). Moreover, China has more NREC than the United States but unable to convert into a higher happiness level. While European countries like Australia and Canada have performed well in preserving their people's happiness despite low NREC. Even though moving to high NREC, India's SWB is the lowest in the sample G20 countries.

Insert [Figure 3]

In Figure 4, the relationship between SWB and CO_2 emissions is presented. In this figure, different scenarios can be observed. Countries like Australia, Canada, and the US have a higher level of SWB with more CO_2 emissions. In contrast to this, India has the lowest level of SWB with the lowest carbon emissions. Countries like South Korea, Japan, South Africa, China, and Russia have high carbon emissions but near to the average level of SWB. While Brazil, France, Mexico, Argentina, and Italy have lesser carbon emissions but their SWB level is above the average.

Insert [Figure 4]

Lastly, Figure 5 shows the relationship between economic growth and SWB. A linear positive relationship is found for most of the countries. India, China, and South Africa have lower SWB with lower GDP per capita. While contrast to this, Canada, Australia, and United States. However, Mexico and Brazil have attained nearly the same level of SWB without higher per capita GDP as compared to Germany and France. Although, Japan has a high GDP per capita, but it has just above the average SWB level.

Insert [Figure 5]

3. Data Sources and Methods

3.1 Data Sources

The paper uses the panel data of 19 G20 countries for the period 2006-2019. This time period and sample G20 countries are chosen on the basis of data availability. The selected countries are Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Mexico, Russia, Saudi Arabia, South Africa, South Korea, Turkey, United Kingdom, and United States. The dependent variable is subjective wellbeing (SWB) which is measured by self-reported life satisfaction data from World Happiness Report (Yuan et al., 2018). SWB is assessed by asking respondents to show how satisfied they are with their life, a scale from 1 (not at all satisfied) to 10 (very satisfied). Independent variables are economic growth, CO_2 emissions, renewable energy consumption (REC), and non-renewable energy consumption (NREC). The variables were converted into the natural logarithm form to explain the estimated coefficients in the elasticities form. A detailed description of the variables is presented in Table 1. The trend of each variable from 2006-2019 is shown in Appendix 1.

3.2. Methodology

3.2.1. Unit Root Tests

Fisher augmented Dickey-Fuller (ADF) unit root test and cross-sectionally augmented ADF (CADF) unit root tests are used to check the stationarity of the variables. The first-generation panel unit root tests neglect cross-sectional dependence (Mahalik et al., 2020). Fisher ADF and CADF unit root tests consider the cross-sectional dependence issues while testing the stationarity of the variables.

3.2.2. Panel Corrected Standard Error (PCSE) Model

Panel corrected standard error (PCSE) approach is applied to investigate the impact of energy consumption and environmental quality on subjective wellbeing. Cross-sectional dependence (CSD), autocorrelation, and groupwise heteroskedasticity issues are generally found in panel data. PCSE model controls the problems of CSD, autocorrelation and heteroskedasticity (Reed & Webb, 2010). Moreover, this model is suitable when the dataset has larger cross-sectional units (N) than time period (T). In our study, cross sectional units (19 countries) are greater than time period (14 years). Therefore, the PCSE model is applied in this study. The PCSE method has been commonly used by various researchers recently in the literature (Kumar et al., 2021; Kongkuah et al., 2021; Dash et al., 2021; Nathaniel et al., 2020; Ikpesu et al., 2019). For robustness purpose, we applied the Newey-West standard model.

3.2.3. Dumitrescu-Hurlin Panel Causality Test

To understand the causation among the variables, this study employs a Granger causality test recently developed by Dumitrescu and Hurlin (2012) to demonstrate the causality relationship. This test is flexible in nature as it can be applied in heterogeneous panels and in the cases where time period is less than or higher than cross sectional units. This test considers cross-sectional dependence in estimating causality among the variables (Mahalik et al., 2020). The test can be represented in the following equation:

$$y_{it} = \alpha_i + \sum_{i=1}^{k} \gamma_i^{(k)} y_{i,t-k} + \sum_{i=1}^{k} \beta_i^{(k)} x_{i,t-k} + \varepsilon_{it} \quad (1)$$

3.3. Model Specification

Energy consumption includes both renewable and non-renewable energy consumption. The conventional energy sources are non-renewable energy like oil, coal, natural gas, and nuclear energy. However renewable energy sources are solar energy, tidal energy, hydropower, geothermal energy, and bioenergy (Owusu & Sarkodie, 2016). Non-renewable energy consumption (NREC) is the most significant contributor to higher economic growth. However, Kraft and Kraft (1978) have found energy consumption has no causal relationship with economic growth, but vice versa is correct from 1950-1970 in the USA. Similarly, Yu and Choi (1985) have found a unidirectional relationship between natural gas and liquid fuel consumption to GNP for the UK and South Korea. Moreover, NREC is the most significant contributor to CO_2 emissions faced by these countries (Paramati et al., 2017; Dong et al., 2019; Ahmed et al., 2019).

However, the REC promotes green growth (Shahbaz et al., 2020; Pao & Fu, 2013) and reduces CO_2 emissions for developed countries in both the short run and long run (Qiao et al., 2019; Paramati et al., 2017). While REC has no impact on CO_2 emissions in developing countries. There is bidirectional causality between REC and economic growth among the panel of 30 developed and developing countries (Ahmed et al., 2019).

Subjective wellbeing is connected with energy consumption from two channels: environmental degradation (CO_2 emissions) and economic growth. On the one hand, an eco-friendly environment i.e., lesser carbon emissions enhance SWB while, on the other hand, economic growth meets the basic needs and brings material prosperity. Therefore, the empirical model examines the impact of renewable, non-renewable energy consumption, and CO_2 emissions on subjective wellbeing. The functional form of the variables is represented in the following equation:

$$SWB_{it} = f(REC_{it}, NREC_{it}, CO_{2it}, GDP_{it}) \quad (2)$$

The model's general specification is represented in Equation (3) by taking the natural logarithm of Equation (2), is given as:

$$lnSWB_{it} = \alpha_0 + \alpha_1 lnREC_{it} + \alpha_2 lnNREC_{it} + \alpha_3 lnCO_{2it} + \alpha_4 lnGDP_{it} + \mu_{it} \quad (3)$$

Where, SWB_{it} is the subjective wellbeing of a country at a time t; REC_{it} is the renewable energy consumption per capita of the country; $NREC_{it}$ is the non-renewable energy consumption per capita of the country; CO_{2it} is the environmental quality of the country; GDP_{it} is the GDP per capita. μ_{it} denotes the error term of the equation. The detailed methodology is presented in Figure 6.

Insert [Figure 6]

4. Results and Discussion

Table 2 shows that the mean value is highest for GDP (9.75), followed by REC (7.35), NREC (2.33), CO_2 (1.94), and SWB (1.80), respectively. Variance of REC (1.92%) is highest, followed by GDP (1.01%), NREC (0.92%), CO_2 (0.74%), and SWB (0.15%). Table 3 displays the correlation matrix among the variables, i.e., SWB, REC, NREC, GDP, and CO_2. It is found that all the variables are positively related to subjective wellbeing except for NREC.

Insert [Table 2]

Insert [Table 3]

The empirical findings of the cross-sectional dependence (CSD) test are reported in Table 4. Since the p-value is less than 0.05, this suggest us to reject the null hypothesis of cross-sectional dependence. It reveals the existence of cross-sectional dependence in all the variables. As a result, the evidence shows the presence of CSD for REC, NREC, CO_2, and GDP.

Insert [Table 4]

Table 5 reports the first-generation Fisher ADF unit root result. The findings show that subjective wellbeing is stationary at level, but renewable energy consumption, non-renewable energy consumption, economic growth, and CO_2 emissions are found stationary at first difference. Overall, the considered variables are stationary either at level or at first difference. Table 6 reports the second-generation unit root test, i.e., CADF. The results reveal that the variables, i.e., SWB, REC, NREC, GDP, and CO_2 emissions, contain unit roots at their level. However, at their first order, they became stationary. We can conclude that all variables are integrated with first-order.

Insert [Table 5]

Insert [Table 6]

In order to assess the long run relationship among the variables, the variables of interest should be cointegrated. This study uses three-panel cointegration tests such as the first-generation Kao, Pedroni cointegration, and second-generation Westerlund (2007) variance tests to establish the long-run relationship between variables. The paper initially explores the feasible cointegration among the variables using Kao (1999) panel cointegration test. The empirical finding shows that three out of five statistics reject the null hypothesis of no long-run relationship amongst the variables (Table 7). This implies that there is a presence of a long-run relationship as per the Kao test. The paper also uses Pedroni (1999) cointegration test. In this test, three out of three statistics reject the hypothesis of absence of panel cointegration amongst the variables (Table 7). So, Pedroni test of cointegration test also suggests the presence of a long-run relationship among the variables. However, Kao and Pedroni cointegration tests have one disadvantage. Both cointegration tests do not consider the presence of CSD among the variable. To overcome this, we use a second-generation cointegration test, i.e., the Westerlund test. The results of this test are presented in Table 7. This test suggests the presence of panel cointegration amongst the variables.

Insert [Table 7]

To investigate the impact of REC, NREC, CO_2, and GDP firstly, the pooled OLS, fixed effect, and random effect model are applied for preliminary analysis. The results of these three models are presented in Table 8. It is found from these three models that non-renewable energy consumption has a negative relationship with subjective wellbeing. A correlation matrix also supports this finding. The literature suggests that fixed effect and random effect models have cross-section dependence, serial correlation, and group-wise heteroscedasticity problems. This is also supported by diagnostic tests, which are presented in Table 9. These diagnostic tests conclude that the fixed effect model suffers from cross-sectional dependence, serial correlation, and panel group-wise heteroscedasticity (Table 4 and Table 9).

Insert [Table 8]

Insert [Table 9]

To overcome the above discussed issues, the panel corrected standard error (PCSE) regression model is used. The results of this model are presented in Table 10. The results of the model reveal that renewable energy consumption has a positive impact on SWB at a 5% significance level. With a one percent increase in renewable energy consumption, there is a 0.01% increase in SWB. This result is consistent with the studies (Qiao et al., 2019; Sarpong et al., (2020); Paramati et al., 2017, Shahbaz et al., 2020; Pao & Fu, 2013). The result might be possible due to (a) better utilization of REC gives happiness to the people as they feel less threatened of their actions on the environment (b) REC reduces the carbon emissions and thus cleaner environment or better air quality lessens the adverse effects on health (c) G20 countries are able to manage their GDP and therefore they did not suffer from the scarcity of goods when shifting from NREC to REC. This argument can be supported by Paramati et al. (2018) who found that the impact of renewable energy is higher on economic growth than non-renewable energy in G20 countries.

However, the coefficient of non-renewable energy consumption is negative and significant at a 1% significance level. It is found that with a one percent increase in non-renewable energy consumption, SWB gets reduced by 0.01%. The result is consistent with the studies (Okulicz-Kozaryn and Altman, 2020; Mazur and Rosa, 1974). One of the primary reasons for having a negative coefficient of NREC is CO_2 emissions which is the biggest contributor to greenhouse gases and climate change, thus affecting people's lives directly. Secondly, increased use of non-renewable energy does not assure a high level of SWB, as evident in the study of Okulicz-Kozaryn and Altman (2020).

Also, the coefficient of CO_2 emissions is negative and significant at 5% significance level. It implies that one percent increase in CO_2 emissions leads to a decrease in SWB by 0.12%. This finding is consistent with studies (Tiwari, 2014; Zhang et al., 2017; Welsch 2006; Cuñado and Gracia, 2013; Paramati et al., 2017; Dong et al., 2019; Ahmed et al., 2019).

Lastly, the result of the study shows that per capita GDP has a negative impact on subjective wellbeing at a 1% level of significance. One percent increase in per capita GDP leads to 0.12% increase in SWB. The result implies that G20 countries have been able to utilize the fruits of economic growth to enhance subjective wellbeing. This result is consistent with the studies (Frijters et al., 2004; Hagerty & Veenhoven, 2003) and in contradiction with (Di Tella & MacCulloch, 2008). It can be said that material prosperity have its importance in SWB in G20 countries. It fulfils the basic needs and provide luxurious life; helps to attain the development goals in different G20 countries. Summary of the findings are presented in Figure 7.

Insert [Table 10]

Insert [Figure 7]

4.1. Robustness Check

To ensure the robustness of the estimated coefficient in the PCSE model, the Newey-West standard model is adopted in this paper. The outcomes of this model are presented in Table 11, shows similar estimates to the PCSE model. Thus, it confirms that the estimated coefficients in the PCSE model are robust. Table 11 shows that a 1% increase in renewable energy consumption increases SWB by 0.004%. Moreover, a 1% increase in GDP per capita raises SWB by 0.12. A one percent rise in CO_2 emissions reduces the SWB by 0.02% at a 5% significance level.

Insert [Table 11]

4.2. Dumitrescu-Hurlin Panel Granger Causality Test Findings

The paper also examines the panel granger causality test among the variables using the Dumitrescu-Hurlin (2012) test. The result of this test is presented in Table 12. There is a bidirectional causality between CO_2 and economic growth, between REC and GDP, NREC and CO_2, between REC and CO_2, and REC and NREC. Pao et al. (2011) also found bidirectional causality between economic growth and CO_2. Moreover, finding of bidirectional causality between renewable energy is consistent with Al-mulali et al. (2013), Sebri and Ben-Salha (2014), Saidi and Mbarek (2016), and Ummalla and Samal (2019). We established a one-way causal relationship running from SWB to CO_2, from SWB to non-renewable energy consumption, and from non-renewable energy consumption to economic growth.

Insert [Table 12]

5. Conclusion and Policy Implications

The world is dealing with the crisis of food, energy, and climate change. It is urgently needed to reduce fossil fuel consumption, increase renewable energy production, and use the innovative path of improving energy efficiency for creating a low carbon global society. It is only possible when the G20 countries will reduce their emissions and come forward to help underdeveloped nations whose major population have not yet accessed electricity and clean fuels. The study empirically investigated the impact of renewable energy consumption, non-renewable energy consumption, economic growth, and CO_2 emissions on subjective wellbeing in G20 countries during 2006-2019. Our empirical results confirm that both economic growth and renewable energy consumption positively influence subjective wellbeing in the selected G20 countries. Over the period, they realized the importance of renewable energy production-consumption and chosen renewable-led economic growth path. These countries have also invested in renewable sources of production techniques and awareness programs, which have enriched their subjective wellbeing.

Moreover, the findings of this study reveal that non-renewable energy consumption and CO_2 emissions deteriorate the subjective wellbeing in G20 countries. Based on these findings, we can propose several suggestions to reduce CO_2 emissions and non-renewable energy consumption. These countries can reduce their non-renewable energy consumption by increasing investment in more renewables energy production, cleaner technologies, and strengthening environmental protection policies. G20 summit on climate change should be taken earnestly not only for adopting a green development path and sustainable energy consumption but also for enhancing citizens' happiness, which is the ultimate goal of any nation. Further, to discourage non-renewable energy consumption, these countries can reduce the fossil fuel subsidies. The study confirms a positive relationship between economic growth and subjective wellbeing. Thus, it can be advocated to promote economic growth in these countries because it can help in two ways. Firstly, shifting from non-renewable energy consumption to renewable energy consumption in each sector of the economy will result in higher production cost, which can be fulfilled by high growth. Secondly, research and development (R&D) for innovation in energy-saving technology demands bulk investment for a longer duration which can be compensated by sustained growth.

The future scope of the paper is to explore the impact of renewable and non-renewable energy consumption in different income group countries which can provide more insights. Moreover, the effect of different forms of renewable and non-renewable energy consumption can be used to have a better understanding of the energy-subjective wellbeing relationship. Studies based on primary data can also be used to understand this relationship at the household level.

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Table 1. Description of the Variables

Symbol	*Description*	*Source*
lnSWB	Life ladder in natural logarithm	World Happiness Report
lnREC	Renewable energy consumption per capita (kWh) in natural logarithm	Energy Statistics
lnNREC	Nonrenewable energy consumption per capita (kWh) in natural consumption	Energy Statistics
lnCO_2	CO_2 emissions per capita in natural logarithm	World Development Indicators
lnGDP	GDP per capita in natural logarithm	World Development Indicators

Table 2. Summary Statistics of the Variables

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
lnSWB	266	1.806	0.154	1.178	2.044
lnREC	264	7.349	1.923	-2.813	10.344
lnNREC	266	2.334	0.923	0.890	4.793
lnCO_2	266	1.936	0.740	0.099	3.015
lnGDP	266	9.746	1.014	7.009	10.954

Table 3. Correlation Matrix

	lnSWB	lnREC	lnNREC	lnCO_2	lnGDP
lnSWB	1				
lnREC	0.369	1			
lnNREC	-0.203	0.056	1		
lnCO_2	0.464	0.051	0.210	1	
lnGDP	0.768	0.393	-0.089	0.739	1

Table 4. Cross-Sectional Dependency Test

	CD-test	P-value
lnSWB	0.55	0.584
lnREC	28.2***	0.000
lnGDP	29.04***	0.000
lnNREC	4.77	0.000
lnCO_2	0.12	0.904

Note. *** p<0.01, ** p<0.05, and * p<0.1

Table 5. Fisher ADF Unit Root Test

			At level		At first difference	
Variables			Statistics	P-value	Statistics	P-value
lnSWB	Inverse Chi2	P	71.068	0.001	153.814	0.000
	Inverse normal	Z	-2.497	0.006	-8.323	0.000
	Inverse logit	L	-2.515	0.007	-9.437	0.000
	Modified inverse Chi2	Pm	3.793	0.000	13.285	0.000
lnREC	Inverse Chi2	P	36.985	0.516	144.746	0.000
	Inverse normal	Z	2.281	0.989	-7.654	0.000
	Inverse logit	L	2.182	0.984	-8.809	0.000
	Modified inverse Chi2	Pm	-0.116	0.546	12.245	0.000
lnGDP	Inverse Chi2	P	27.569	0.894	191.221	0.000
	Inverse normal	Z	2.919	0.998	-8.861	0.000
	Inverse logit	L	2.822	0.997	-11.674	0.000
	Modified inverse Chi2	Pm	-1.197	0.884	17.576	0.000
lnNREC	Inverse Chi2	P	71.003	0.001	109.224	0.000
	Inverse normal	Z	-1.291	0.098	-5.212	0.000
	Inverse logit	L	-2.009	0.024	-6.080	0.000
	Modified inverse Chi2	Pm	3.786	0.000	8.170	0.000
$lnCO_2$	Inverse Chi2	P	31.048	0.781	133.492	0.000
	Inverse normal	Z	1.014	0.845	-7.274	0.000
	Inverse logit	L	1.073	0.857	-8.117	0.000
	Modified inverse Chi2	Pm	-0.797	0.787	10.954	0.000

Table 6. CADF Unit Root Test

	At level		At first difference	
Variables	t-bar	P-value	t-bar	P-value
lnSWB	-2.428	0.242	-3.771	0.000
lnREC	-1.658	0.049	-7.841	0.000
lnGDP	-2.424	0.247	-3.176	0.000
lnNREC	-1.649	0.991	-3.273	0.000
$lnCO_2$	-1.836	0.948	-3.264	0.000

Table 7. Cointegration Tests

	Statistic	P-value
Kao Test for Cointegration		
	Statistic	P-value
Modified Dickey-Fuller t	-0.736	0.231
Dickey-Fuller t	-1.709**	0.044
Augmented Dickey-Fuller t	-0.409	0.341
Unadjusted modified Dickey	-5.391***	0.000
Unadjusted Dickey-Fuller t	-4.232***	0.000
Pedroni Test for Cointegration		
Modified Phillips-Perron t	3.482***	0.000
Phillips-Perron t	-5.511***	0.000
Augmented Dickey-Fuller t	-6.086***	0.000
Westerlund Test for Cointegration		
Variance ratio (all panel are cointegrated)	1.352*	0.088
Variance ratio (some panel are cointegrated)	-1.344*	0.090

Note. *** p<0.01, ** p<0.05, and * p<0.1

Table 8. Panel Regression Models

Variables	OLS	Fixed Effects	Random Effects
lnREC	0.004	0.006	0.002
	(-0.004)	(-0.007)	(-0.006)
lnNREC	-0.017**	-0.158**	-0.058***
	(-0.007)	(-0.079)	(-0.022)
lnCO_2	-0.029**	0.081	0.011
	(-0.015)	(-0.065)	(-0.035)
lnGDP	0.127***	0.031	0.076***
	(-0.011)	-0.0470	(-0.027)
Constant	0.631***	1.669***	1.163***
	(-0.084)	(-0.379)	(-0.215)
Observations	264	264	264
R-squared	0.621	0.020	
Number of Cross-Sections		19	19
Hausman Test		Chi^2 12.22	P-value 0.0158

Note: (a) Standard errors in parentheses (b)*** p<0.01, ** p<0.05, and * p<0.1

Table 9. Diagnostic Tests

	Chi-square	P-value
Heteroscedasticity	13245.76***	0.000
Serial-Correlation	7.372**	0.014

Note: *** p<0.01, ** p<0.05, and * p<0.1

Table 10. Results of Panel Corrected Standard Errors (PCSE)

Variables	Coefficients	Panel Corrected Standard Error	P-value
lnREC	0.004**	0.002	0.045
lnNREC	-0.017***	0.004	0.000
$lnCO_2$	-0.029***	0.009	0.002
lnGDP	0.127***	0.008	0.000
Constant	0.631	0.063	0.000
R-squared	0.6213		
Number of observations	266		
Number of Groups	19		

Note: *** p<0.01, ** p<0.05, and * p<0.1

Table 11. Results of Newey-West Standard Error Model

Variables	Coefficients	Newey-West Standard Error	P-value
lnREC	0.004	0.004	0.283
lnNREC	-0.017**	0.007	0.022
$lnCO_2$	-0.029**	0.014	0.041
lnGDP	0.127***	0.011	0.000
Constant	0.631***	0.089	0.000
Number of observations	266		
Number of Groups	19		

Note: *** p<0.01, ** p<0.05, and * p<0.1

Table 12. Dumitrescu-Hurlin Panel Granger Causality Tests

Null Hypothesis:	W-Stat.	Zbar-Stat.	Prob.	Conclusion
lnGDP does not homogeneously cause lnSWB	1.900	1.309	0.191	
lnSWB does not homogeneously cause lnGDP	1.975	1.459	0.145	
$\ln CO_2$ does not homogeneously cause lnSWB	1.630	0.764	0.445	
lnSWB does not homogeneously cause $\ln CO_2$	2.982	3.487***	0.001	$\mathrm{lnSWB} \rightarrow lnCO_2$
lnNREC does not homogeneously cause lnSWB	2.028	1.566	0.118	
lnSWB does not homogeneously cause lnNREC	2.828	3.178***	0.002	$\mathrm{lnSWB} \rightarrow \mathrm{lnNREC}$
lnREC does not homogeneously cause lnSWB	1.412	0.314	0.754	
lnSWB does not homogeneously cause lnREC	1.654	0.798	0.425	
$\ln CO_2$ does not homogeneously cause lnGDP	2.680	2.879***	0.004	$\ln CO_2 \leftrightarrow \mathrm{lnGDP}$
lnGDP does not homogeneously cause $\ln CO_2$	3.002	3.528***	0.000	
lnNREC does not homogeneously cause lnGDP	2.117	1.745*	0.081	$\mathrm{lnNREC} \rightarrow \mathrm{lnGDP}$
lnGDP does not homogeneously cause lnNREC	1.358	0.218	0.828	
lnREC does not homogeneously cause lnGDP	2.374	2.235**	0.025	$\mathrm{lnREC} \leftrightarrow \mathrm{lnGDP}$
lnGDP does not homogeneously cause lnREC	2.899	3.284***	0.001	
lnNREC does not homogeneously cause $\ln CO_2$	2.654	2.828***	0.005	$\mathrm{lnNREC} \leftrightarrow \ln CO_2$
$\ln CO_2$ does not homogeneously cause lnNREC	2.881	3.283***	0.001	
lnREC does not homogeneously cause $\ln CO_2$	3.497	4.478***	0.000	$\mathrm{lnREC} \leftrightarrow \ln CO_2$
$\ln CO_2$ does not homogeneously cause lnREC	3.155	3.794***	0.000	

lnREC does not homogeneously cause lnNREC	3.296	4.075***	0.000	lnREC ↔ lnNREC
lnNREC does not homogeneously cause lnREC	2.258	2.003**	0.045	

Note: *** p<0.01, ** p<0.05, and * p<0.1. → denotes unidirectional causality and ↔ shows bidirectional causality

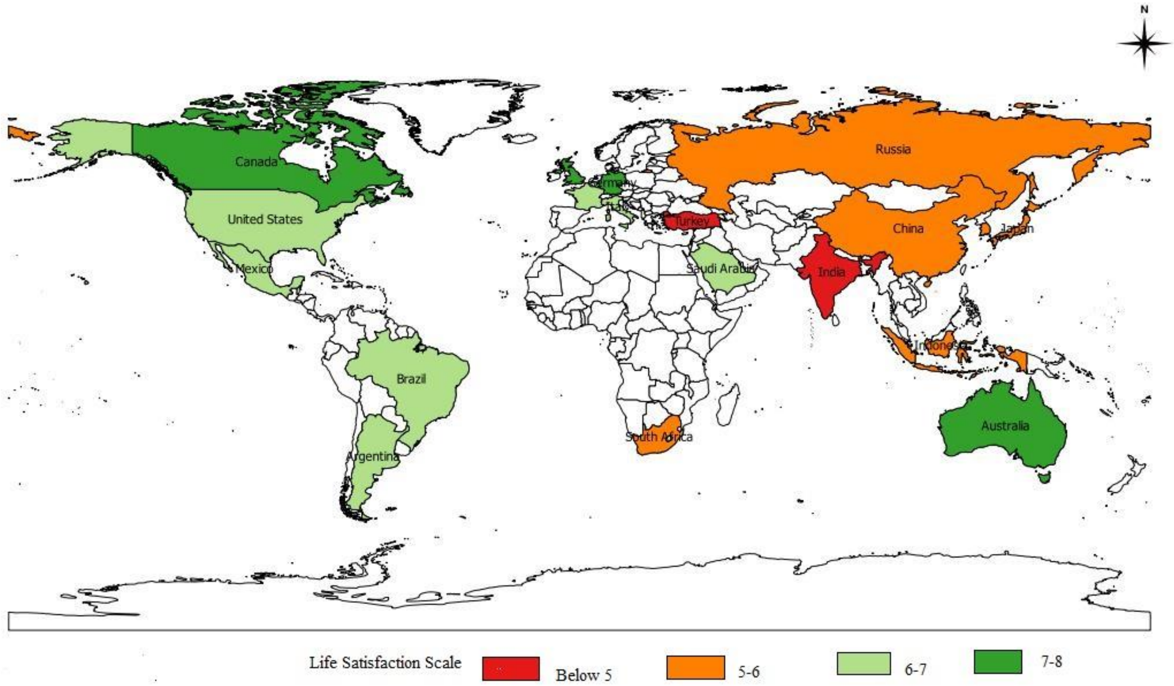


Figure 1. G20 Countries in World Happiness Report 2019

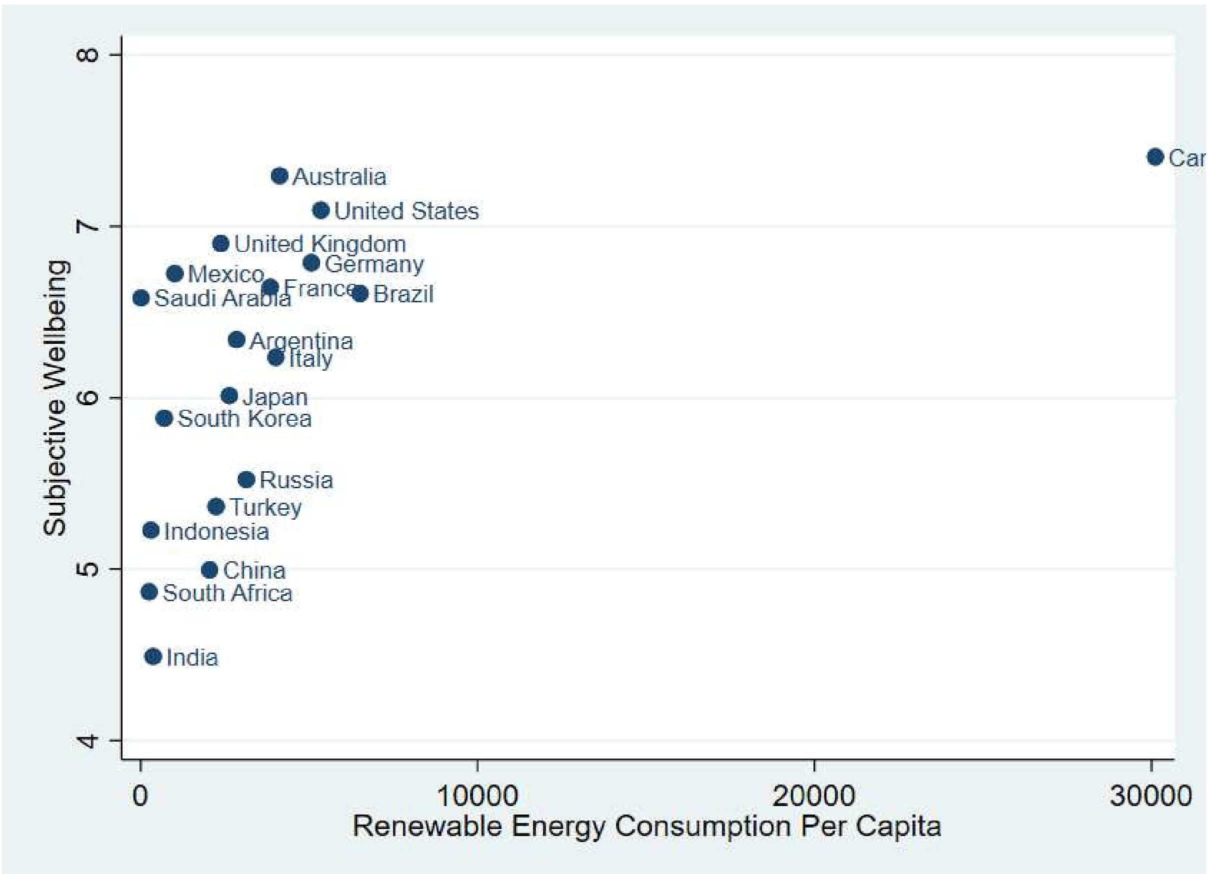


Figure 2. Subjective Wellbeing and REC

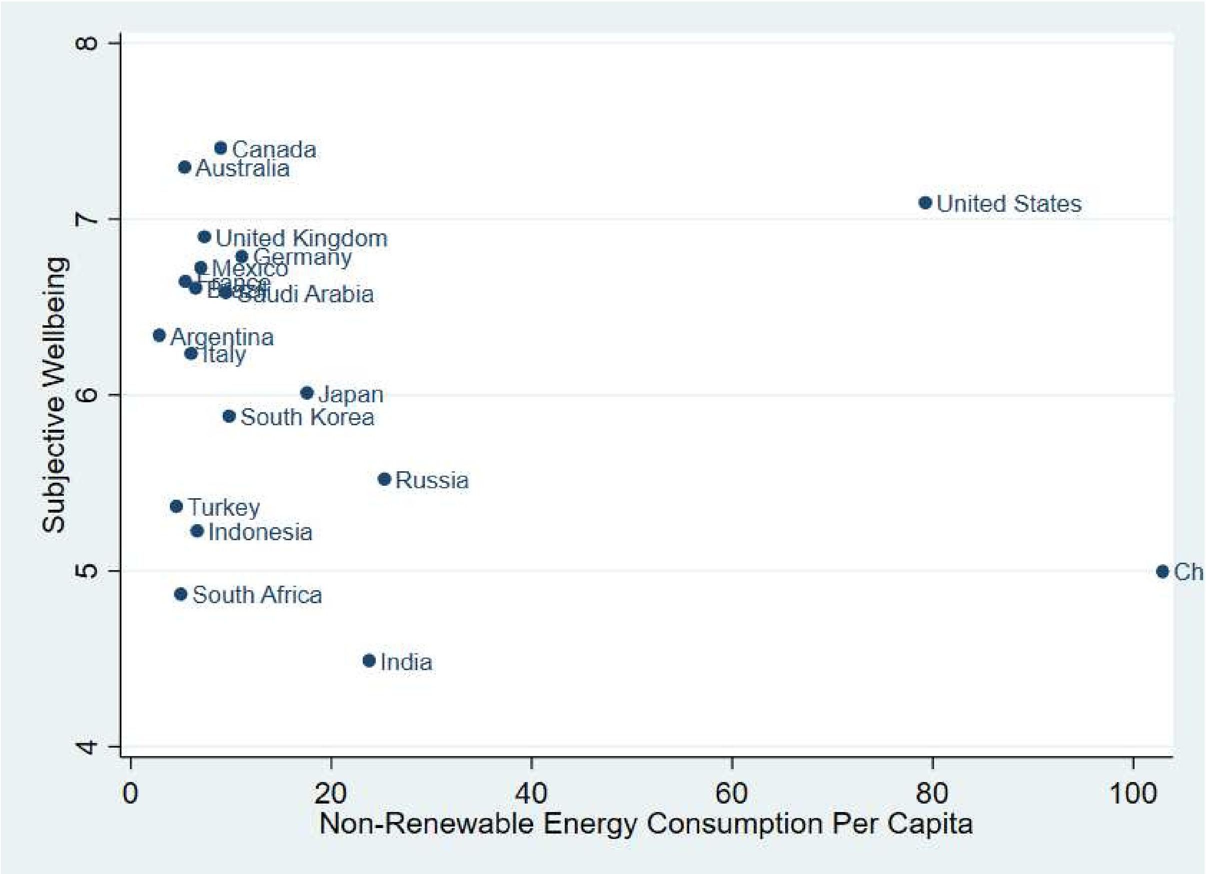


Figure 3. Subjective Wellbeing and NREC

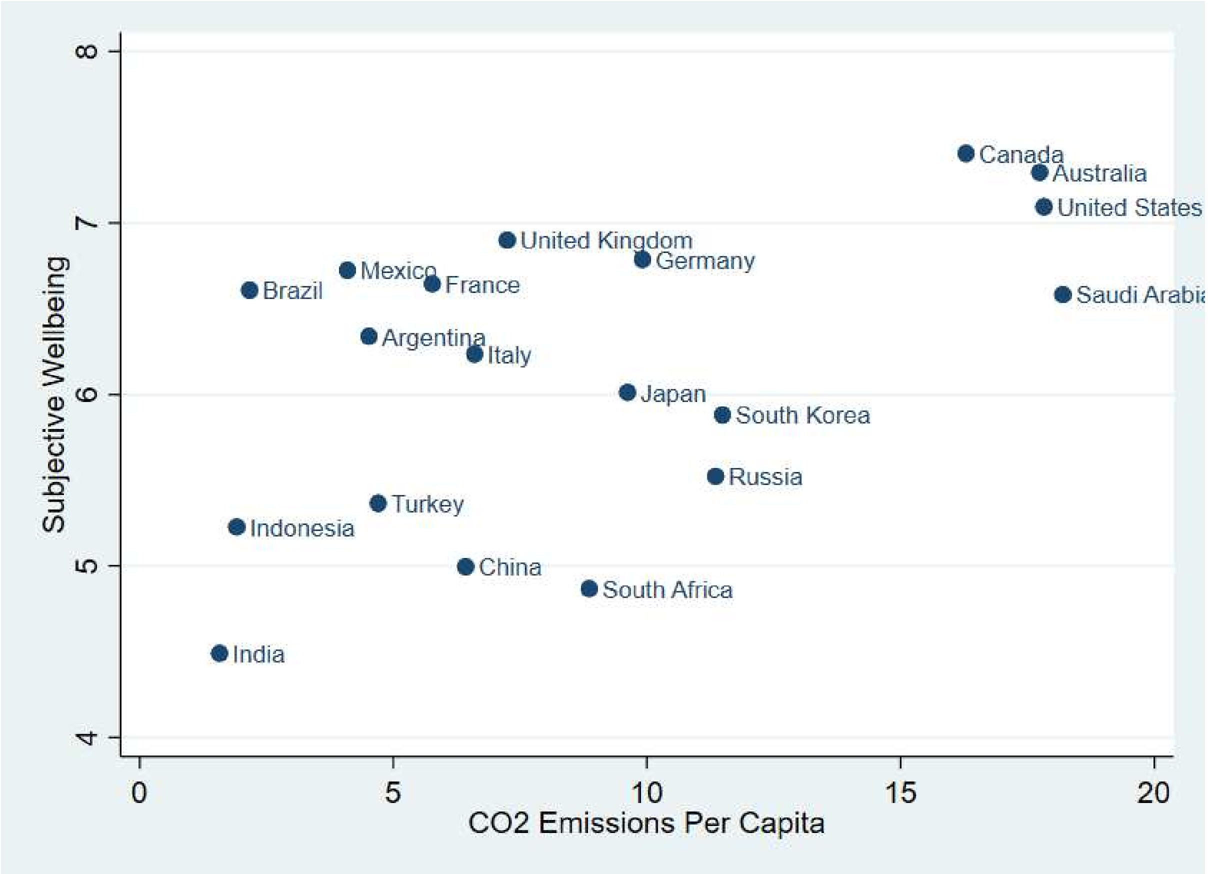


Figure 4. Subjective Wellbeing and CO_2 Emissions

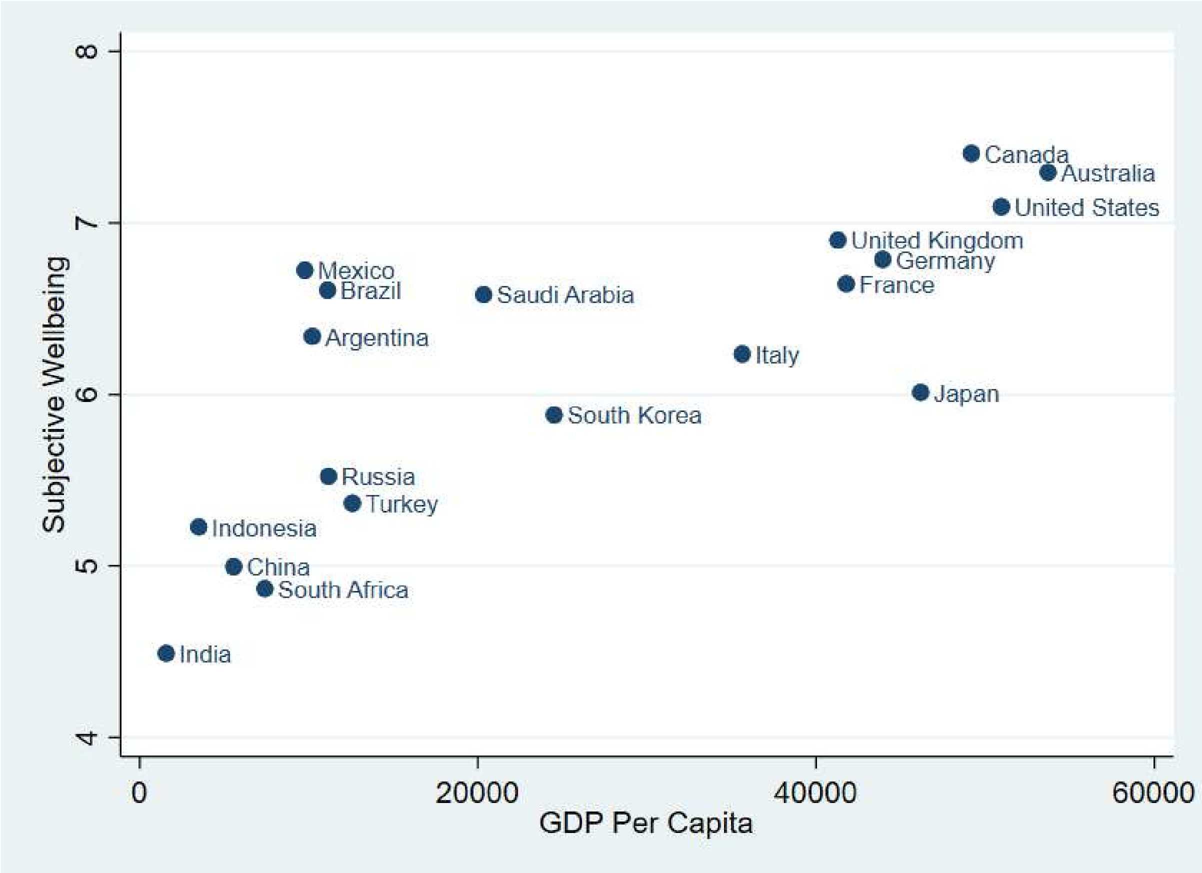


Figure 5. Subjective Wellbeing and GDP Per Capita

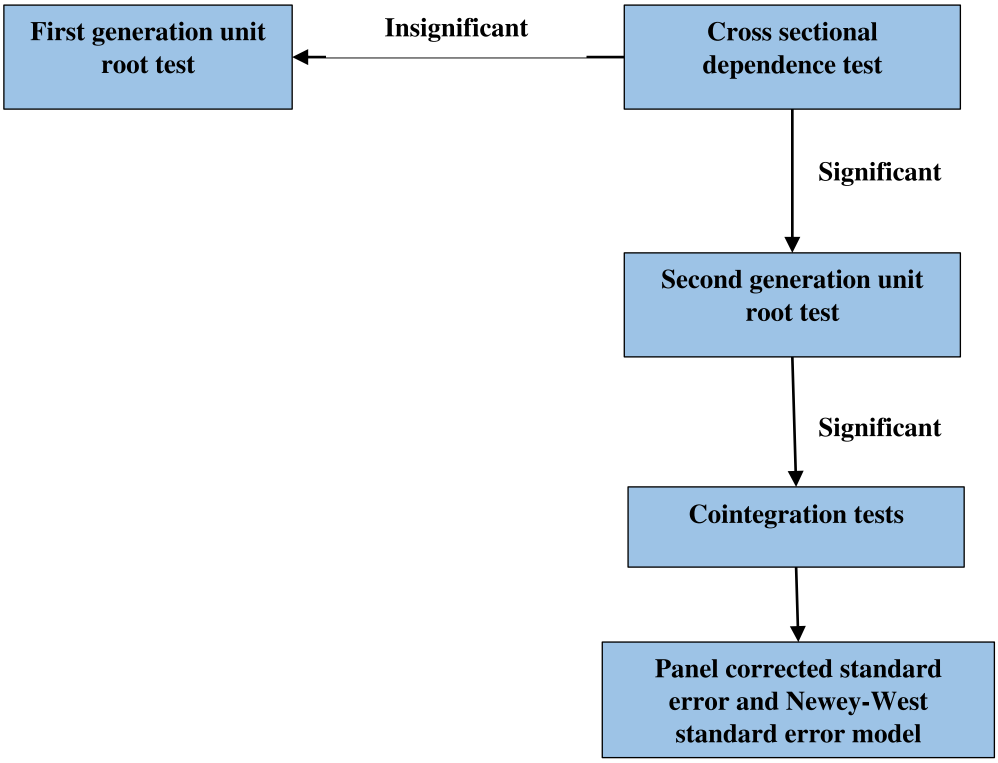


Figure 6. Scheme of Methodology

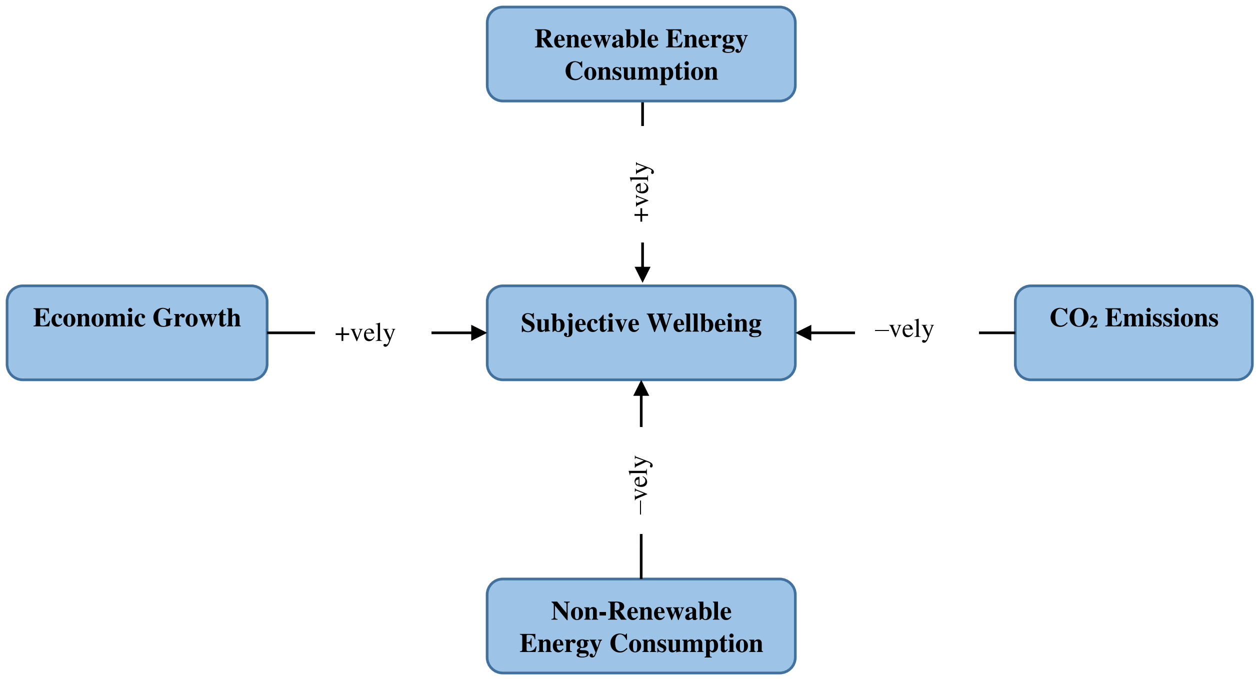
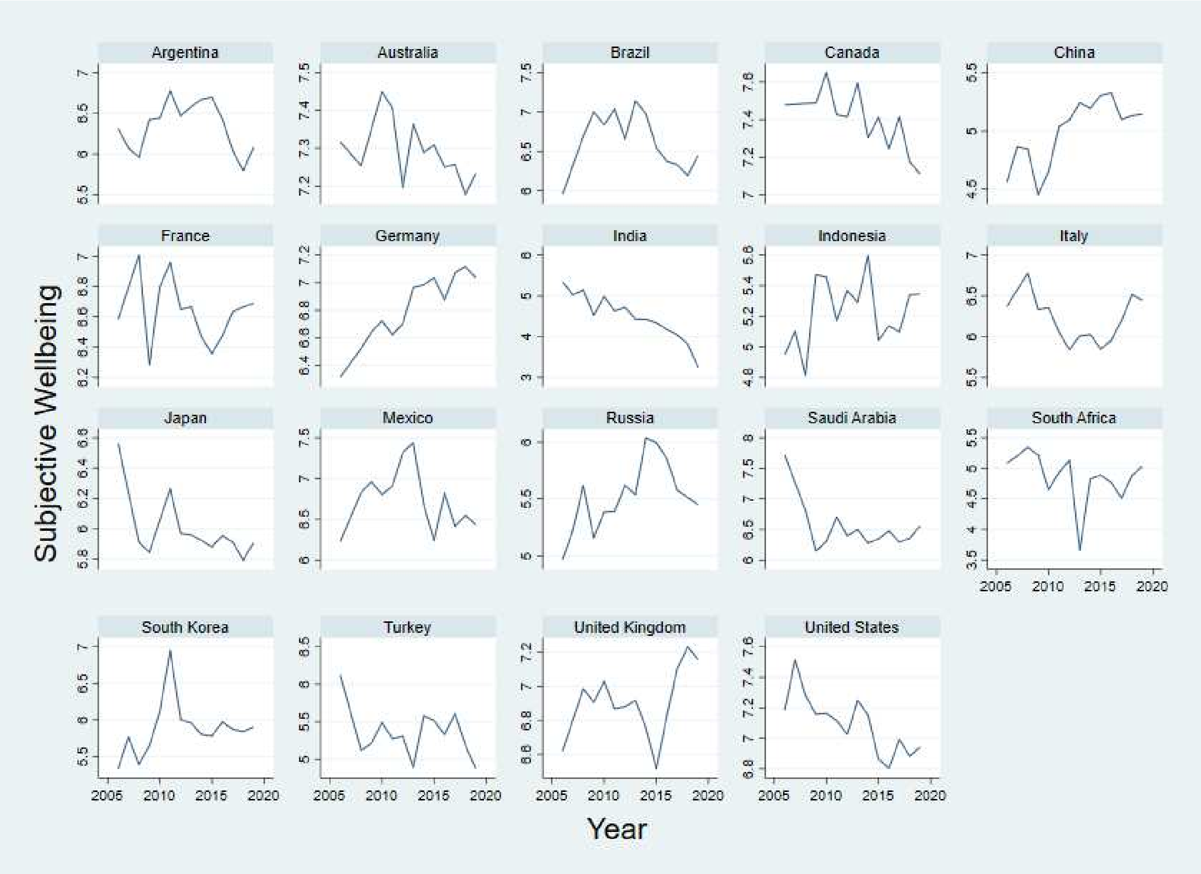
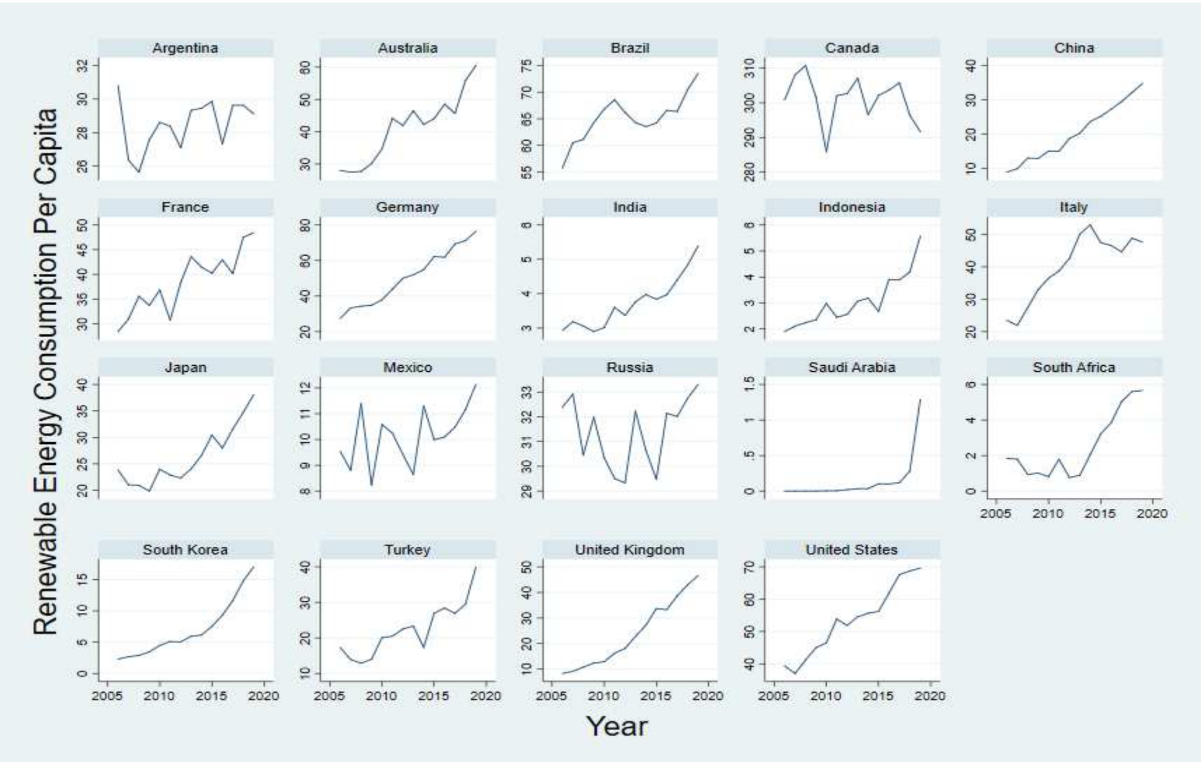
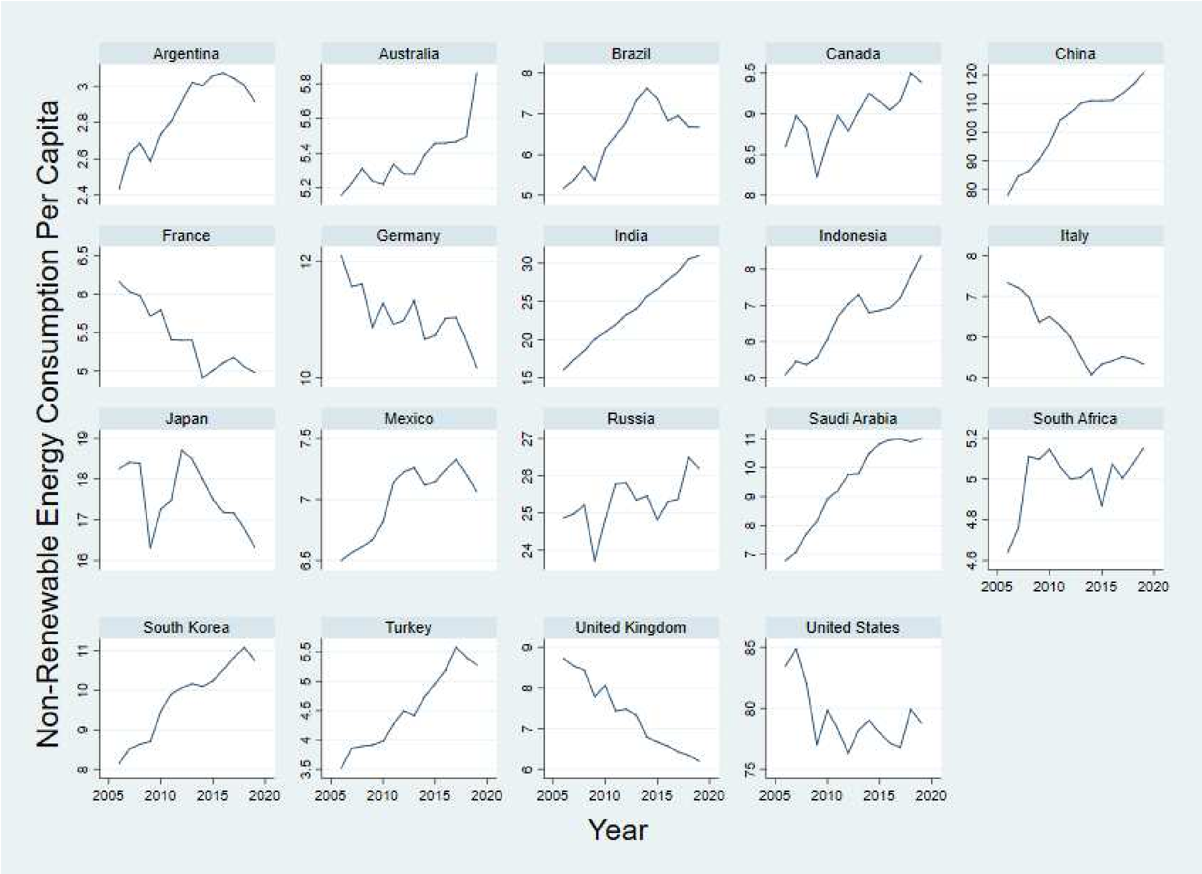


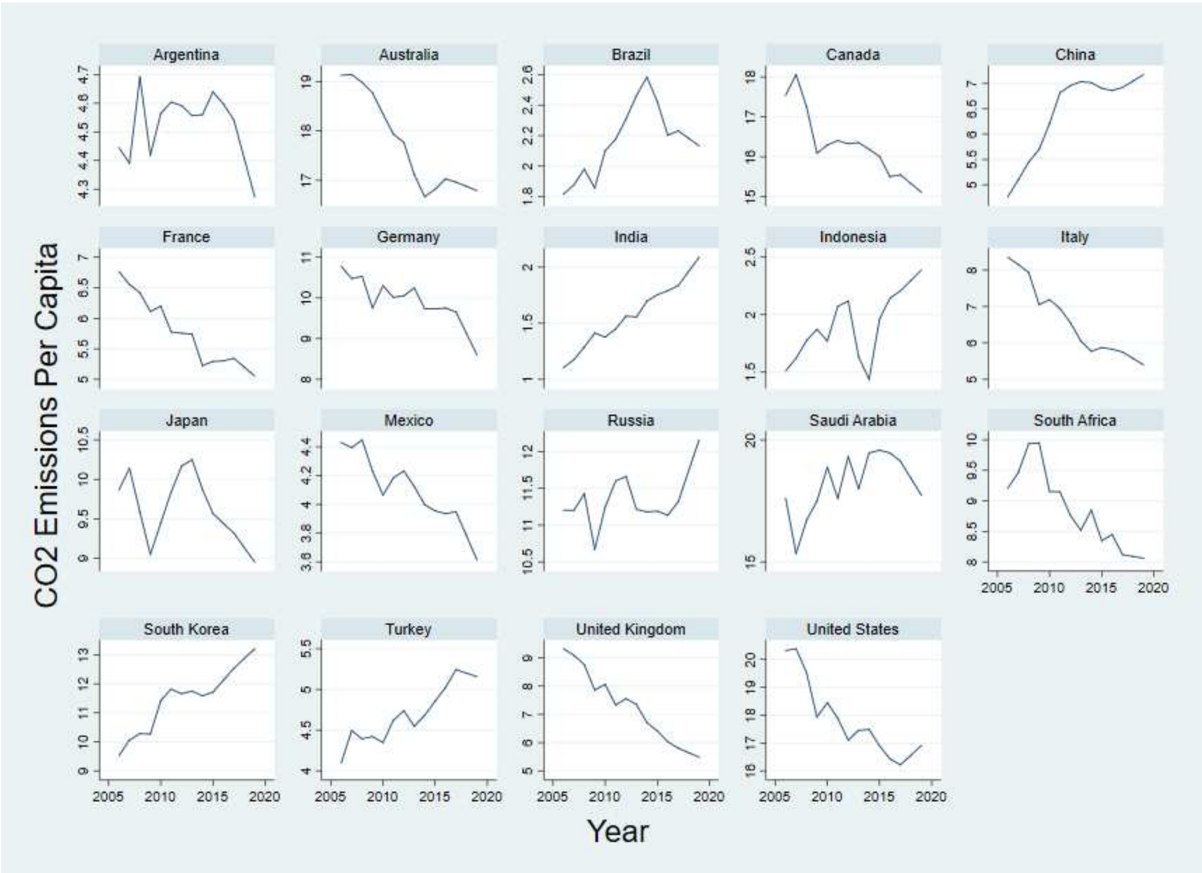
Figure 7. Summary of Findings

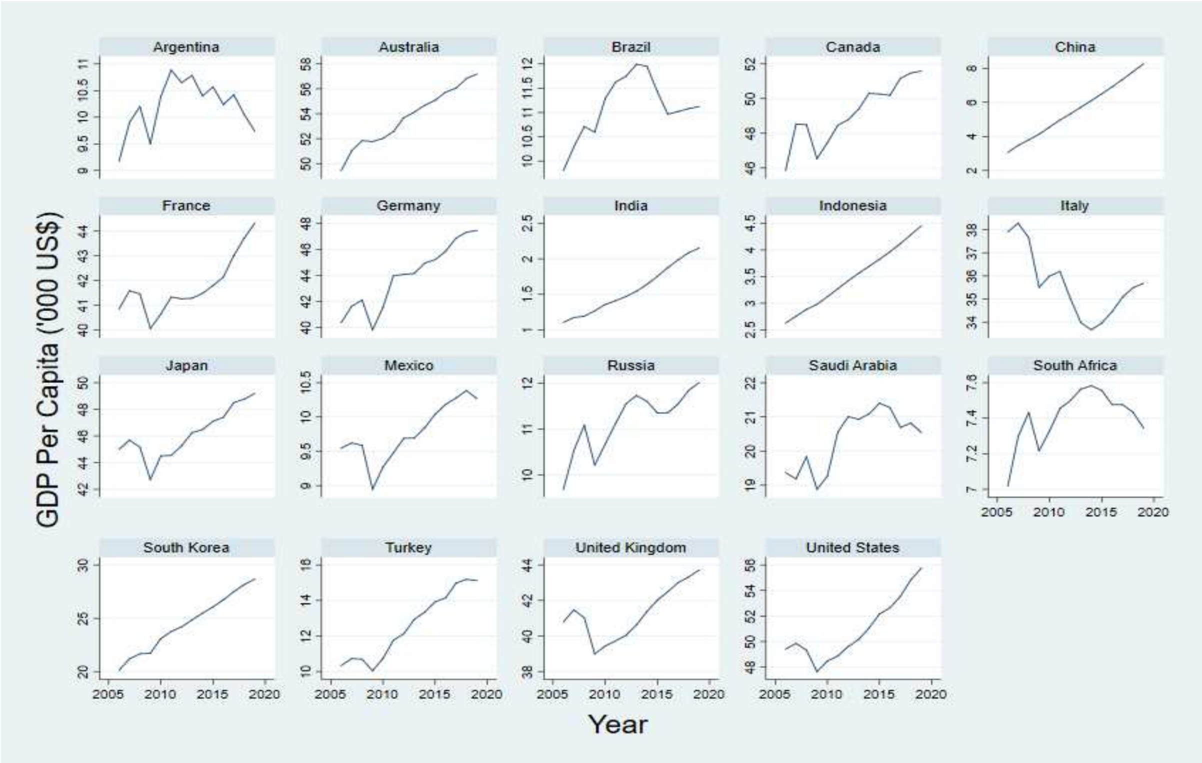
Appendix 1: Trends of the Variables for G20 Countries during 2006-19






Non-Renewable Energy Consumption Per Capita
Argentina
Australia
Brazil
Canada
China
France
Germany
India
Indonesia
Italy
Japan
Mexico
Russia
Saudi Arabia
South Africa
South Korea
Turkey
United Kingdom
United States
Year


CO2 Emissions Per Capita
Argentina
Australia
Brazil
Canada
China
France
Germany
India
Indonesia
Italy
Japan
Mexico
Russia
Saudi Arabia
South Africa
South Korea
Turkey
United Kingdom
United States
Year



Argentina
Australia
Brazil
Canada
China
France
Germany
India
Indonesia
Italy
Japan
Mexico
Russia
Saudi Arabia
South Africa
South Korea
Turkey
United Kingdom
United States
GDP Per Capita ('000 US$)
Year

Figures

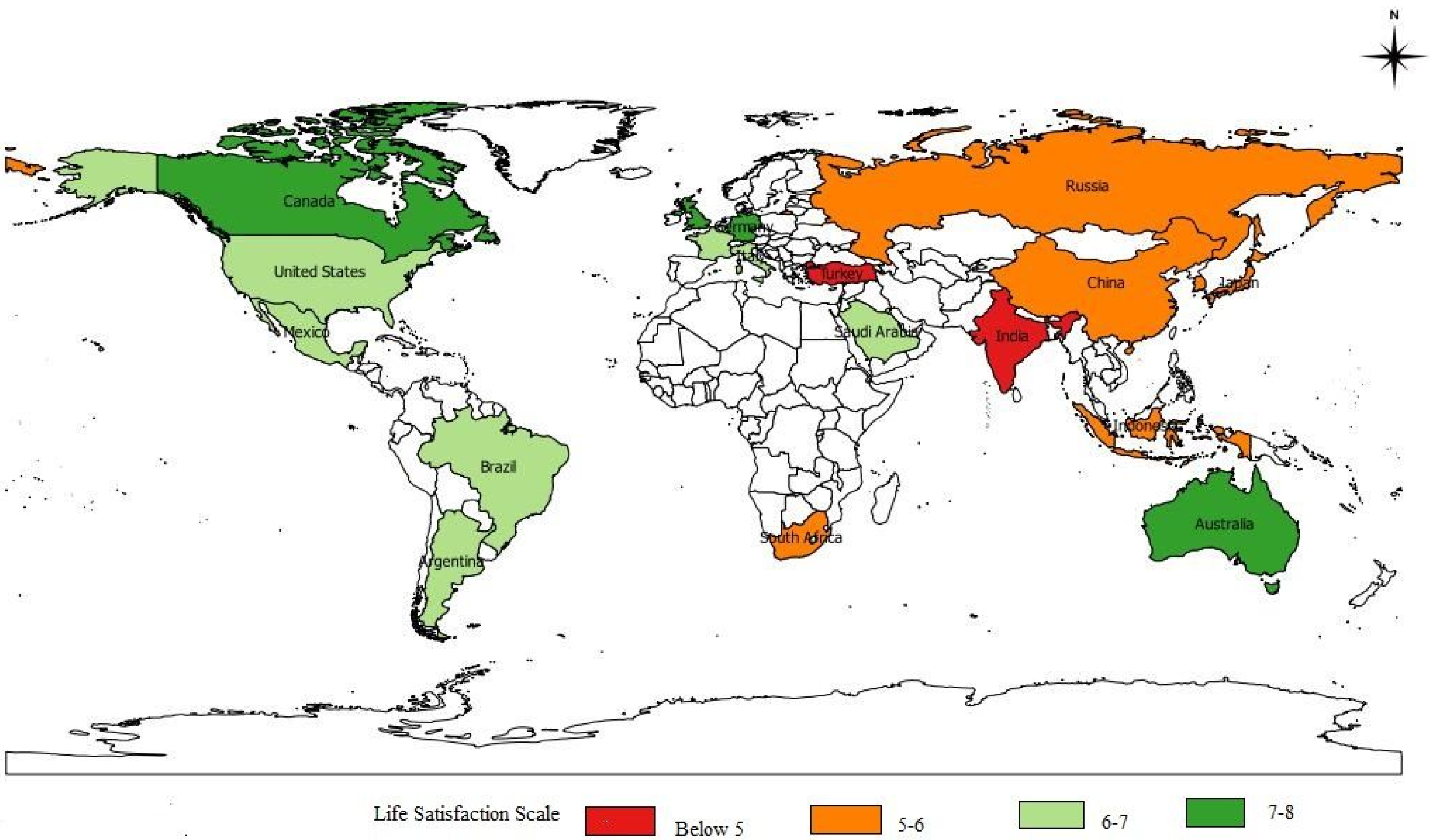


Figure 1

G20 Countries in World Happiness Report 2019. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

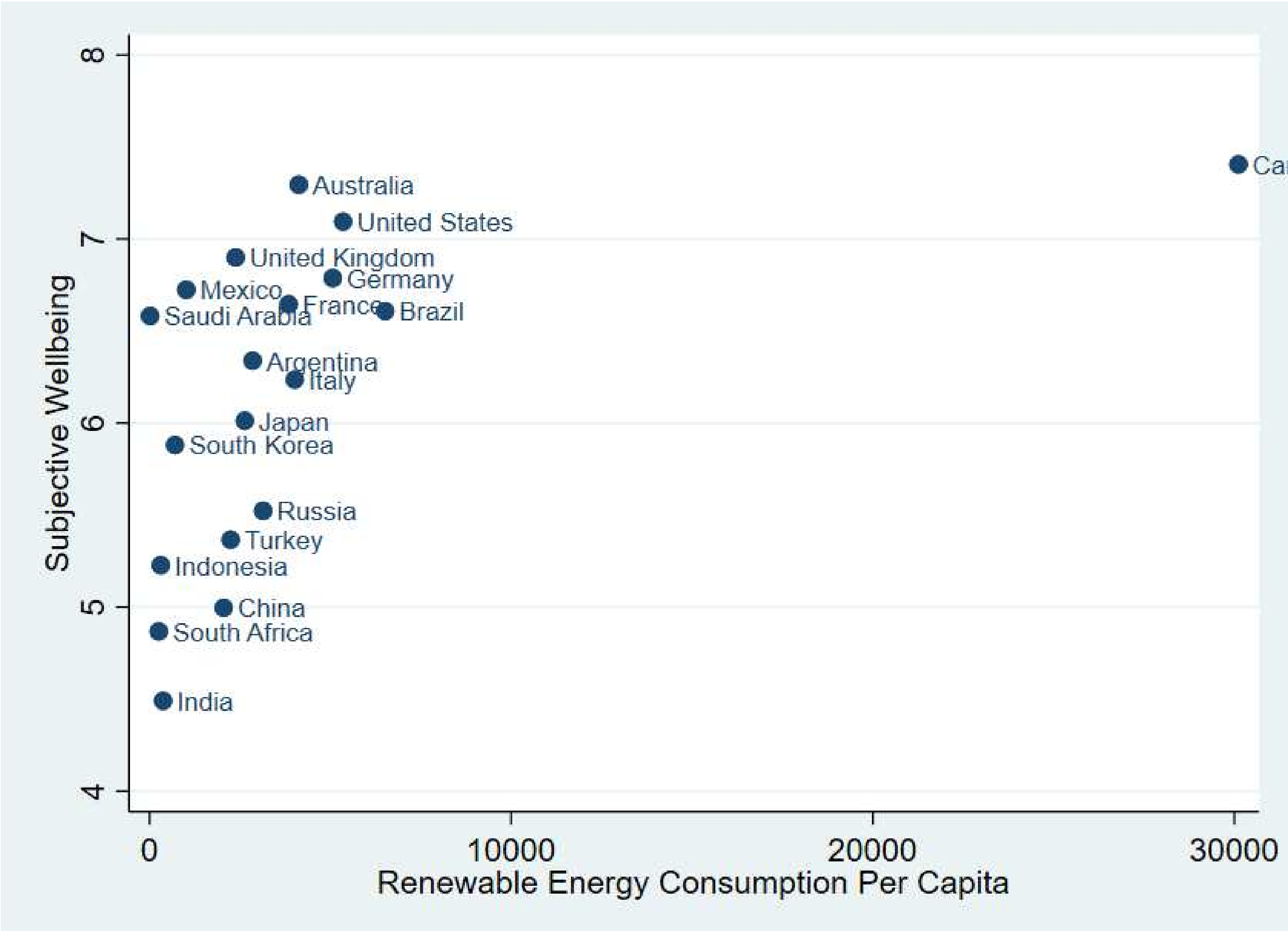


Figure 2

Subjective Wellbeing and REC

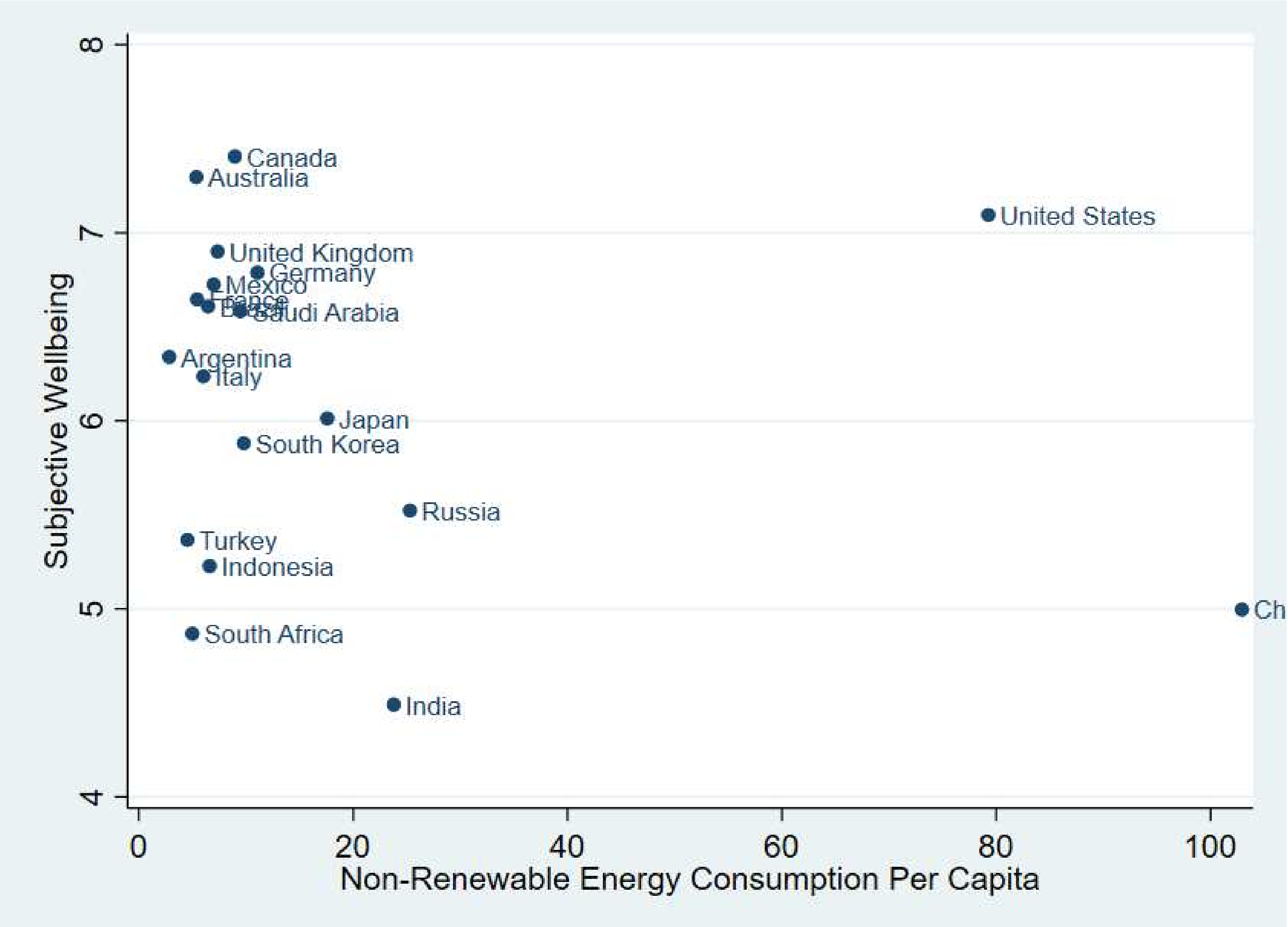


Figure 3

Subjective Wellbeing and NREC

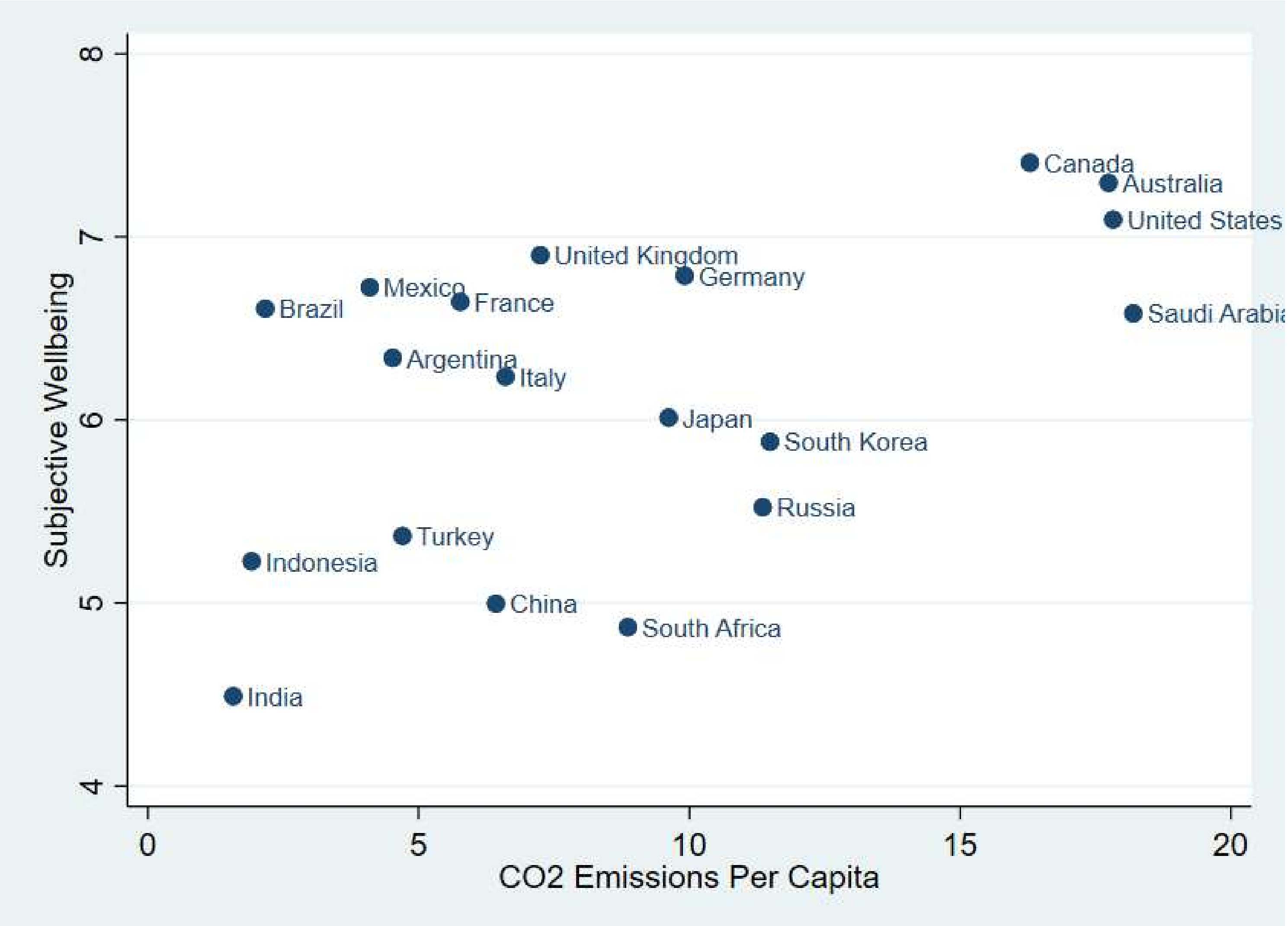


Figure 4

Subjective Wellbeing and CO2 Emissions

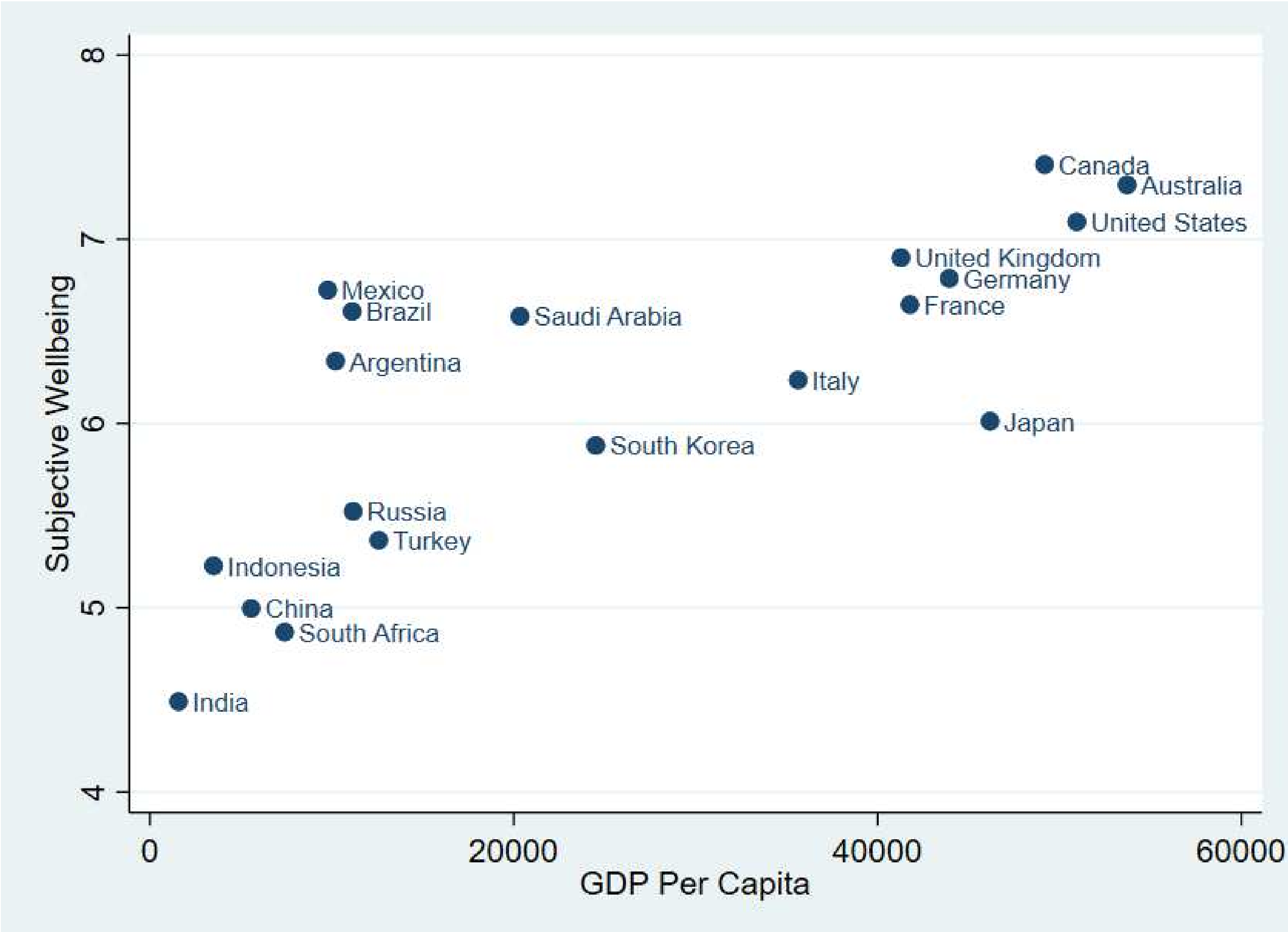


Figure 5

Subjective Wellbeing and GDP Per Capita

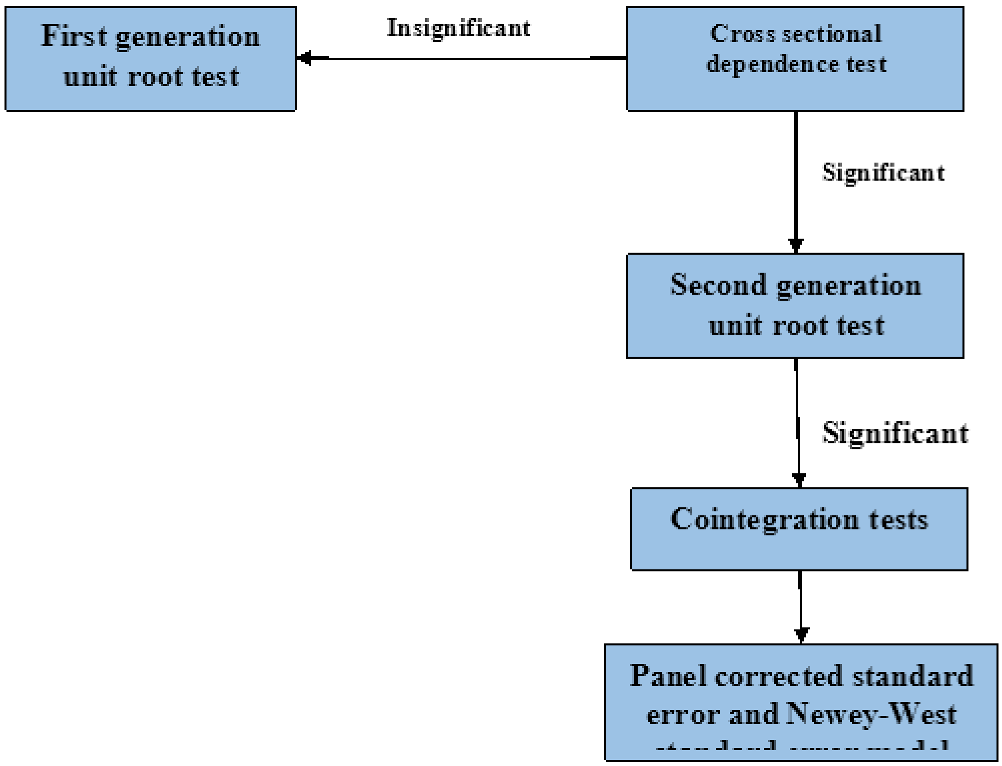


Figure 6

Scheme of Methodology

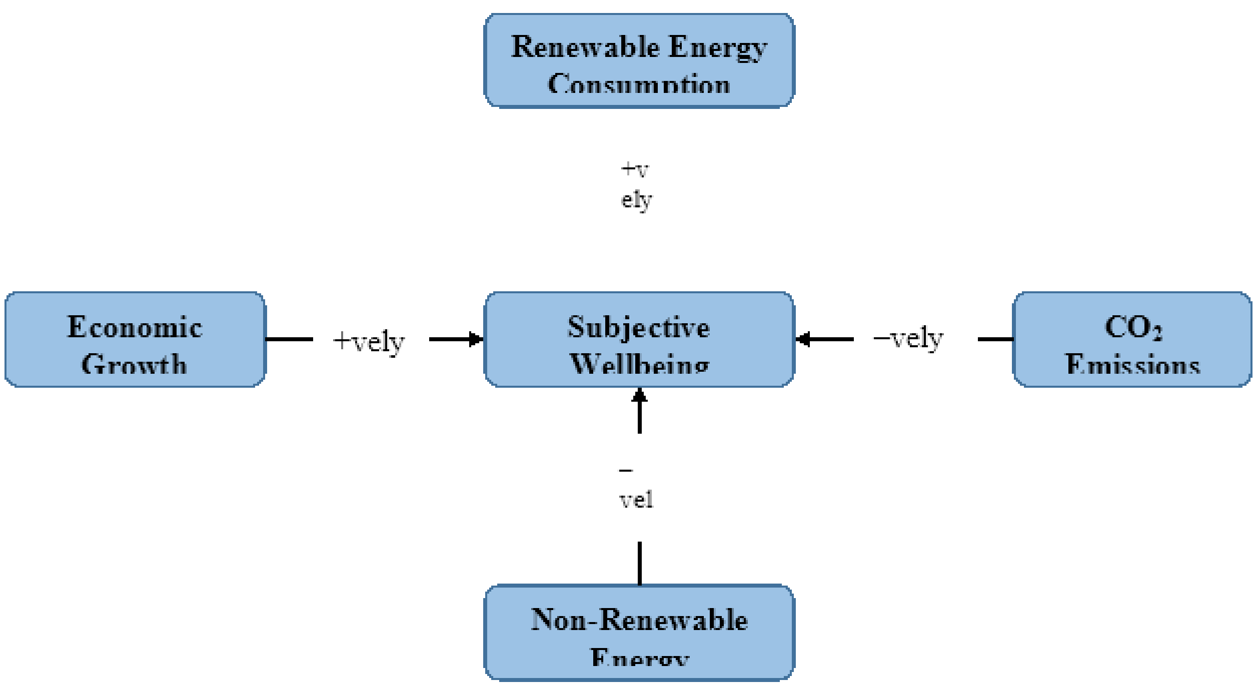


Figure 7

Summary of Findings