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Impact of Climate Change on Income of Developing Countries

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Abstract
This study estimates the impact of climatic factors on developing countries income level by incorporating the geographic, demographic and climatic variable. The correlation between these variables indicated significant relationship among these variables with expected direction through different linkage. First Ordinary Least Square regression is estimated by adding one or more variable then the model with two Stage Least Square is used to solve the endogeneity problem caused by institution quality by taking energy production and mortality rate as an instrument variables. Results indicated population growth and temperature has negative and significant impact on per capita GDP while precipitation, carbon dioxide and institution has positive impacts while variable for latitude dummy is insignificant.
Keywords: Climatic Factors, Ordinary Least Square, Two Stage Least Square, Energy Production, Population Growth, Institution, Latitude

1. INTRODUCTION

Climate changes play an important role in wellbeing of human life. Especially temperature has a great influence in our daily life activities that result in ultimate productivity and overall income level Horanont,et al (2013). Many studies prove that hot countries are poorer than cool countries (Acemoglu et al. 2002; Easterly and Levine 2003; Kamarck 1976). We extend these studies by incorporating other factors that directed or indirectly effected by climate change and in turn determine the overall growth of country economy. Temperature is view as a factor in economic activities that influence the performance of individual entity that affect productivity at macro level.

Long run temperature and precipitation along with increase in carbon dioxide concentration are important indicators of climate change[1]. According to IPCC (2014) over the last decade there is increase in surface temperature of approx. 0.4 to 0.8°C. while predicted estimates indicated an increase in global mean surface temperature ranging from 0.15 to 0.3°C for the coming decade of years, while the atmospheric CO2-concentration will be more than twice. Global warming is serious threat to our future generation. It affects not only alternating the ecosystems and human health but also economies of different countries through a variety of channels. Developing countries, particularly low income ones faces a complex challenge of climate change over a few decades. These countries affected by climate change varies from one to another it depends not only on country's initial conditions, but also on its adaptive capacity, geographic and agro-ecological characteristics, natural and environmental resources as well as economic structure (Hamilton, 2011).

In developing countries per capita carbon emissions are on average is third of those high income countries .In the pursue of economic development there is a need in the expansion of

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energy and investment that contributed to increase in production and that generate more greenhouse gases that result in climate change. Carbon dioxide emission is one of the global issues and main cause of global warming, many scientists focuses of attaining a long run atmospheric co_2 target of 550 parts per million it is necessary to cut global emission by 60 to 80 percent (Stern 2007). . Increase in carbon dioxide in the naturally hottest countries result in worse the condition that influence country socioeconomic conditions, health, agriculture, infrastructure and governance that directly or indirectly causes a decrease in overall productivity. According to international energy agency (2008) it is possible for the developing countries to reduce carbon emission without sacrificing growth by applying best practice to curb energy consumption in industry and power sector by an amount of 20 to 30 %. It means economies have relied on climate and now the climate in turn depends on their action.

According to world development report (2010) Climate change is the biggest threat for developing countries because they are more exposed to climate shocks and lower ability to adapt. We further show that increases in global temperature worsen the economic growth in countries closer to the Equator, while its impact is negligible in countries at high latitudes changes in elevation also causes the variation in the amount of rainfall that each country receive. Consistent with this evidence, we show that there is a parallel between a country's distance to the Equator and the economy's dependence on climate sensitive sectors; in countries closer to the Equator industries with a high exposure to temperature are more prevalent. In addition to country income and temperature relationship as described in environmental Kuznets curve we also develop a relationship between income and rain fall for each country in a panel group of developing ones.

We study the impact of climatic factors on developing countries income level by incorporating their latitude following the assumption of Acemoglu, et al.2001 According to him the high latitude countries are more richer than lower latitude or tropical countries. The correlation between latitude climatic variables and economic growth is therefore arbitrated by institution where climatic factors such as temperature, rainfall and carbon dioxide emission determine technology that affect institution quality that ultimately determine country GDP and economic growth. The population growth with poor health decreases the working capacity of these institution, Climate also effect the productivity through channel other than institution energy production causes increase in carbon dioxide emission that further enhance these adverse effects. In this paper we analyze the impact of climate change by considering natural physical environment such as geography as well as man-made climatic impacts such as carbon dioxide emission which affected directly and indirectly on country income level by considering the above mention factors and correlation among these variables.

2: LITERATURE REVIEW

To establish the regression between GDP per capita and long run temperature, precipitation and carbon dioxide along with other explanatory variables that directly or indirectly affected by climate change and itself contribute to the decline in income per capita is used. Various study has been conducted to explain the historical relationship between temperature and income but little focus on its effect through institutional quality along with other climatic

factors such as precipitation and carbondioxide. one of which is Nordhaus (1994) who make a wide-ranging discussion of how temperature is consider as a factor of economic activities, particularly at the individual level, as when worker as well as student performance is affected by increase in temperature. Similar studies conducted by Acemoglu *et al* 2002,Easterly and Levine 2003 and Kamarck 1976 who find out that hot countries are poorer than cool countries by establish a relationship between income and temperature. In the same way very cold climate estimate also hamper economic activity. Masters and McMillan 2001, Mendelsohn *et al*. 1994, Quiggin and Horowitz 1999 found that there is hump-shaped relationship between temperature and income. Hence there are several channels through which temperature can effect productivity growth. Higher temperatures have a negative impact on labor productivity (Huntington (1915), Crocker and Horst (1981), Meese, Kok, Lewis, and Wyon (1982)), human capital through health (Curriero, Heiner, Samet, Zeger, Strug, and Patz (2002), Gallup and Sachs (2001)), crime and social unrest (Jacob, Lefgren, and Moretti (2007)). More recently, Dell, Jones, and Olken (2009) document that higher temperatures have a negative impact on agriculture, innovation, and political stability, and Zivin and Neidell (2010) find large reductions in U.S. labor supply in industries with high exposure to climate which can potentially lower economic growth. In order to develop a relationship between income and carbon dioxide emission a green Solow model was established that result in environmental kuznet curve that is humped shape and strickly decline (Brock 2004).Numerious finding contradict the original the original EKC finding Grossman and Krueger (1994, 1995).Brown *et al* (2009) find that change in rainfall also adversely affected GDP and increase poverty in sub Saharan Africa. On the other side Bansal and Ochoa (2011) estimates the long-run relationship between temperature betas and expected returns by incorporating risk premium in his Risks based model. This model is based on quantitatively covariance among the variables across thirty eight developed countries for twenty years of data. They conclude that the countries which are closer to the Equator have a positive temperature risk premium while those who were farther away from the equator risk premium will decreases. They further found that real equity return and average volatility is higher for the countries closer to the equator as compared to those who were furthest from it. . It shows that there exists a negative relationship between returns on equity and temperature betas. This negative relationship implies that the market price of temperature risk is negative. While the correlation between distance to the Equator and the average share of agriculture in GDP is positive. On average, a quarter of the GDP in countries closest to the Equator comes from agriculture, while in high-latitude countries agriculture represents only 3% of GDP. These results are also consistent with the study of Dell, Jones, and Olken (2009) that conclude temperature lowers growth rates and have negative impact on agriculture, innovation, and political stability, particularly in emerging economies. They also examine the year to year changes in temperature and shows that unseasonably warm year reduce both the current and subsequent growth rate of GDP in developing countries. McArthur and Sachs (2001) by commenting on Acemoglu, Johnson and Robinson (2001) show that both institution and geographic factor contributing in determining economic growth by using the same data and by expanding the number of countries they analyzed. According to him geography has a limited contribution in development because of small sample size of ex colonies and limited climate diversity and most of these are located in

tropical zones. They further conclude those countries which are located in favorable geographic positions will have suitable climatic conditions and resource abandoned for the working of institution and they were more developed as those which were located in unsavory conditions. Along with temperature rainfall fall distribution also affected by geographic position and is one of the important factors in crop production and major water source. Brown et al (2009) also find out that in Sub-Saharan African changes in rainfall pattern harmfully affected GDP and increased poverty. Similarly, Dercon (2004) also shows that consumption in Ethiopia depressed and people are malnutrient due to harshly reduced rainfall even after four to five year.

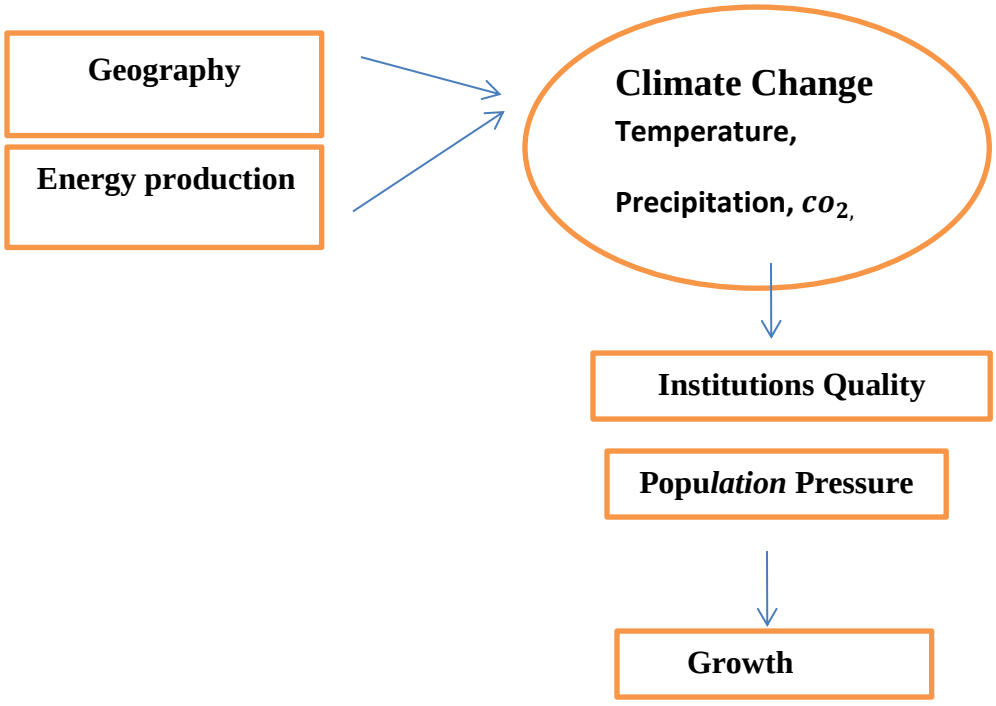
There is also important to explain the environmental damages caused by the people even living in suitable geographic position that adversely affected the people health living in these countries which are important factor that affects labour force participation rate. Ward and Shively (2012) studies the impact of change in GDP and energy consumption on vulnerability to climate change and found that reduction in carbon dioxide emission has significantly affect vulnerability especially in low income developing countries. Dasgupta, *et al* (2006) concludes that policy reforms are insufficient to reduce pollution in geographically vulnerable cities which were further overcrowded as a result of an increase in population pressure. Air quality is worsening in the city with poor governance and rapidly growing population that result in falling income of these countries. They find that by improving environmental governance quality of life can be improved. They rejected the traditional environmental Kuznets curve that poor and low income countries first grow and the make a policy for green environment he extended the model by incorporating governance and finds that improve governance and reduce the air quality along with increase income level of the countries. Dao,Minh Quang (2011) provides a correlation between climate change and economic growth by using the data of twenty two developing economics and found that change in precipitation and temperature pattern significantly influence the growth rate in these countries. In turn they also in investigate the impact of growth on climatic factors that causes the change in level of temperature and precipitation patterns. The country with high income level faces longer heat wave duration couple with increase in carbon dioxide emission. A country with higher per capita income then experiences more adverse climatic conditions need more demographic regimes to mitigate climate change effects. Recently, Dell, et al (2012) studies the impact of higher temperature on aggregate output through its impacts on reduction in agricultural and industrial level of output through the last half century. He also links the political instability that are associated with these factors. They found that in poor countries with one degree rise in temperature is associated with 1.3 percentage point reduction in economic growth on average while Bloom and Sachs (1998) highlight the important factor that hampers economic growth in African economy. They develop an interaction between geography, demography and economics. He concluded that Physical environment have significant influence on social outcomes. They develop the interaction by using of climatic variable with life expectancy rate, and tropical forestry and the adaptation of food production to tropical conditions. They find that environmental factors have a major share in economic policy and development then governance and economic policy itself. Similarly the study of Rati ram (1999) measures the impact of geographic factors on per capita income of US states and conclude that there exist a significant relationship between distance from the equator and economic growth ,elasticity

of per capita income with respect to latitude shows a steady decline over a period of 60-year.Therefore tropicality of a country is an important indicator which is need to consider in developmental measures because physical determinism have a controlling influence over the society and hence development.

3. THEORETICAL FRAMEWORK

Two stage least Square is used for estimation procedure first correlation matrix is discussed to explain the relationship between GDP and explanatory variables. In per capita GDP is used as dependent variable while institutional quality, population growth rate, carbon dioxide emission, mean annual temperature, precipitation and latitude as explanatory variables while energy production and mortality rate are serve instrumental variable which are highly correlated with explanatory variable but uncorrelated with the error term. Change in latitude or distance from the equator are associated with the change in climatic conditions like change in temperature and precipitation pattern while increase in energy production causes additional contribution in these climatic phenomena by increase in the carbon dioxide emission in the atmosphere which indirectly affected the institutional quality as a result of poor performance of the people along with increase in population pressure that ultimately result into GDP output of these country which is an important indicator of poverty.

Hypothesized Relationship of Geography, Climate change, Institutions and Growth



Source: Authors own construction

4. DATA AND MODEL

$$y_{it} = \beta Z_{it} + \gamma I_{it} + U_{it} \dots\dots\dots (1)$$

In this equation, y_{it} is the per capita GDP, Z_{it} indicates the climatic variables carbon dioxide, temperature and precipitation such as such that affect per capita GDP and I_{it}show the effect of other controlled include variables latitude, institutional quality, energy production, mortality rate and population growth, respectively; U_{it} is the stochastic disturbance term that is normally distributed.

$$y_{it} = \beta_1 CO_{2it} + \beta_2 temp_{it} + \beta_3 Prec_{it} + \gamma_1 latitude_{it} + \gamma_2 Q_{it} + \gamma_3 pop_{it} + U_{it} \dots\dots\dots (2)$$

Here y indicates GDP per capita, CO2 is the carbon dioxide, temp indicates temperature, prec is the precipitation, pop is population growth rate and Q indicates democratic institutions. We construct dummies for climatic variables such as precipitation, temperature and geographic variable latitude by taking their median as bench mark. Those values which are below median are assign 0 and values above median are assigned 1.List of country is present in Appendix.

Variables Description and Source

Dependent Variable	Definition	Source
GDP	(Per capita GDP)(1972-2012)	World Bank Data source(WDI)
Explanatory variables		
CO2 emissions	(metric tons per capita) (1972-2012)	World Bank Data source (WDI)2011
Population growth	(Annual %)(1972-2012)	-
Institutional Quality	Polity IV	The macro data Guide
Energy production	(kt of oil equivalent) (1972-2012)	- World Bank Data source
Latitude	Degree(absolute value)	La Porta et al data set(1999)
Mean annual Precipitation	(1961-1999) average in mm	Climate data API world bank2
Mean annual Temperature	(1961-1999)average in centigrade	-
Mortality rate	1972-2012	WDI

Data of GDP per capita, population growth rate, CO2, energy production and mortality rate is collected from World Development Indicator. Data of latitude is taken from the study of La Porta, et al. (1999). Data of mean annual precipitation and mean annual temperature are taken from API World Bank. Data of democratic institution is taken from the macro data guide. List of variables and countries are given in appendix.

5. RESULTS AND DISCUSSION

Before estimation variables are analyzed descriptively and it is given in appendix. Correlation matrix[3] is also constructed and it indicates positive and significant relationship among GDP per capita, CO2, institutions, latitude and precipitation. However, there exists a negative relationship between population, mortality rate and temperature. Firstly equation 2 is estimated by using panel least square method. But institutional quality accounts endogeneity problem. To fix this problem, two stage least square methods is used to regress institution on mortality rate and energy production. Put differently, mortality rate and energy production are used as instruments for institutions. Column 1 of table 1 displays the results of base line model estimation through panel OLS. Population growth rate has negative and significant impact on per capita GDP. Coefficient of population growth rate depicts that 1% increase in population growth rate reduces per capita GDP by 29%. This result is consistent with the findings of previous studies (Solow, 1956; Barro, 1990; among many). Moreover, democratic institutions, which are captured through Polity IV, positively influence the per capita GDP.

Table 1 indicates that 1 standard deviation improvement in institutions leads to 0.28 % change in per capita GDP. Previous studies find the same results (Mauro, 1995). In column 2, carbon dioxide is included as a controlled variable and it positively contributed to GDP per capita (Brock 2004). If more investment is made in industries to foster economic growth and development, then it results in more carbon dioxide emission (Acemoglu et al., 2001). In column 3, precipitation is included to examine the impact of rainfall on economic growth. More but moderate rainfall increases agriculture productivity that has positive impact on growth (Brown et al., 2009; and Dercon, 2004). In columns 4 and 5, temperature and latitude are included in addition to other variables to check their effect on per capita GDP. Table 1 shows that temperature and latitude have insignificant impact on economic growth. However other variables turn out with same sign and have vice versa impact on per capita GDP. Institutions have endogeneity problem and to fix this problem by using two stages least square method. In 2 SLS, mortality rate and energy production are used as instruments for institutions to resolve this problem. Results of 2SLS are reported in following table 3. Again column 1 indicates that population growth rate has negative impact on GDP per capita. As population increases, then per capita GDP deteriorate. Institution has also positive impact on GDP per capita. As institution's quality is improved, then resources are properly managed and used. Therefore, it enhances the productivity of physical capital and labor. Similarly more industrial development leads to creation of more carbon dioxide emission that could have either positive or negative impact on per capita GDP. More than this, precipitation has negative impact on GDP per capita whereas latitude has also negative but significant impact on GDP per capita. However coefficient of temperature has insignificant impact on GDP per capita.

6. CONCLUSION

The results indicates the impact of demographic, climatic and geographic variables on per capita GDP through one channel or another correlation among these variables are significant at .01 and .05% level of significance. The results support the Acemoglu statement that in the

process of industrial transition in developing countries increase in investment causes increase in energy production and carbon dioxide emission that result in increase in per capita GDP currently but it may have harmful effect in future with increase in population rate that negatively contributes to per capita GDP. On other side improvement in institutional quality increases per capita GDP which itself badly affected by population pressure and harsh climatic conditions.

Results indicated that institutions quality along with climatic factors causes 0.28 % change in per capita GDP. While carbon dioxide has positive relationship at current GDP If more investment is made in industries to foster economic growth and development, then it results in more carbon dioxide emission (Acemoglu et al., 2001). Precipitation is positively contributed to GDP while coefficient of temperature and latitude are insignificant. In 2SLS results indicated temperature and latitude negatively contributed to per capita GDP. Institution and carbon dioxide are positively related and precipitation is negatively contributed.

Adverse impacts of climate change due to increase in the amount of greenhouse gases are already being felt around the world and damages by this time accruing in various forms, and this presents inevitable risks to developing and developed countries. Response to climate change is often delayed, especially in developing countries, due to lack of financial resources, technologies, and expertise. Such delay would constitute a major obstacle in the way of the sustainable development in developing countries. It is therefore important to utilize financial resources, technologies and expertise of developed countries for taking adaptation measures in developing countries vulnerable to the impacts of climate change, and for promoting mitigation in emerging countries that are experiencing rapid growth.

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Appendix:

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
country	1517	1	37	19.00	10.681
Years	1517	1972	2012	1992.00	11.836
gdp	1517	78.884000	15245.468000	1749.46452144	2112.592277717
co2	1517	.0206	11.7201	1.576859	1.7030344
pop	1517	-1.6096	11.1807	2.271340	.8621095
energy	1517	.6930	518670.5420	42452.877302	81764.9976276
POLITY	1517	-10	10	.36	6.912
Mortality	1517	3.3750	23.9440	9.244593	4.1108436
Tem	1517	8.3698	28.1764	22.291166	4.6555510
Pres	1517	32.9133	3268.2662	1239.156775	832.5258100
Valid N (listwise)	1517				

Correlation Matrix:

	GDP	CO2	Pop	Energy	Institutions	Mortality	latitute	Tem	Pres
GDP	1	0.565**	-0.283**	.144**	0.305**	-0.384**	.096**	-0.238**	0.092**
		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CO2	0.565**	1	-0.180**	0.388**	0.066*	-0.366**	0.212**	-0.252**	-0.079**
	.000		.000	.000	.010	.000	.000	.000	.002
Pop	-0.283**	-0.180**	1	-0.187**	-0.388**	0.329**	-0.022	0.038	-0.197**
	.000	.000		.000	.000	.000	.400	.135	.000
Energy	0.144**	0.388**	-0.187**	1	0.115**	-0.203**	0.083**	-0.005	-0.073**
	.000	.000	.000		.000	.000	.001	.851	.004
Institutions	0.305**	0.066*	-0.388**	0.115**	1	-0.392**	-0.081**	0.026	0.382**
	.000	.010	.000	.000		.000	.002	.312	.000
Mortality	-0.384**	-0.366**	0.329**	-0.203**	-0.392**	1	-0.176**	0.209**	-0.173**
	.000	.000	.000	.000	.000		.000	.000	.000
latitute	0.096**	0.212**	-0.022	0.083**	-0.081**	-0.176**	1	-0.752**	-0.576**
	.000	.000	.400	.001	.002	.000		.000	.000
Tem	-0.238**	-0.252**	0.038	-0.005	0.026	0.209**	-0.752**	1	0.388**
	.000	.000	.135	.851	.312	.000	.000		.000
Pres	0.092**	-0.079**	-0.197**	-0.073**	0.382**	-0.173**	-0.576**	0.388**	1
	.000	.002	.000	.004	.000	.000	.000	.000	

Table 1: GDP per capita, Institution and Climate Change (OLS)

Variables	1	2	3	4	5
Population	-0.292*	-0.239*	-0.243*	-0.244*	-0.244*
	(0.020)	(0.020)	(0.020)	(0.021)	(0.021)
Institution	0.040*	0.040*	0.040*	0.040*	0.040*
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
CO2		0.179*	0.176*	0.176*	0.175*
		(0.016)	(0.016)	(0.016)	(0.016)
Precipitation			0.103**	0.106***	0.118**
			(0.047)	(0.056)	(0.058)
Latitude				0.006	-0.015
				(0.050)	(0.058)
Temperature					-0.039
					(0.055)
Constant	7.556*	7.152*	7.117*	7.113	7.144*
	(0.048)	(0.058)	(0.061)	(0.072)	(0.085)
R^2	0.297	0.357	0.476	0.476	0.480

*, ** and *** indicates 1%, 5% and 10% level of significance. Source: Author's own estimation

Table2: 2SLS Results

Variables	1	2	3	4	5
Population	-0.282*	-0.221*	-0.243*	0.074*	0.069***
	(0.020)	(0.020)	(0.020)	(0.041)	(0.041)
Institution	0.038*	0.044*	0.040*	0.158*	0.158*
	(0.003)	(0.003)	(0.003)	(0.011)	(0.011)
CO2		0.167*	0.176*	0.146*	0.142*
		(0.015)	(0.016)	(0.025)	(0.025)
Precipitation			0.103**	-0.381*	-0.341*
			(0.047)	(0.095)	(0.097)
Latitude				-0.511*	-0.577*
				(0.089)	(0.101)
Temperature					-0.132
					(0.085)
Constant	7.557*	7.151*	7.106*	6.914*	7.021*
	(0.047)	(0.057)	(0.059)	(0.113)	(0.131)
R^2	*	*	*	*	*

*, ** and *** indicates 1%, 5% and 10% level of significance. Source: Author's own estimation

Country List

Country Name	
Bangladesh	Jordan
Benin	Malavi
india	Mexico
nepal	Morocco
Pakistan	Nicaragua
Srilanka	Panama
Iran	peru
Algeria	Philippines
Burkina Faso	Senegal
Cameroon	Syrian Arab Republic
Chile	Sudan
Costa Rica	Uruguay
kenya	Thailand
Egypt, Arab Rep.	Togo
El Salvador	Turkey
Gabon	Venezuela, RB
Honduras	Zambia
Indonesia	Zimbabwe
Jamaica	

[1]"Climate change can refer to long-term change in average weather conditions" (WMO). "All changes in the climate system, including the driver of change, the changes themselves and their effects" (GCOS). Or "Human only induces changes in the climate system" (UNFCCC).

[2] This workbook contains historical temperature and precipitation data derived from the Climate Research Unit (Mitchell et al, 2003), aggregated to the country and basin levels. The time period for all data in this workbook is 1961-1999
http://data.worldbank.org/developers/climate-data-api.

[3] Table is given in appendix