CLIMATE CHANGE AND ECONOMIC GROWTH: An Empirical Analysis of Pakistan

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Though the Pakistan's contribution to greenhouse gases (GHG) emissions is miniscule as compared to other countries i.e., only 0.8 per cent of the total GHG emissions, yet it is one of the major victims of climate change effects. The present study is an attempt to explore the impacts of climate change on economic growth of Pakistan by conducting national as well as provincial level analysis for the period 1973-2010. The study uses temperature as proxy for climate change. It has been found that temperature has a negative and significant relationship with GDP and productivity in agriculture, manufacturing and services sectors. However, severity of these negative impacts is higher in agriculture in comparison with manufacturing and services. The provincial results suggest that there is a negative and significant relationship of climate change with growth in the provinces of Balochistan and Khyber Pakhtunkhwa (KPK) while insignificant relationship with growth in Punjab and Sindh provinces. The results reveal that a comprehensive policy regarding adoption of mitigation strategies to combat climate change is very crucial for Pakistan.

I. Introduction

There exists a strong correlation between the emissions and economic growth. It has been estimated that since 1850 developed countries, like North America and Europe, have produced approximately 70 per cent of CO2 emissions of the world, whereas, the developing countries have produced less than one-quarter of it. It implies that economic growth depends on fossil fuel that results in environmental degradation. However, economic growth may bring an initial phase of deterioration but at the latter phase (due to adoption of better abatement technologies) it might bring some improvement in the environmental quality [Grossman and Kruger (1995)]. Accelerating emissions of GHGs in developing countries, especially in emerging economies, it has raised serious concerns on relationship between the climate change and economic growth.

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Rising GHG emission is resulting in raising the temperature and has serious impact on climate. Although the climate change may initially have some positive effects for some developed countries (e.g., Canada) but in the long run it will be destructive [Parry et al. (2007)].

The climate change is not evenly distributed - people of poor countries are likely to suffer earliest and the most, due to their extended vulnerability [Stern (2006), Nordhaus (1991)]. These countries are dependent on climate-sensitive sectors and they have low adaptive capacity to develop and implement adaptation strategies. Similarly, due to limited adaptive capacities in these countries, poor communities are especially more vulnerable [Sathaye et al. (2006), Parry et al. (2007)].

Being a developing country Pakistan needs to boost this industry, to accelerate economic growth and curtail poverty to accelerate economic growth and curtail poverty. Resultantly, emissions of GHG's are accelerated and it results in changing the climate considerably. However, climate change and associated risks were not on the policy agenda in Pakistan until the country faced numerous devastating natural disasters. In this regard earthquake-2005 was a turning point as it forced the government to take major steps in the form of disaster preparedness and mitigation. Recognizing this National Disaster Ordinance was promulgated in 2006 and the National Disaster Management Authority (NDMA) was set up. It is noteworthy that efficiency and technical capacity of NDMA was not remarkable during the Floods 2010-11 bringing horrendous devastation, the aftermaths of which are still being experienced. It can be summarized that Pakistan's vulnerability to repeated natural disasters e.g., droughts (2000), earthquake (2005) and floods (2010 and 2011) alerted the government towards the risks posed by natural disasters. In this regard 'National Environment and Climate Change Policy' was formulated in 2005 and in 2008. Planning Commission formed a special task force on Climate Change to deal with various climate change issues in Pakistan: like increased variability of monsoon, rapid melting of Himalayan glaciers and increased siltation of dams, etc. The present study will analyze the effects of climate change on the overall economic growth of Pakistan as there is very limited research available that had analyzed how climate change is affecting our economy.

The organization of the paper is as follows: after Introduction (Section I), Section II presents the Literature Review, whereas Section III describes the scenario of Pakistan Climate Change in Asia. In Section IV discussing on the theoretical background, a Theoretical Model for climate change, and economic growth is developed. Empirical Model along with Description of Data is described in Section V. Section VI is devoted to discussion of the Estimation Results while the last Section VII concludes the paper, presents some policy implications, and suggestions for further research.

II. The Literature Review

Besides economic analysis, climate change is a comparatively new issue, yet numerous studies have estimated the impacts of it on economic growth in different regions of the world. Most of these studies are numerical in nature and bit speculative but anyhow they provide a solid foundation for future research. Regarding analysis of the effects of climate change on economic growth there are three crucial classifications of these studies.

First and the far most important studies are those that are focused on how the overall economic growth and the structure of economy is affected by the climate change. Due to climate change, some sectors of the economy grow faster in comparison to the others; leading to change in the size and composition of GDP. These changes also affect the long-term growth potential of the country [Scheraga (1993)]. Nordhaus (1991) finds that warming of 30C would reduce 0.25 per cent of GDP of the USA. However, if un-measureable impacts of warming are also included then damage may increase to 1-2 per cent of the GDP. On the other hand, Stern et al. (2006), has projected that in the next fifty years world temperature would raise to 2-30C. These climate changes have several socioeconomic impacts; including impacts on water, agricultural productivity (food), health, etc. It will result in a loss of at least 5 per cent of the global GDP per year. However, Weitzman (2007) have criticized these findings by saying that while measuring the impact of climate change some uncertainties are associated. Conclusions are drawn by assuming a very low discount rate.

Fankhauser and Tol (2005) argued that climate change has only a limited effect on development. It affects the capital accumulation and people's propensity to save and economic growth. Using different growth model specification, the study finds that dynamic effects are relatively larger as compared to direct or static impacts of climate change. Calzadilla et al. (2006) have also supported these findings by concluding that extreme weather will result in raising the global savings; because when it is expected that in future, if global damage will increase then people will save more to avoid anticipatory negative effects of climate change and hence investment may also increase. Similarly, climatic shocks affect the total factor productivity and technical change. Decrease in total factor productivity strongly affects the long run equilibrium growth even in one-sector neoclassical growth model. According to Lecocq and Shalizi (2007) although there is no direct effect of climate change on the GDP; the GDP will be affected indirectly by variations in the demand structure.

The second important class consist of those studies that has analysed; how Climate Change affects the major determinants of GDP and how these effects are transmitted to GDP growth. Among these studies IPCC reports are very crucial; Parry et al. (2007) have analysed the impact of climate change on different sectors. The study projects a decline in water supplies stored in glaciers and snow cover which results in water scarcity. If global average temperature exceeds 1.5-2.5°C then approximately 20-30 per cent of plant and animal species will face the danger of extinction. As far as food production is concerned, if temperature increases in the range of 1-3°C then potential for food production will increase but increase in temperature beyond that would decrease the food production. Rise in sea surface temperature of about 1-3°C would cause more frequent coral bleaching events and widespread mortality, unless there is thermal adaptation or acclimatisation by corals. Sea-level rise will negatively affect the coastal wetlands including salt marshes and mangroves. Costs and benefits of climate change for industry, settlement and society depends on location and scale. Projections made by Agrawala et al. (2003) reveals that climate change affects the economy through sea level rise, higher temperatures, enhanced monsoon precipitation and run-off, potentially reduced dry season precipitation, and increase in cyclone intensity. This situation has created serious hurdles for sustainable economic development in Bangladesh.

Since temperature and precipitation are direct inputs in agricultural production, many writers believe that the largest effects will be on agriculture. However, the production rises in the higher latitudes, partly because of an increase in arable land, and tends to fall in the tropics, primarily because of an assumed decline in the availability of water [Cooper (2000)]. Similarly, in the context of food security, Gregory (2005) suggests that climate change plays an important role but its relative importance varies, both between regions and between different societal groups within a region. For example, in southern Africa, climate is among the most frequently cited drivers of food insecurity because it acts both as an underlying, on-going issue and as a short-lived shock. In other regions, though, such as parts of the Indo-Gangetic Plain of India, other drivers, such as labour issues and its availability, and quality of ground water for irrigation, rank higher than the direct effects of climate change as factors influencing the food security. The climate change can affect food systems in several ways: including the direct effects on crop production (e.g., change in rainfall leading to drought or floods, or warmer or cool temperature leading to change in the length of growing season) impacts on markets, food prices and supply chain infrastructure.

The studies conducted on USA suggest that it is unlikely that a country face adverse impacts of climate change on Agriculture. Deschenes and Greenstone (2007) finds that in USA climate change will increase profits in agriculture for approximately 4 per cent. Furthermore, it also reveals that projected increase in temperature and precipitation have no impact on the yield of Maize and Soya bean. Similarly, Mendelsohn and Williams (1994) has explored the economic benefits for Agriculture of USA by the global warming. Moreover, Kaiser et al. (1993) and Easterling et al. (1993) predict that in order to mitigate potential reductions in yield due to climate change, farmers of USA take optimal decisions for crops, varieties and farming practices.

However, studies conducted on developing countries suggest that higher temperature will be harmful for most of them, because in these countries water is inadequate and temperature is high [Rosenzweig and Parry (1994), and Reilly (1995)]. Due to these factors an increase in temperature will make many agricultural areas less productive-and some completely unsuitable. Mendelsohn and Dinar (1999) concluded that as the cool wheat-growing areas get warmer, higher temperature will reduce the grain yields. However, it is found that in the case of India and Brazil, although the agricultural sector is very sensitive to climate but the individual farmers do consider local climate, and they try to minimize the effects of global warming. Latter Mendelsohn et al. (2001) and Mendelsohn and Williams (2004) found that most of the market sector impacts of climate change have a hill-shaped relationship with temperature. Cool countries/area would likely get benefit from warming and temperate locations will have modest effects, while the hot areas will be damaged.

Despite the importance of livestock to poor people and expected impacts of climate change on the livestock systems, the analysis of relationship between climate change and livestock in developing countries is a relatively neglected research area. The feeds, its quantity and quality; heat stress, water, livestock diseases and disease vectors, biodiversity are the major channels through which climate change affects the livestock [Thornton et al. (2009)].

The unusual climate also significantly affected the various endangered species of fish, especially those which live in lower temperature environments. For instance, the population of various types of fish, especially salmon and trout have become particularly vulnerable to higher temperature in Canada [Minns and Moore (1992)], [Regier and Meisner (1990)]. Similarly, Tseng (2008) finds that due to increase in temperature the population of Tiwan's trout fish have also significantly decreased. It has been further estimated that per person per year mean willingness to pay to avoid a change in the trout stock, caused by climate change is found to be USD 16.22, USD 25.72, and USD 33.60, respectively.

Gilbreath (2004) discuss a report of WHO and states that climate change may increase the risk of death and suggest that most diseases which are common in developing countries are sensitive to climate change and even a proportionally small change in the global incidence of some diseases may result in significant public health impacts. It has been estimated that due to climate change in some regions risk of diarrhoea has increased to 10 per cent. Similarly, large increase is also estimated for malaria. Gallup (1999) has pointed out that any change in climate results in changes in the pattern of disease burden and agricultural growth. It has been found that there exists correlation between spread of malaria due to climate change in India [Bhattacharya et al. (2006)]. Similarly, the degree of global warming can increase malaria around 10 per cent [McMillan and Masters (2001)].

The third and very important issue that is discussed in some of the studies is that whether controlling the greenhouse gases have some positive impacts on the long run economic growth. It is a general perception that environmental regulations will impose constraints on production possibilities, leading harmful impacts on the economic growth. However, it has been argued that effects of environmental policy on economic growth vary through stages of development [Bretschger et al. (2001), Smulders et al. (2005)]. The environmental regulation will enhance prospects for growth if improved environmental quality increase productivity of inputs or efficiency of the education system. Because the environmental regulation promotes pollution abatement activity, leading to increasing returns to scale; these regulations can also stimulate innovations [Ricci (2007)]. Greiner (2003) finds that higher abatement activities may reduce greenhouse gas emissions and lead to higher economic growth. The study is further extended and Greiner (2005) finds that an increase in greenhouse gas emissions, negatively affects aggregate output and the marginal productivity of capital.

III. Scenario of Pakistan

Global Climate Change Impact Study Centre (GCISC) has analyzed the trends in temperature and precipitation for the period 1951-2000 in Pakistan by its agro-climatic zones. It has been found that Baluchistan plateau, Central and South Punjab have experienced a warming trend, whereas the other regions have a cooling trend. Furthermore it has been projected that average annual temperature in Pakistan will increase by 4.3-4.90C by 2085 and increase in temperature will be lower in the Southern parts in comparison to the Northern parts of the country.

The United Nations Environment Programme (2000), by developing an integrated scenario explained the future impact of climate change on various sectors of the Pakistan economy like energy, agriculture, water resources, forestry, etc. It has been found that an increased temperature and decreased precipitation rate will negatively affect the agricultural production. In these circumstances crop yields depends on groundwater and farmers have to bear extra cost, therefore, it hinders the production. The study has also predicted that there is likelihood of occurrence of extreme weather events in the form of floods. It was also indicated that infrastructure in Pakistan is not adequate to meet challenges like lack of education and health care facilities which have been recognized as the major cause of increased mortality (heat-related), water and vector-borne diseases, respiratory diseases, etc.

Another study by GCISC found that all fourteen crops (under the analysis) were affected by heat stress. It was also found that 6 per cent reduction in rainfall results in an increase of 29 per cent irrigation water requirements. Similarly except for northern mountainous region in all other regions wheat yield has shown a decline due to climate change. Ahmad et al. (2004) found that one per cent increase in temperature will reduce the wheat yield by 1.74 per cent. Hussain et al. (2005) also found a depressing impact of climate change on agricultural productivity, especially that of wheat.

Oxfam (2009) investigated the impact of climate change on rural communities in Pakistan by selecting three disaster prone areas of Pakistan, namely Badin, Rajanpur and Khuzdar. In the coastal region of Badin, it was found that sea water has caused floods and soil had become saline which caused difficulties to farmers in crop harvesting. The number and intensity of heavy rainfalls had increased vector and water-borne diseases like diarrhoea and malaria. In the flood-prone villages of Rajanpur, it was found that due to climatic change both cultivation and harvesting periods moved backwards, therefore, farmers had to face shorter growing season. Similarly, diarrhoea and gastrointestinal diseases have also increased. According to the survey in drought-prone district of Khuzdar, duration of the growing season had also decreased and due to scarcity of water livestock had badly been affected.

The above review shows that most studies conducted in context of the climate change in Pakistan were carried out in the context of investigating its impact on agriculture, water and natural resource base of the country.

IV. Theoretical Background

To analyse the impact of climate change on economic growth two types of approaches are most widely used: one, in the `enumerative approach' the economic impact of climate change is analysed separately, sector by sector i.e., the impact of climate change on Agriculture, Ecosystem, and Tourism, etc. Latter, these effects are added to get an estimate of total change in the social welfare from the climate change [Nordhaus et al. (1991), Cline (1994), Tol (1995)]. In this approach the effect of climate change is analysed by focusing on only one time period. In an `enumerative approach', inter-temporal effects were ignored and these studies failed to provide information on how climate change may affect welfare in the long run. This approach also ignores the significant 'horizontal inter-linkages', that is, the interaction of sectoral impacts. In this approach, mostly the CGE models and simulation techniques are used. Two, the 'Integrated assessment models' with an economic foundation are referred as dynamic approach. In this approach, different specifications of growth models are used by incorporating the climate change damage function. Solow–Swan and Ramsey–Cass–Koopmans growth models are most widely used for analysing the impact of climate change on economic growth. However, Mankiw–Romer–Weil and Romer model is also used [Fankhauser (2005)]. In these models it is assumed that, if there is a constant saving rate then, if climate change has a negative impact on output the amount of investment will be reduced (and vice versa, if impacts are positive). In the long run, this will lead to a decline in the capital stock; a reduced consumption per capita will shrink the aggregate demand and result in curtailing the GDP. In an endogenous growth model, situation becomes even worse if lower investment (caused by capital accumulation effect) slows down the technical progress and improves labour productivity or human capital accumulation [Lecocq and Shalizi (2007)]. Similarly, as climate change reduces the productivity of capital, then in future, if it is expected that climatic situation will worsen, then the economic agents would prefer to consume more and invest less. This behaviour of economic agents would also affect the accumulation of capital and GDP.

The present study will use both these approaches to some extent and analyse the impacts of climate change on economic growth and its components, i.e., agriculture, manufacturing and services. The study will incorporate indicators of the climate change into growth model.

a) The Theoretical Model

Dell et al. (2008) has incorporated the climate change in the production function which is used as baseline in the present study. This model provides theoretical basis for incorporating the climate change into economic growth equations. Consider the production function as:

$$Y_t = e^{\alpha T_t} A_t L_t K_t \tag{1}$$

$$\frac{\Delta A_t}{A_t} = \beta T_t \tag{2}$$

where Y is GDP, L is Labour force, A is technology which can also be referred as labour productivity. T is the impact of climate and K is physical capital. Equation (1) captures the direct effect of climate change on economic growth, e.g., impacts on labour productivity. While Equation (2) captures the indirect effect of climate, i.e., the impact of climate on other variables that indirectly influence the GDP growth. It is noteworthy that Equation (1) directly relates to climate change to GDP, whereas, in Equation (2) climate change affects labour productivity that will affect the GDP growth.

After taking logs of Equation (1) and differencing with respect to time, following equation can be derived:

$$g_t = (\alpha + \beta) T_t - \alpha T_{t-1} \tag{3}$$

where g_t is the growth rate of per-capita output. Direct effects of climate change on economic growth appear through α and indirect effects appear through β.

This equation separately identifies the direct and indirect effects of climate change. Both these affects GDP growth rate in the initial period. However, when climate returns to its prior state direct effect reverses itself. For example, rise in temperature may harm agricultural production, but whenever temperature returns to its normal level the agricultural production once again accelerates. On the other hand indirect effect emerges during the climate shock and their affect persists even in the normal conditions, e.g., a failure in human capital development results in a permanent deterioration in human capital and economic growth.

V. Empirical Model and Description of Data

As there are huge spatial variations in temperature across Pakistan therefore it is very crucial that subnational analysis may also be conducted. The empirical analysis is divided into two parts:

1. National Analysis

Following the Supper Reduced form equation, in light of the theoretical model, the economic growth will be estimated. The equation is an empirical specification of Equation (3) of the preceding section.

$$Y_t = \alpha_0 + \alpha_1 k_t + \alpha_2 pop_t + \alpha_3 op_t + \alpha_4 tmp_t + \varepsilon_t \tag{A}$$

where y represent GDP, k, pop, op and tmp denotes investment, population growth, openness and temperature, respectively.

In order to see which sector of economy is affected more by climate change the model will also be regressed on main sectors of the GDP, i.e., Agriculture (ag), Manufacturing (mn) and Services (sr). The model that will be estimated in this regard is as under:

$$\left.\begin{aligned} Ag_t &= \alpha_0 + \alpha_1 k_t + \alpha_2 pop_t + \alpha_3 tmp_t + \xi_t \\ Mn_t &= \alpha_0 + \alpha_1 k_t + \alpha_2 pop_t + \alpha_3 tmp_t + \psi_t \\ Sr_t &= \alpha_0 + \alpha_1 k_t + \alpha_2 pop_t + \alpha_3 tmp_t + \delta_t \end{aligned}\right\} \quad \text{(B)}$$

Time series econometric techniques will be used to estimate Model A. However, Model B is a Seemingly Unrelated Model; therefore, it will be estimated by using the Seemingly Unrelated Regression (SUR) technique.[1]

2. *Provincial Analysis*

The availability of data is a major constraint in the provincial analysis in Pakistan. The data regarding GDP is not available for the provinces and; therefore, the study used the data of expenditure as proxy for the provincial GDP.

$$exp_{it} = \alpha_0 + \alpha_1 pop_{it} + \alpha_2 tmp_{it} + \varepsilon_{it} \quad \text{(C)}$$

It is noteworthy that sectoral data is also not available and therefore impacts of climate change on various sectors of the economy cannot be analysed. However, at the provincial level the individual province have been examined separately.

In the present study the data over 1973-2010 for the Pakistan and the four provinces, i.e., Balochistan, Khyber Pakhtunkhwa (KPK), Punjab and Sindh have been used. A brief description and details of the data sources is presented in Table 1.

VI. Estimation Results

1. *National Analysis*

In order to guard against spurious regression for the time series and to ensure that unit root tests are used the first step is to see whether the series are stationary or non-stationary.[2] The results of the unit root test reveals that the model consist of I(I) variables,[3] in these circumstances Co-integration technique have been used. To test the co-integration among the variables, there are two main techniques; the Engle and Granger (1987), and the Johansen (1988) approach. As the number of variables in the study is more than two; the co-integration procedure developed by Johansen (1988) is applied.

[1] For details of estimation methodologies, see, Wooldridge [(2002), (2005)].
[2] Newbold (1974).
[3] For results of the unit root tests, see Appendix.

TABLE 1

Data Description

Sr. No.	Name of Variable	Data Source	Comments
1.	GDP (Y)	SBP	Real GDP at constant factor cost1999-2000.
2.	Investment (K)	SBP	Gross capital formation as percentage of GDP.
3.	Labour (pop)	SBP+	Population growth rate.
4.	Openness (op)	SBP	(Exports+Imports) as percentageof GDP.
5.	Agriculture (Ag)	SBP	Share of Agriculture.
6.	Manufacturing (Mn)	SBP	Share of Manufacturing.
7.	Services (Ser)	SBP	Share of Services.
8.	Expenditure (exp)	SBP	Provincial Government Expenditure.
9.	Temperature (Tmp)	Pakistan-Meteorological Department.	Data on daily and monthly temperature from 1961 onwards is available for selected stations. Annual average for all stations in Pakistan and all its provinces have been calculated from the monthly data.

There are four different steps involved: while testing co-integration in the first step the order of stationarity is determined where variable must be stationary at the same level. It has already been found that all variables are stationary at the first difference, i.e., series of the model are I(1). Therefore, the cointegration can be determined between the variables. Choosing the optimal lag length the second step is involved. To determine the lag length, VAR model has been used and on the basis of AIC criteria, the lag length of one for the model is determined. Step three deals to determine the number of co-integrating vectors. In this study, both trace statistic and Eigen value statistic are used.

The results of both the statistics are summarized in Tables 2 and 3. Both the Trace and Maximum Eigen value tests suggest that there exist a co-integrating vector among variables at the national level. In the fourth step the normalized equation of the co-integration equation is analyzed; the results of which are presented in Table 4.

TABLE 2

Unrestricted Co-integration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistics	0.05 Critical Value	Prob.**
None*	0.699483	94.116520	69.818890	0.0002
At most 1*	0.523026	53.239950	47.856130	0.0143
At most 2	0.358979	28.069950	29.797070	0.0781
At most 3	0.262605	12.950400	15.494710	0.1166
At most 4	0.073427	2.592923	3.841466	0.1073

Trace test indicates 1 co-integrating equation(s) at the 0.05 level.
* denotes rejection of the hypothesis at the 0.05 level.
**MacKinnon-Haug-Michelis (1999) p-values.

TABLE 3

Unrestricted Co-integration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistics	0.05 Critical Value	Prob.**
None*	0.699483	40.876570	33.876870	0.0062
At most 1	0.523026	25.170000	27.584340	0.0988
At most 2	0.358979	15.119550	21.131620	0.2806
At most 3	0.262605	10.357480	14.264600	0.1895
At most 4	0.073427	2.592923	3.841466	0.1073

Max-eigenvalue test indicates 1 co-integrating equation(s) at the 0.05 level.
* denotes rejection of the hypothesis at the 0.05 level.
**MacKinnon-Haug-Michelis (1999) p-values.

TABLE 4

Normalized Co-integrating Coefficients

	Coefficient	Std. Error	t-Statistics
KT	1.469507	0.38464	3.820474
OP	2.617887	0.48039	5.449504
POP	-9.727380	-0.51152	19.016620
TMP	-17.547100	-3.09975	5.660815
Log likelihood	338.556300		

The normalized co-integration coefficients indicate that in the long run investment has a positive and significant impact on economic growth. This finding is in accordance with the theory that investment enhances economic growth; which is supported by various studies including [Mankiw et al. (1990), Barro and Martin (2003), Akram (2010)]. Our results also support an important empirical regularity: namely, that population growth results in curtailing the economic growth of a country although the effect is found to be insignificant. Coale and Hoover (1958) also come to the same result. Openness is significant with positive sign in all specifications which is consistent with expectations and which also supports the findings of Akram (2010), Coe (1995), and Lucas (1988). The temperature being the indicator of climate change affect economic growth of the selected countries negatively. It may also be noted that coefficient of the temperature is highest revealing that it is the major factor which is affecting the GDP growth.

Results of estimating the Empirical Specification B (Supper reduced model of various sectors of the economic growth) by using the Seemingly Unrelated Regression (SUR) which are summarized in Table 5.

The estimated results are similar to the pervious estimation results. It shows that investment has a positive relationship with all sectors of GDP; while rest of the variables i.e., population growth and temperature (climate change) have a negative and significant impact on all the sectors. However, these results reveal that impact of various variables is not evenly distributed. It suggest that investment stimulate the manufacturing most and agriculture the least. Similarly, population growth rate have highest negative impact on the services sector where the negative impact of population growth rate is very limited to the agriculture sector. It shed light on issue that agriculture has comparatively higher labour absorption capacity. As far as rise in the temperature is concerned the agriculture sector is most badly affected by it, due to which the manufacturing is the least. The severe impact of climate change on agriculture is highlighted in various earlier studies on the subject, including Reilly (1995) and Mendelsohn (1999).

2. *Provincial Estimation Results*

Although it seems appropriate to use the per capita expenditure, but due to limitation of data and to bring symmetry in the analysis the data of expenditure and the provincial population growth rate, as independent variable have been used in various provinces. Results of the unit root test reveal that in all provinces selected variables are I(I),[4] similar to the national analysis at provincial level Johansen (1988) Co-integration technique will also be used.

The results of Trace and Maximum Eigen value statistics for the four provinces are summarized in Table 6. The results reveal that in all the four provinces there exists a co-integrating vector among variables.

[4] For details, see Appendix.

TABLE 5

System Estimation Results (SUR)

	Coefficient	Std. Error	t-Statistic
Equation 1	$Ag_t = \alpha_0 + \alpha_1 k_t + \alpha_2 pop_t + \alpha_3 tmp_t + \xi_t$		
Constant	40.513890*	3.535847	11.458050
K	0.759943*	0.227903	3.334494
PoP	-0.476863**	0.205958	-2.315344
TMP	-6.045614*	1.097994	-5.506052
R-squared	0.109898	Durbin-Watson stat.	0.182644
Adjusted R-squared	0.100495		
Equation 2	$Mn_t = \alpha_0 + \alpha_1 k_t + \alpha_2 pop_t + \alpha_3 tmp_t + \psi_t$		
Constant	34.812350*	3.897628	8.931676
K	1.822921*	0.251222	7.256211
PoP	-0.874367*	0.227031	-3.851313
TMP	-5.267636*	1.210339	-4.352198
R-squared	0.221505	Durbin-Watson stat.	0.191950
Adjusted R-squared	0.213281		
Equation 3	$Sr_t = \alpha_0 + \alpha_1 k_t + \alpha_2 pop_t + \alpha_3 tmp_t + \delta_t$		
Constant	39.232460*	3.633546	10.797290
K	1.401911*	0.234201	5.985942
PoP	-0.988432*	0.211649	-4.670157
TMP	-5.939864*	1.128333	-5.264283
R-squared	0.202578	Durbin-Watson stat.	0.184048
Adjusted R-squared	0.194155		
Determinant residual covariance of the Model			0.024305

* denotes rejection of the hypothesis at the 0.05 level. **MacKinnon-Haug-Michelis (1999) p-values.

TABLE 6

Co-integration Test Results (Provincial level)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistics	0.05 Critical Value	Prob.**
Punjab				
	Unrestricted Cointegration Rank Test (Trace)			
None*	0.412389	25.796070	24.275960	0.0319
At most 1	0.202974	7.718619	12.320900	0.2593
At most 2	0.000150	0.005100	4.129906	0.9535
	Unrestricted Cointegration Rank Test (Maximum Eigenvalue)			
None*	0.412389	18.077450	17.797300	0.0454
At most 1	0.202974	7.713519	11.224800	0.1936
At most 2	0.000150	0.005100	4.129906	0.9535
Trace and Max-eigenvalue test indicates no cointegration at the 0.05 level in the Punjab				
Sindh				
	Unrestricted Cointegration Rank Test (Trace)			
None*	0.369214	24.427200	24.275960	0.0479
At most 1	0.227047	8.760374	12.320900	0.1835
At most 2	0.000121	0.004119	4.129906	0.9581
	Unrestricted Cointegration Rank Test (Maximum Eigenvalue)			
None*	0.369214	15.666830	17.797300	0.1016
At most 1	0.227047	8.756255	11.224800	0.1316
At most 2	0.000121	0.004119	4.129906	0.9581
Trace and Max-eigenvalue test indicates no cointegration at the 0.05 level in Sindh				

(Continued)

TABLE 6
(Continued)

Co-integration Test Results (Provincial level)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistics	0.05 Critical Value	Prob.**
Balochistan				
	Unrestricted Co-integration Rank Test (Trace)			
None*	0.425040	28.419200	24.275960	0.0142
At most 1	0.244113	9.601734	12.320900	0.1369
At most 2	0.002538	0.086386	4.129906	0.8092
	Unrestricted Cointegration Rank Test (Maximum Eigenvalue)			
None*	0.425040	18.817470	17.797300	0.0350
At most 1	0.244113	9.515348	11.224800	0.0985
At most 2	0.002538	0.086386	4.129906	0.8092
Trace and Max-eigenvalue test indicates no cointegration at the 0.05 level in Balochistan				
Khyber Pakhtunkhwa				
	Unrestricted Cointegration Rank Test (Trace)			
None*	0.450807	25.387930	24.275960	0.0361
At most 1	0.131364	5.011539	12.320900	0.5660
At most 2	0.006546	0.223298	4.129906	0.6940
	Unrestricted Cointegration Rank Test (Maximum Eigenvalue)			
None*	0.450807	20.376390	17.797300	0.0200
At most 1	0.131364	4.788240	11.224800	0.5076
At most 2	0.006546	0.223298	4.129906	0.6940
Trace and Max-eigenvalue test indicates no cointegration at the 0.05 level in KPK				

* denotes rejection of the hypothesis at the 0.05 level.
**MacKinnon-Haug-Michelis (1999) p-values.

The normalized co-integration coefficients (summarized in Table 7) reveals that in the long run population growth rate is an obstacles for the economic growth (proxy by provincial expenditure) in all the four provinces. However climate change has negative and significant relationship with growth in Balochistan and Khyber Pakhtunkhwa suggesting that economy of these provinces is sensitive to variations in the climate change. However, the relationship of climate change with economic growth is insignificant in Punjab and Sindh. It is noteworthy that these results were used with caution in the present study and we did not include the expenditures incurred in the situation of natural disasters like floods, droughts, etc. It has been assumed (rather strong assumption) that natural hazards are coped by financial support of the federal government.

TABLE 7

Normalized Co-integrating Coefficients (Provincial Level)

	Variables	Co-efficient	Std. Error	t-Statistic
Punjab	POP	-0.8663*	-0.1525	-5.6800
	TMP	-0.1257	-0.0939	1.3385
	Log likelihood		75.5080	
Sindh	POP	-0.1303*	-0.0458	2.8467
	TMP	-0.1998	0.1118	-1.7872
	Log likelihood		91.8960	
Balochistan	POP	-0.1264*	-0.0564	-2.2405
	TMP	-0.1171*	-0.0473	2.4774
	Log likelihood		86.6950	
KPK	POP	-1.8664*	-0.1130	16.5207
	TMP	-0.0043*	-0.0017	2.5636
	Log likelihood		99.5320	

* denotes rejection of the hypothesis at the 0.05 level.

VII. Conclusions and Policy Implications

The present study has analyzed the relationship between climate change and economic growth in Pakistan. Climate effects were estimated directly by analyzing historical relationship between variations in climate and economic growth for the period 1973-2010. Moreover, the study has also analyzed the effects of climate change on various sectors of the economy and has also tried to analyse impacts at the provincial level.

The results show that temperature (proxy for climate change) has negative and significant relationship with GDP as well as with the productivity in agriculture, manufacturing and services sectors. However, severity of these negative impacts is higher in the agriculture sector as compared to the manufacturing and services. The provincial results suggest a negative and significant relationship of climate change in Balochistan and KPK, while insignificant relationship in the Punjab and Sindh. It asserts the need for a joint and comprehensive policy regarding adoption of mitigation strategies to control the climate change because if climate change is not controlled then it will hurt the economic growth to a great extent. The reduction in economic growth will also result in raising the poverty. Though, the poor contribute the least to causing climate change but they experience impacts of the climate change most severely; due to their dependency on agriculture and are least able to afford to pay for resources necessary to adopt the preventive measures and mitigation strategies. Therefore, control of climate change is not only important for economic growth but it is also crucial for poverty alleviation.

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APPENDIX

Results of ADF Test

Variable	Level			1st Difference		
	Intercept	Trend and Intercept	None	Intercept	Trend	None
Yt	-0.430519	-3.038414	2.558856	-3.183120*	……	……
Kt	-1.452271	-1.388672	0.398104	-4.462361*	……	……
PoPt	-1.261823	-2.719233	-1.625222	-7.117041*	……	……
TMPt	-1.590867	-1.928845	0.515775	-5.170954*	……	……
Opt	-2.547031	-2.524208	-0.134555	-6.596946*	……	……
EXP(Punjab)	-1.103918	-2.050260	2.212675	-5.336505*	……	……
EXP(Sindh)	-1.295660	-3.134140	-3.202540	-3.989190*		
EXP(Balochistan)	-2.310550	0.278320	1.991700	-5.704970*		
EXP(KPK)	-0.999210	-1.158560	-1.203240	-4.526520*		
POP(Punjab)	-2.783690	-2.621010	-0.168660	-5.182730*		
POP (Sindh)	-2.103570	-2.920690	-0.781750	-7.921540*		
POP (Balochistan)	-1.120900	-0.290480	-2.815260	-3.032700*		
POP (KPK)	-0.682670	-1.699220	-2.237060	-4.001700*		
TMP(Punjab)	-0.796450	-0.479750	-0.274400	-3.258540*		
TMP (Sindh)	-0.596480	-1.236240	-2.319300	-5.365930*		
TMP (Balochistan)	-0.146410	-0.636100	-1.775010	-8.083200*		
TMP (KPK)	-0.881120	-0.691490	-0.826280	-3.025700*		

* Denotes significance at 5% level.