ANALYSIS OF GROWTH AND CONVERGENCE OF CO2 EMISSIONS IN BRICS NATIONS

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Abstract

The developmental gap among the countries or regions sometimes depends on the narrowing of the gap between carbon emissions as the latter leads to more industrial growth. The present study endeavors to test whether the BRICS nations are converging in terms of per capita CO2 emission over time for the period 1992-2014. We have applied the Barro and Sala-i-Martin's (2004) unconditional and conditional β convergence definitions, and σ convergence definition on the data of the World Bank for the said period. The results show that there were no signs of cross country convergence in terms of β convergence definition (or the catching up process) but the countries were converging in line with the σ convergence definition for three different time durations indicating pre entry to and post entry of the BRICS Group. Attempting to a set of conditional variables like fuel consumption, energy intensity, per capita growth rate, FDI flow, trade openness, population, import share to GDP, etc. we did not find any such variable explaining whether there were any sort of conditional convergence. The cross country convergence in income in the group can also be attributable to this CO2 convergence.

Keywords: Per capita CO2 emission, β convergence, σ convergence, BRICS
JEL classification:

1. Introduction

Before to the commencement of the 9th BRICS Summit scheduled for September 3-5, 2017 in Southeast China's Xiamen city, Brazilian President Michel Temer said that his country would seek real convergence among the bloc members on economic and financial issues and common challenges (China Daily, 29.08.2017). As the group consists mainly of the highly emerging countries of the world, besides economic challenges, there is also a tough challenge regarding the emission levels of CO2. The Kyoto Protocol has put deadlines of the carbon emission, a major part of greenhouse gases, for all the countries with different status of development. Based on the EDGAR database created by European Commission and Netherlands Environmental Assessment Agency released in 2015 that China leads the list of countries with 10,641,789 kt of CO2 followed by USA with 5,172,336 kt, European Union with 3,469,671 kt, India with 2,454,968 and Russia with 1,760,895 kt. The striking fact for the BRICS nations is that out of top five countries/regions in the list of CO2 emitter, three are belonging to the group with about 40 per cent of world CO2 emissions. The developed countries always blame that the growth and progress of the emerging countries like China is due to the destruction of the global environmental quality which put a cost to the global community. It is further that, being CO2 emission as one of the important determinants of industrial production and GDP of the countries, the progress of BRICS nation is subject to divergence or convergence. The Brazillian President's urge towards real convergence among the group nations, thus, carries a valuable point.

Besides technological and natural factors, there are several economic factors behind the increase in the CO2 emission level irrespective of the status of developments of the countries. There is a long list of studies available in the literature on the determinants of CO2 emissions in countries and regions of the world. For instance, the study of Friedl and Getzner (2003) on a small open and industrialized country like Austria explored that import shares reflecting the well-known pollution haven hypothesis and the share of the tertiary sector of total production are the significant factors on determining CO2 emission of the country. In another study, Cerdeira Bento (2014) points out that there are the factors like trade openness and energy consumption are responsible for CO2 emission in a small open economy, Italy. In their study, Morales-Lage, Bengochea-Morancho & Martínez-Zarzoso (2016) have identified three

factors, namely, population, industry and energy use having role in making CO2 emissions in the 28 European countries. The study by Jawara (2016) on the Gambia economy has shown that GDP per capita, population density and trade balance have significant role on CO2 emission of the country. There may be a list of remaining factors that can be responsible for carbon emission in some countries. The socio-economic factors responsible in determining the volume of CO2 emission, as mentioned in the above studies, sometimes work as conditional variables in explaining the growth and divergence of CO2 emission across the countries.

The countries in the BRICS groups are among the highly emerging economies in the world for the last two to three decades in terms of their volume of GDP and industrial production. But, according to the data by World Bank, China and India are among the vibrant economies in recent times in the group. Hence, there is the possibility that there is divergence among the member nations. Also, it is that, diverging tendency among them is not the expected outcome of the member countries; it can destabilize the core of the group. Under this backdrop, the present study examines whether the BRICS nations are converging in terms of CO2 emissions for the period 1992-2014 as carbon emission is an important determinant of GDP of the countries.

2. Review of Relevant Literature

In carrying out the above study, we point out here the extant studies on carbon emission in particular and income convergence in general across the countries and regions. In a front line study, Strazicich and List (2003) tested for convergence of per capita CO2 emissions in 21 OECD countries over the time period 1960-1997. They observed strong sign of convergence and also that gasoline prices and temperature had significant roles behind conditional convergence. Stegman and McKibbin (2005) attempted to examine whether there was any evidence of convergence with respect to per capita carbon emissions from fossil fuel for 26 OECD countries and 97 countries in total for different periods of the twentieth century. The observed strong evidence of convergence for the OECD countries but the there was little evidence of convergence for the 97 countries as a whole. In a similar type of study, Aldy (2006) showed that the high income countries were converging in per capita emission while the entire set of countries did not show any sign of convergence. In a further study at some micro levels, Aldy (2007) tried to show whether income convergence is sufficient for convergence in per capita carbon dioxide emissions on a set of the U.S. states for the period 1960-1999. The findings showed that, although incomes continue to converge, there were severe divergence in production CO2 per capita and no evidence of convergence for consumption CO2 per capita. In a different methodological approach, Panopoulou & Pantelidis (2009) examined convergence in carbon dioxide emissions among 128 countries out of OECD, EMU and other regions for the period 1960–2003 and the results suggested convergence in per capita CO2 emissions among all the countries. Vargas-Hernandez (2009) focused on the environmental and economic shrinkage impact it has had the transfer of ownership from state owned Paper Mill Company to a corporate private ownership as an effect of the ongoing economic process of globalization, after the industrial boom of the paper mill during the second half of the last Century. It observed that the impact on the environmental and economic development had initiated the shrinking and declining of Atenquique but also of the surrounding cities and towns. Brock & Taylor (2010) investigated unconditional and conditional β-convergence through a cross-sectional approach for 22 OECD countries for the time period 1960-1999 and observed the evidence of both unconditional and conditional β-convergence for the club of countries. Differences in countries arose from savings rates, pollution abatement intensities and effective depreciation rates. Hossain and Miyata (2012) have attempted to study the growth of Toyohashi city over time and resultant increase in consumption of electricity and gas. The results of the study show that manufacturing and trading sector of the economy are causing expansionary pressure on use of combustion energy leading to imbalanced environment. In their study, Camarero et al. (2013a) analyzed convergence in CO2 emission intensity for 23 OECD countries over the period 1960-2008 based on its determinants such as energy intensity and the carbonization index and showed that the differences in emission intensity convergence are more determined by differences in convergence of the carbonization index. Yavuz and Yilanci (2013) have

tested the convergence of per capita carbon dioxide emissions of the G7 countries during 1960–2005. Using the threshold autoregressive panel unit root test, data are decomposed into two regimes, and the results showed that convergence existed in the first regime and divergence, in the second. In its attempt for micro levels, the study of Das (2013) tried to examine whether the Indian states are converging in CO2 emissions for the period 1980-2000. The study observes that the states are insignificantly β converging and significantly σ converging for the period 1980-2000. Segregating the data for pre reform (1980-91) and post reform (1992-2000) periods, the study observes that the states are unambiguously converging in the former period but diverging in the later period at least by the definitions of σ convergence. There is an extensive review of literature on convergence of carbon dioxide emissions by Petterson et al (2014) and its extract shows that the developed countries under the banner of OECD are converging in terms of per capita emission while the countries at the global level are not converging. The study of Pourmohammadi, Valibeigi and Sadrmousavi (2014) investigated the situation and tendencies in the field of quality of life in Iran based on comparison, convergence and investigated whether there were convergences in human development indicators. The results of this study revealed that the order of provinces in terms of quality of life had not changed, but HDI, access to clean water and average income levels had been increased and the relative convergence with both in unconditional β-convergence and σ-convergence analyses had been occurred. In a study related to different regions of Turkey, Duran (2015) analyzed regional income convergence in 67 provinces for the period 1975-2000 by using nonparametric convergence regressions. The result obtained was that the relationship between initial income and growth took an inverted-U shape which meant that the very low-income and high-income group of provinces experienced a slow growth pattern compared to middle-income group. The study by Tiwari and Mishra (2016) examined the convergence in CO2 emissions across 18 Asian countries over the period of 1972–2010. The results showed that there were significant beta and sigma convergence of the group countries. In a recent study, Akar and Lindmark (2017) have analyzed convergence in CO2 emissions in the OECD countries with respect to oil and coal sources of emissions for the period 1973-2010. The study also decomposed the total time period into 1973–1991 for oil price shock and 1992–2010 for Cold War strategic considerations. The study revealed stronger convergence with respect to oil-related emissions until 1991 conditional on gross domestic product per capita is compatible with a situation where the rising oil prices led to a strong transformation in the countries of interest. In a bit different study, Batabyal (2017) highlighted on some measurement issues while analyzing the long run behavior of the creative region's output per creative class member by applying the unconditional and conditional convergence, and sigma convergence. It studied how to estimate the regression coefficient from the knowledge of the coefficients of a related cross region growth regression.

2.1. Lacuna of the previous studies

The survey of existing literature so far did not disclose any study on carbon convergence or divergence for the BRICS nations and hence our proposed study has potential to make some additional value to the existing literature on this particular area.

3. Data and Methodology

We have used the data for CO2 emissions, GDP, GDP growth rates, population, energy consumption, trade openness, industrial value added, and electricity production published by the World Bank for the time period 1992-2014 for the BRICS members namely Brazil, Russia, India, China and South Africa. The total data set has also been bifurcated in to 1992-2005 which is the pre BRICS phase and 2006-2014 as the post BRICS phase. The choice of 1992 as the initial time point since World Bank published data for Russia from this year on CO2 emission.

At first we have divided the total CO2 emission (in kilo tone units) by population figure and derived the per capita CO2 emissions for all the five countries. Then we have applied the unconditional or absolute β convergence, conditional β convergence and σ convergence principles in line with Barro and Sala-i- Martin (1992 & 2004) to test whether the BRICS nations are converging in terms of per capita CO2 emissions.

We can now derive the expression for β in the form of cross section regression. Let us suppose that there are n numbers (here n = 5) of countries within a geographical boundary with k_{it} being the per capita CO2 emission quantity of the i^{th} country. Consider the following regression model

$$log\left(k_{it}\right) = \alpha + (1-\beta)\, log\left(k_{i,t-1}\right) + u_{it} \ldots\ldots\ldots\ldots\ldots..(1)$$

It can be rewritten as

$$log\left(k_{it} / k_{i,t-1}\right) = \alpha - \beta log\left(k_{i,t-1}\right) + u_{it} \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

where α and β are constants respectively for intercept and slope with β>0 and u_{it} is a regular disturbance term following properties of normal distribution. In this equation a positive sign of β means absolute convergence. That is, growth rate of per capita CO2 emission [= log (k_{it}/ $k_{i,t-1}$)] is inversely related to the initial per capita quantity of emission (= $k_{i,t-1}$). It is also to note that β is nothing but the slope of the per capita emission growth function. In other words β = - dlog (k_t/k_{t-1})/dlog (k_{t-1}). Here β also plays the role of speed of convergence. More specifically the speed of convergence depends on different structural factors like the base level of the concerned variable. Rassekh (1998) provides one possible derivation of computing speed of convergence by the help of the slope factor β. Since the rate or speed of convergence depends on the gap between the initial value and the steady state value of the variable so it can be determined by the reorientation of the growth equation (Equation 2) in the following form:

$$1/T\left[log\left(k_{it} / k_{i,t-1}\right)\right] = \alpha - \left[\left(1-e^{-\lambda t}\right)/T\right].log\left(k_{i,t-1}\right) + \varepsilon_{it} \ldots\ldots\ldots\ldots\ldots..(3)$$

where λ stands for the speed of convergence and T stands for total period of time under observation. According to the study λ can be simplified by the following relation

$$\lambda = -log\left(1 + \beta\right) \ldots\ldots\ldots.(4)$$

The estimated value of speed of convergence λ determines the time required for all countries to reach the steady state point in the long run. Since the value of the variable at steady state depends on so many parameters appearing in the future sometimes it is estimated the time to cross the half line of the steady state value. Battisti and Di Vaio (2006) has shown in their study that the time to cross the half of the value is 35 years with the value of speed of convergence 0.02 by using the formula $e^{-\lambda t} = 1/2$ or t = log(2)/ λ.

If we plot the data of each country's growth rate and initial value of per capita CO2 emission in a scatter diagram and fit a linear trend through these points then a downward trend will imply convergence of this region. On the contrary, if the fitted line is upward sloping then there is divergence, which means the richer zones become more and more rich and the poorer zones become more and more poor. The hypothesis of Absolute β Convergence works well when the group of economies is homogeneous in character with similar values of the parameters. This condition is more likely to be satisfied for different regions of the same country or same geography. But under heterogeneous nature of the regions there should be difference in the steady state levels. Each economy has a separate steady state of per capita CO2 emission but at the steady state, growth rate of per capita CO2 emission will be zero. We then have to modify the theory of absolute convergence to accommodate the concept of conditional convergence. This theory of convergence is developed by the endogenous growth theory. *Conditional* β *Convergence* can be presented by the following equation

$$log\left(k_{it}\right) = \alpha + (1-\beta)\, log\left(k_{i,t-1}\right) + \eta W_t + u_{it} \ldots\ldots\ldots\ldots\ldots\ldots(5)$$

where 'W' is the vector of other variables (also known as conditional variables) that affect consumption expenditure such as per capita GDP, emission intensity, trade openness, population, electricity production, industrial output growth, carbonization index, carbon intensity, etc. relevant for CO2 emission and η captures the effects of these vector of conditional variables upon per capita CO2 emission. Conditional convergence occurs when the partial correlation between the growth rate of CO2 emission and the initial level of emission per capita is negative and significant along with the significant signs and values of the coefficients of the conditional variables. The essence of the conditional convergence is that an economy grows faster the further it is from its own steady state values of the variables.

The methodology of absolute β convergence by means of Barro regressions has been criticized by Friedman (1992) and Quah (1993). They point out that these regressions are liable to produce biased estimates of β convergence. The insight of Friedman's (1992) work suggests that the simple trend in the *coefficient of variation* of *per capita* GDP provides an unbiased estimate of β convergence which is known as σ convergence. We can express the concept of σ Convergence by means of the following regression equation

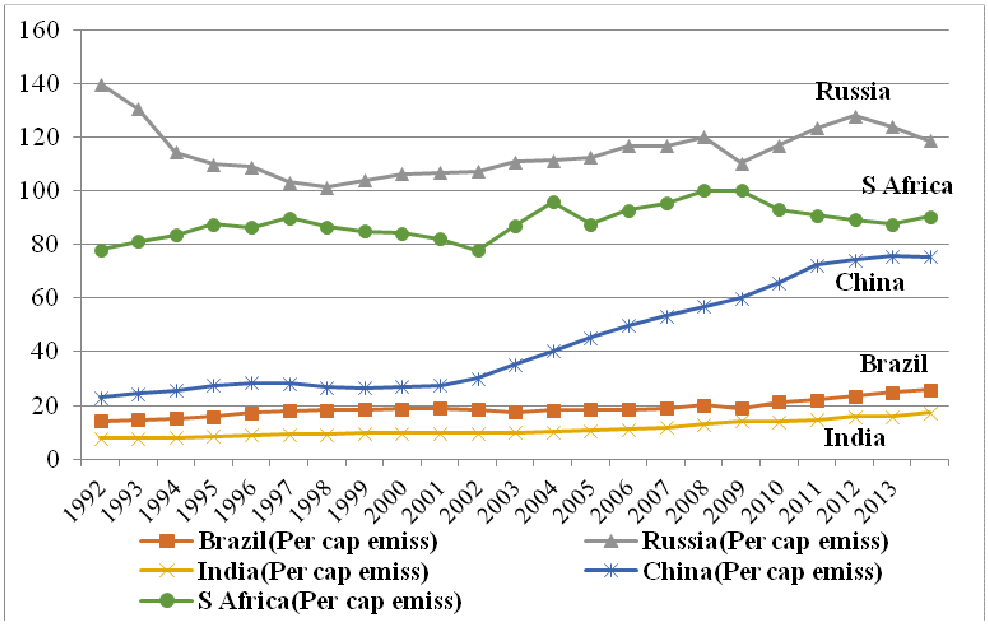
$$CV = a + bt + u_t \ldots\ldots\ldots\ldots (6)$$

where 'a' is intercept constant, 'b' is the slope constant signifying the changes of CV over time and u is the random disturbance term. If the sign of 'b' is found to be negative and significant then we can say that the trend of CV is downward and that there is convergence among the countries by the criterion of σ convergence.

4. Results and Discussion

Before going into the analytical part of the study, we present the graphical view of the trends in the per capita CO2 emissions and base values of per capita CO2 emission quantity for the BRICS nations. Figure 1, 2 and 3 present them.

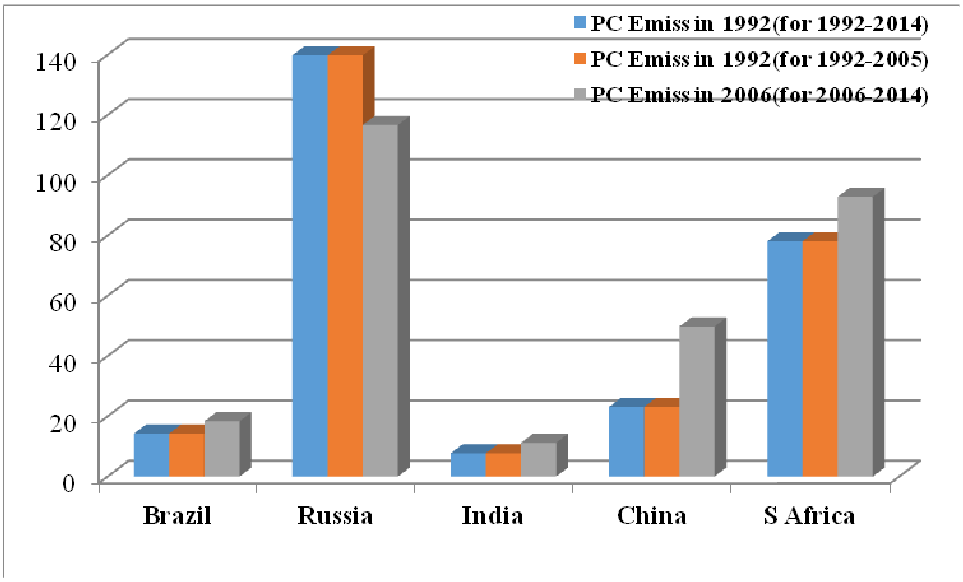
Figure 1. Trends of per capita CO2 emissions (in quintals) of countries



It is observed from Figure 1 that Russia and South Africa are the leaders in the group in terms of per capita CO2 emissions and India is at the trough throughout the entire period, and China is at the third position followed by Brazil. But the striking result is that China has maintained increasing trends in per capita emission. On the other hand, China, Russia and India maintained rising emission after the joining of BRICS whereas South Africa maintained falling trend in emission position after her joining in 2009.

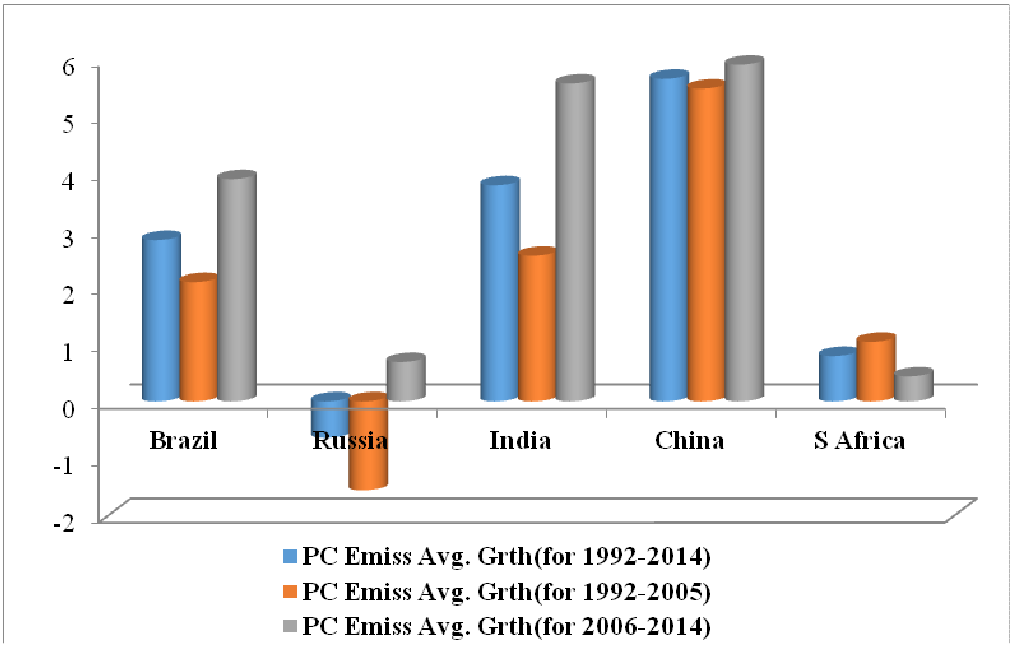
Figure 2 presents the base values of per capita CO2 emission for all the five countries in the group for the first year of three different time periods: entire period (1992-2014), pre BRICS period (1992-2005) and post BRICS period (2006-2014). Although South Africa joined the Group in 2009, we have counted its entry from the year 2006 to make parity in the analysis of convergence.

Figure 2. Base values (in 1992) of per capita emission during 1992-2014 across the countries



We observe from Figure 2 that Russia and South Africa top the list in the year 1992 and 2006 for all the three time phases in per capita CO2 emission but the remarkable result is that the values for per capita CO2 emissions for Russia has fallen in 2006 compared to that in 1992 whereas the values for all the remaining countries have increased in 2006 vis-à-vis 1992. Hence, the possibility of convergence may arise in the post BRICS phase. To supplement our idea we need to observe the status of average growth rates of per capita CO2 emissions for all the three phases (Figure 3).

Figure 3. Average growth rates of per capita emissions for different phases across the countries



It is observed from the figure that Russia and South Africa have maintained lower average growth rates in the post BRICS period compared to the other three member countries and China, India and Brazil with very high average growth rates. That means, combining Figure 2 and 3, we may get the convergence result in the post BRICS phase. But for the entire period

and pre-BRICS phases, average growth rates of Brazil, India and China are not too high like that of the post-BRICS phase and hence there may not be the possibility of convergence. To get concrete results we need to make the quantification of convergence by means of the β (absolute and conditional) and σ convergence.

4.1. Absolute β convergence test

At first we plot the annual average growth rate of per capita CO2 emission and the initial logarithmic values of per capita CO2 emission corresponding to the year 1992 for the entire period of study and draw the trend line along the five coordinating points of the scatter diagram. Figure 4 depicts this. There are five scattered coordinates for five countries and the trend line shows signs of convergence among the countries which means the country with relatively higher initial values of per capita CO2 emissions may have relatively lesser growth rates in per capita CO2 emissions and conversely the country with relatively lower initial values of per capita CO2 emissions may have relatively higher growth rates in per capita CO2 emissions. But the actual sign and magnitudes of the β coefficient cannot be derived from the diagram and we can do it by estimating regression equation (2).

Figure 4. Scatter diagram for 1992-2014

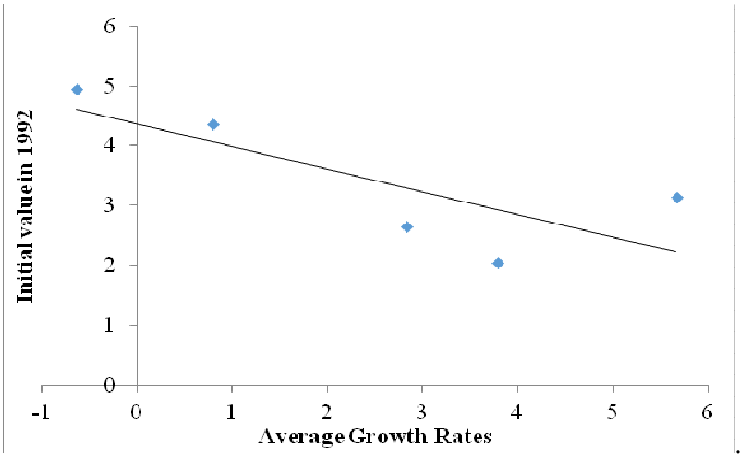


Table 1 depicts the estimated sign and value of the β coefficient using equation (2). The sign and value of the β for 1992-2014 phase is (-) 1.61 which is not significant at least at 5% level of significance. That means, the BRICS nations have not converged to a common steady state value in terms of per capita CO2 emissions so far as the definition of unconditional β convergence is concerned.

Table 1. Absolute β convergence and σ convergence results

Periods	Absolute β Convergence Results				σ Convergence Results		
	Constant	β (p)	λ(speed)	R^2	Constant	b (p)	R^2
1992-2014	**8.03**	-1.61 (0.11)	-	0.61	**1.01**	**-0.015(0.00)**	0.94
1992-2005	**6.77**	-1.41(0.22)	-	0.44	**1.012**	**-0.015(0.00)**	0.78
2006-2014	**10.49**	-1.93(0.14)	-	0.56	**0.80**	**-0.016(0.00)**	0.96

Source: Computed by the author

Let us analyze for the breakup of the total period. The scatter diagram for the pre-BRICS phase has been given in Figure 5. The trend line shows negatively sloped. The estimated sign and value of β coefficient is (-) 1.41 (refer to Table 1) which shows

insignificant absolute convergence. That means, the countries prior to entering into the group were not converging in terms of per capita CO2 emissions.

Figure 5. Scatter diagram for 1992-2005

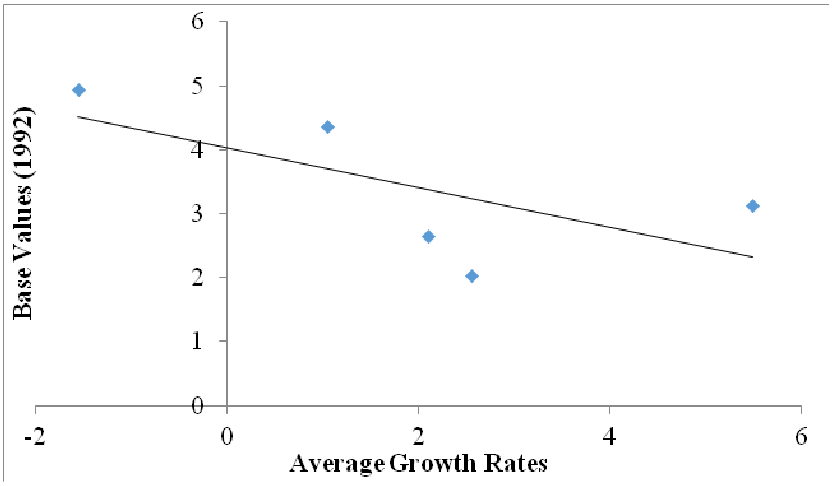
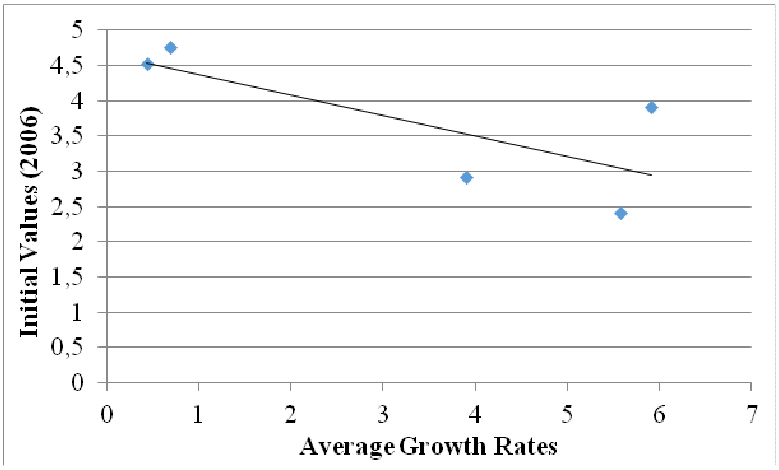


Figure 6. Scatter diagram for 2006-2014



Finally, the sign and value of β for the post BRICS phase is (-) 1.93 but still insignificant (refer to Table 1 and Figure 6). Hence, so far as the definition of unconditional β convergence is concerned, the countries are not converging significantly, although there are signs of convergence.

4.2. Conditional β convergence test

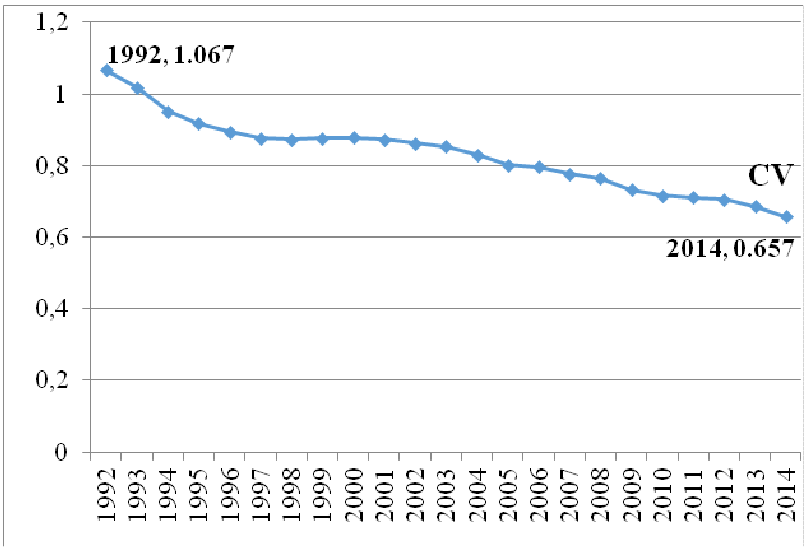
The existing literature shows that there are the variables like fuel consumption, energy intensity, per capita growth rate, FDI flow, trade openness, population, import share to GDP, etc. which affect CO2 emission (Friedl & Getzner, 2003; Cerdeira Bento, 2014; Morales-Lage, Bengochea-Morancho & Martínez-Zarzoso, 2016; Jawara, 2016). In the present study we have tried to test the roles of different pairs of variables for identifying possible conditional variable to explain the per capita CO2 emission in the BRICS nations. But, we did not find any one or any pair of variables capable of explaining the conditional β convergence in per capita emission. Hence, there is no conditional convergence in per capita CO2 emissions in the member countries.

4.3. σ convergence test

We have already stated in the methodology section that convergence or divergence as par the β convergence (both unconditional and conditional) does not necessarily mean that the cross country dispersion as measured by coefficient of variation (CV) will not decline over

time. If we get the declining trend of CV then we can say that there is the prevalence of σ convergence among the countries. Figure 7 presents the trend of CV for the entire period.

Figure 7. Trend of CV in per capita CO2 emission



It is observed from the figure that the values of CV are continuously declining except some stagnancy for the period 1998-2001. Starting from the value of 1.067 in the year 1992, it turns down to 0.657 in the year 2014. But the quantification of the gradient is not clear from the figure.

Using Equation (6), we estimate the signs and values of regression coefficient, b, for all the three different phases. The results are given in Table 1. We observe from the table that the member countries have converged over time in respect of per capita CO2 emissions. The estimated signs of the regression coefficient, b, for all the three different time phases are negative and the values are statistically highly significant. The post BRICS convergence is little bit stronger as the magnitude of the regression coefficient is relatively higher than all the values (0.016 > 0.015) corresponding to the entire period and pre-BRICS period.

Therefore, we can conclude that the BRICS nations are not converging in any phase in terms of per capita CO2 emissions so far as the definitions of β convergence is concerned but they are converging in terms of σ convergence definition.

5. Conclusion

In our endeavor to test whether the BRICS nations are converging in terms of per capita CO2 emission over time for the period 1992-2014, we are now in a position to conclude the entire study. Applying the unconditional and conditional β convergence definitions, and σ convergence definition, we saw that there were no signs of cross country convergence in terms of β convergence definition (or the catching up process) but the countries were converging in line with the σ convergence definition for three different time durations indicating pre entry to and post entry of the BRICS Group. Attempting to a lot of conditional variables like fuel consumption, energy intensity, per capita growth rate, FDI flow, trade openness, population, import share to GDP, etc. to justify whether there were conditional convergences in the countries, we did not find any such variable explaining whether there were any sort of conditional convergence. Hence, the relative dispersions among the member countries are falling with respect to carbon emission in per capita terms but no catching up process has worked. The cross country convergence in income in the group can also be attributable to this CO2 convergence.

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