

IS CLIMATE CHANGE HINDERING ECONOMIC GROWTH OF ASIAN ECONOMIES?

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Asia is recognized as one of the most vulnerable regions to climate change on the planet. With approximately 60 per cent of world's population residing in Asia, this phenomenon presents serious concerns for policymakers in the region. The present study analyses the impacts of climate change on economic growth for selected Asian countries during the period 1972-2009. A growth model has been developed by incorporating temperature and precipitation as proxies for climate change in the production function and a fixed effect model (FEM) and seemingly unrelated regression (SUR) have been used to estimate the model. The results reveal that economic growth is negatively affected by changes in temperature, precipitation and population growth whereas urbanization and human development stimulates economic growth. The results also indicate that agriculture is the most vulnerable sector to climate change and manufacturing is the least affected sector.

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Key words: Climate change, economic growth, fixed effect model, seemingly unrelated regression.

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I. INTRODUCTION

A strong correlation exists between energy consumption and economic growth. Energy use results in accelerating greenhouse gas (GHG) emissions. Estimates indicate that approximately 75 per cent of all CO₂ emissions have come from developed countries. These results imply that economic growth depends on energy usage that leads to environmental degradation. However, economic growth may bring an initial phase of deterioration but later on, due to the adoption of better abatement technologies, it might bring some improvement to the quality of the environment (Grossman and Krueger, 1995; Hitz and Smith, 2004). Recently, accelerating emissions of GHGs in developing countries, especially in emerging economies, such as Brazil, China and India, have raised serious concerns about the relationship between climate change and economic growth. Although climate change may initially have some positive effects for some developed countries, it will be destructive in the long run (Hope, 2006).

Moreover, the impacts of climate change are not evenly distributed. The poorest countries and people feel the adverse impacts of climate change first and will suffer the most from them as these countries are more vulnerable to the negative effects of rising sea level and the impact on water resources, ecosystems, crop production, fisheries and human health (Stern and others, 2006; Nordhaus, 1991; Tol, 2008; Yohe and Schlesinger, 2002). In less developed countries, a large percentage of the population is dependent on climate-sensitive sectors and there is low capacity to develop and implement adaptation strategies. Nevertheless, these countries have to bear the cost for promotion and adoption of different mitigation strategies (Adger, 2006). Notably, the impact of mitigation will only be felt in the long run by future generations (Sathaye, Shukla and Ravindranath, 2006). Similarly, due to limited adaptive capacities, these countries' poor communities are more vulnerable to natural hazards (Smith and Wandel, 2006).

In order to accelerate economic growth and curtail poverty, developing countries need to expand their industrial development and improve living standards. As this takes place, emissions of GHG rise, which, in turn, leads to considerable changes in the climate. Therefore, it is very crucial that a comprehensive study on Asian countries be conducted to analyse the effects of changing weather patterns (an indicator of climate change) on economic growth. Despite data limitations, the present study has attempted to empirically test the relationship between weather patterns and economic growth.

The organization of the paper is as follows: after the introduction, section II presents a brief review of the literature and contains a description of the situation of climate change in Asia. In section III, a theoretical background of the study is presented followed by a discussion on a model for climate change and economic growth that has been developed. The empirical model along with the description of data are presented in section IV. Section V is devoted to a discussion of the estimation results and the last section concludes the paper in which some policy implications and suggestions for further research are presented.

II. LITERATURE REVIEW

Although economic analysis of climate change is a comparatively new issue, numerous studies have estimated the impacts of climate change on economic growth in different regions of the world. Most of these studies are numerical in nature and a bit speculative but they do provide a solid foundation for future research.

Due to climate change, some sectors of the economy may grow faster in comparison to the others and at the same time, the size and composition of some countries' gross domestic product (GDP) may change. Climate change also affects the long-term growth potential of the country. Furthermore, the effects of climate change are not homogeneous within countries; it was found that agriculture, coastal zones and elderly people are more heavily affected than their counterparts. (O'Brien, Sygna and Haugen, 2004; Parry and others, 2007; Lucas and Simone, 2011). According to Stern and others (2006), in the next fifty years, world temperatures are expected to rise 2-3°C. This increase will have severe consequences on economic development as it will affect water quality, agricultural productivity and human health. It was further calculated that about 5 per cent of global GDP per annum would be lost by these impacts. Weitzman (2007) has criticized these findings by indicating that there are uncertainties associated with the measurement of the impacts of climate change and the conclusions drawn were based on a very low discount rate.

Dell, Jones and Olken (2008) found that because of climate change, the growth rate of poor countries would be reduced by 0.6 to 2.9 percentage points. According to Fankhauser and Tol (2005), climate change affects capital accumulation and people's propensity to save, which, in turn, reduces economic growth. By using different growth model specifications, it was found that dynamic effects are relatively larger as compared to direct or static impacts of climate change. However, Calzadilla, Pauli and Roson (2007) concluded that extreme weather would result in savings. This is based on the assumption that in line with expectations that global damage would increase, people would increase savings to avoid the anticipatory negative effects of

climate change. Notably, extreme weather is expected to boost investment as well. According to Lecocq and Shalizi (2007), GDP will be affected indirectly by variations in demand structure even though there is no direct effect of climate change on it. Climate change can result in resource scarcity, which could lead to violent conflict and consequently reduce economic growth in the long-run (Zhang and others, 2007; Tol and Wagner, 2010; Butkiewicz and Yanikkaya, 2005).

Parry and others (2007) projects that a decline in water supplies stored in glaciers and snow cover will result in water scarcity. If global average temperature increases by 1.5-2.5°C then approximately 20-30 per cent of plant and animal species will face the danger of extinction. An increase of temperature in the range of 1-3°C has the potential to increase food production but an increase in temperature beyond that would result in a decline in food production. A rise in sea surface temperature of 1-3°C would cause more frequent coral bleaching events and widespread mortality, unless there is thermal adaptation or acclimatization by corals. Sea level rise will negatively affect the coastal wetlands, including salt marshes and mangroves (Nicholls and Tol, 2006). Projections made by Agrawala and others (2003) reveal that the economy of Bangladesh is affected by climate change through sea level rise, higher temperatures, enhanced monsoon precipitation and run-off, potentially reduced dry season precipitation and an increase in cyclone intensity. This situation has created serious hurdles for the sustainable economic development of the country.

As temperature and precipitation are direct inputs in agricultural production, many believe that the largest effects of climate change will be on agriculture. However, under the conditions of climate change, agriculture production rises in the higher latitudes, partly because of an increase in arable land, and production tends to fall in the tropics, mainly due to an assumed decline in the availability of water (Cooper, 2000; Parry and others, 2007). Gregory, Ingram and Brklacich (2005) suggested that climate change was playing an important role for agriculture but its relative importance varied among regions as well as among different societal groups within a region. For example, in southern Africa, climate is among the most frequently cited drivers of food insecurity. In other regions, such as the Indo-Gangetic Plain of India, other factors, including inefficient labour, availability and quality of ground water for irrigation, ranked higher than the direct effects of climate change as a factor influencing food security. Climate change can affect food systems in several ways, such as having direct effects on crop production through changes in rainfall and temperature. Changes in rainfall lead to drought or flooding, whereas warmer or cooler temperatures will change the length of the growing season. Both of these will affect food prices and the supply chain infrastructure.

Mendelsohn and Dinar (1999) concluded that higher temperatures would reduce grain yields. They also found that India and Brazil had attempted to minimize the effects of global warming on agriculture and that individual farmers had played a very crucial role in that regard. Later on Mendelsohn, Dinar and Sanghi (2001) and Mendelsohn and Williams (2004) found that most of the market sector impacts of climate change have a hill-shaped relationship with temperature. Global warming will likely benefit cool countries/areas, have modest effects on temperate locations and negatively affect hot areas.

Despite the importance of livestock to poor people and the expected effects of climate change on livestock systems, the impacts of climate change on livestock in developing countries are a relatively neglected research area. Livestock feeds, its quantity and quality, heat stress, water, livestock diseases and disease vectors and biodiversity are the major channels through which climate change affects livestock (Thornton and others, 2009).

Gilbreath (2004), in a discussion of a report of the World Health Organization (WHO), states that climate change may increase the risk of death and suggests that most of the diseases common in developing countries are sensitive to climate change. The discussion also notes that even a proportionally small change in the global incidence of some diseases could result in significant public health impacts. It has been estimated that in some regions, the effects of climate change will increase the risk of diarrhoea to 10 per cent in 2030 from the 1990 level. Similarly, the degree of global warming can raise the risk of contracting malaria, leading to expectations that the disease will likely affect 1 million persons and cause the death of about 27,000 persons by 2030 (McMichael and others, 2004). It has also been found that there is a correlation between the spread of malaria and climate change in India (Bhattacharya and others, 2006).

Environmental regulations are generally perceived to impose constraints on production, which lead to harmful impacts on economic growth. However, it has been argued that the effects of environmental policy on economic growth vary through the stages of development (Bretschger and Smulders, 2001; Smulders, Bretschger and Egli, 2011). Environmental regulations will enhance the prospects for growth if improved environmental quality increases the productivity of inputs. Because environmental regulation promotes pollution abatement activities, increasing the returns to scale and these regulations can also stimulate innovations (Ricci, 2007). Greiner (2004; 2005) has found that an increase in GHG emissions will negatively affect the aggregate output and the marginal productivity of capital and that higher abatement activities might reduce GHG emissions and lead to higher economic growth. Tol (2009) has also argued that GHG emissions had severely affected economic

development and called for a higher carbon tax to reduce the emissions.

Asian countries collectively encompass the world's greatest economic, cultural and ecological diversity. About 60 per cent of the world's population live in these countries, making Asia the most populated continent. The total economic activities of Asia make up about 25 per cent of the world's GDP (World Bank, 2010). Consequently, the region is facing many environmental and socioeconomic challenges.

In 2010, Maplecroft released a climate change vulnerability index.¹ Out of 170 countries, 16 countries were identified to be in a condition of extreme risk. Among them, 10 are in Asia. Below is the list of the most vulnerable countries.

Table 1. List of the most vulnerable countries

| | | | |
|-----------------------|------------------------|----------------------|----------------------|
| Bangladesh (1) | Mozambique (5) | Zimbabwe (9) | Viet Nam (13) |
| India (2) | Philippines (6) | Myanmar (10) | Thailand (14) |
| Madagascar (3) | Haiti (7) | Ethiopia (11) | Malawi (15) |
| Nepal (4) | Afghanistan (8) | Cambodia (12) | Pakistan (16) |

Note: Value in parenthesis is the respective rank of the country.

It is worth mentioning here that the variation in climate and geographic features among Asian countries is very large. For example, in China and some parts of India and Pakistan (particularly areas around the Himalayas), winter temperatures are at or below freezing. On the other hand, South-East Asia and the Pacific islands generally experience temperatures above 25°C throughout the year. Consistent with global temperature trends, Asian countries have also been experiencing a warming trend in recent decades. Climate modelling indicates an increase in temperature in Asia by 0.5-2°C by 2030 and 1-7°C by 2070 and predict that arid areas of northern Pakistan and India and western China are likely to warm more quickly. In addition, models indicate increasing rainfall during the summer monsoon season and a reduction in winter rainfall and predict that Asia will also be affected by a rise in the global sea level of approximately 3-16 cm by 2030 and 7-50 cm by 2070 (Parry and others, 2007).

¹ To calculate the vulnerability of 170 countries for the impacts of climate change over the next 30 years, 42 social, economic, and environmental indicators have been used. The index can be downloaded at www.maplecroft.com.

Climate change is resulting in the degradation of land, ecosystems, water and air quality in Asian countries. It is threatening to undermine food security as well as causing health problems. Crop yields are estimated to fall by up to 30 per cent and one billion people may be affected by a water shortage, leading to drought and land degradation by the 2050s (Christensen and others, 2007; Cruz and others, 2007). Climate change has also resulted in the melting of the Himalayan glaciers, which in the short run has raised the risk of mudslides, erosion and flooding. The health impacts primarily consist of epidemics of malaria, dengue, and other vector-borne diseases (Martens and others, 1999). In summer, the increase in humid conditions and severe heat waves can increase the risk of mortality and morbidity in poor communities (Epstein, Sohar and Shapiro, 1995).

Notably, Asia is dealing with increasing cases of natural hazards, such as landslides in the Philippines (2006), extreme weather events in China (2006) including storms, flooding in the east and south, heat and drought in the central and north-eastern regions, and catastrophic floods in Pakistan (2010 and 2011). The impacts of these disasters include hunger, disease, loss of income and livelihoods, collateral damage to infrastructures, all of which affect the survival and well-being of the population.

III. THEORETICAL BACKGROUND

The two most widely used types of approaches for analysing the impacts of climate change on economic growth are the enumerative approach and the dynamic approach. In the enumerative approach, the economic impacts of climate change are analysed separately sector by sector, such as the effects of climate change on agriculture, the ecosystem or tourism. These effects are evaluated together to obtain an estimate of the total change in social welfare stemming from climate change (Nordhaus, 1991; Cline, 1994; Tol, 1995). In this approach, the effects of climate change are analysed by focusing on only one period. Intertemporal effects are ignored. These studies, however, have failed to provide information on how climate change may affect welfare in the long run. This approach also ignores the significant “horizontal interlinkages”, such as the interaction of sectoral impacts. It mostly uses computable general equilibrium (CGE) models and simulation techniques.

In the dynamic approach, different specifications of growth models are used by incorporating the damage function. The Solow-Swan and Ramsey-Cass-Koopmans models are the most widely used growth models for analysing the impacts of climate change on economic growth. The Mankiw, Romer and Weil (1992) model is also applied (Fankhauser and Tol; 2005), but to a lesser degree. In all three of these models, under the assumption of a constant savings rate, it has been found that if climate

change has a negative impact on output, then the amount of investment will also be reduced. In the long run, capital stock and consumption per capita will decline, which will result in shrinking aggregate demand and will adversely affect GDP. In an endogenous growth model, the situation becomes even worse if lower investment (caused by capital accumulation effect) slows the technical progress and improvements in labour productivity or human capital accumulation (Lecocq and Shalizi, 2007).

Both of these approaches were used to some extent to conduct the present study and analyse the impacts of climate change on economic growth and its components, such as agriculture, manufacturing and services.

Theoretical model

Dell, Jones and Olken (2008) incorporated the climatic variables in the production function of their model, which was used as the baseline for the present study. The model provided the theoretical basis for incorporating climate change into growth equations and the guidelines for decomposition of the impacts of changes in weather on economic growth.

Consider the production function.

$$Y_{it} = e^{\alpha T_{it}} A_{it} L_{it} K_{it} \quad (1)$$

$$\frac{\Delta A_{it}}{A_{it}} = g_i + \beta T_{it} \quad (2)$$

Where Y is GDP, L is labour force, A is technology and can be referred to as labour productivity and T are the impacts of climate, g is the growth rate of GDP and K is human capital. Equation (1) captures direct effects of climate change on economic growth, such as impacts on labour productivity. Equation (2) captures the indirect (dynamic) effect of climate, such as the impact of climate on other variables that indirectly influence GDP. Notably, equation (1) directly relates climate change to GDP whereas in equation (2), climate changes affect labour productivity, which will, in turn, affect GDP growth.

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

$$g_{it} = g_i + (\alpha + \beta)T_{it} - \alpha T_{it-1} \quad (3)$$

Where g_{it} is the growth rate of output, direct effects of climate change on economic growth appear through α and indirect effects appear through β while g_i denotes the fixed effects.

This equation separately identifies the direct and indirect effects of climate change. Both of these affect GDP growth rate in the initial period. However, when climate returns to its prior state, direct effect reverses itself. For example, a 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, an indirect effect emerges during climate shocks and their effects persist even in the normal conditions, such as failure in human capital development resulting in a permanent deterioration in human capital and economic growth.

IV. EMPIRICAL MODEL AND DESCRIPTION OF DATA

In the light of the theoretical model, the following super reduced form equation of economic growth will be estimated. The equation is an empirical specification of the equation (3) of the preceding section.

$$y_{it} = \alpha_0 + \alpha_1 hc_{it} + \alpha_2 pop_{it} + \alpha_3 ur_{it} + \alpha_4 tmp_{it} + \alpha_5 pr_{it} + \varepsilon_{it} \quad (A)$$

Where y represents GDP growth rate and hc , pop , ur , tmp and pr denotes human capital, population growth, urbanization, temperature and precipitation, respectively. In order to see which sector of the economy is affected more by climatic conditions, the model is also regressed on the main sectors of GDP, such as agriculture (Ag), manufacturing (Mn) and services (Sr). The model that is estimated in this regard is the following:

$$\left. \begin{aligned}
 Ag_{it} &= \alpha_0 + \alpha_1 hc_{it} + \alpha_2 pop_{it} + \alpha_3 tmp_{it} + \alpha_4 pr_{it} + \xi_{it} \\
 Mn_{it} &= \alpha_0 + \alpha_1 hc_{it} + \alpha_2 pop_{it} + \alpha_3 tmp_{it} + \alpha_4 pr_{it} + \psi_{it} \\
 Sr_{it} &= \alpha_0 + \alpha_1 hc_{it} + \alpha_2 pop_{it} + \alpha_3 tmp_{it} + \alpha_4 pr_{it} + \delta_{it}
 \end{aligned} \right\} \quad (B)$$

Three different specifications are tested: temperature in the first specification, precipitation in the second specification, and both temperature and precipitation are used as indicators of climate change in the third specification. The random effect model and fixed effect model technique were considered to estimate model (A). The Hausman test of endogeneity was used to select the suitable technique. For the estimation of model (B), which is a seemingly unrelated model, the seemingly unrelated regression (SUR) technique was used.² Panel data spanning the period 1972-2009 for the selected Asian countries, namely Bangladesh, India, Indonesia, Malaysia, Pakistan, the Philippines, Sri Lanka and Thailand, were used.

The selection of an indicator of climate change is an extremely critical issue. In this regard, GHG emission levels, atmospheric GHG concentration levels, global mean temperature, sea-level rise and intensity or frequency of extreme events are the most commonly used indicators.

In the study, annual temperature and precipitation have been selected as an indicator of the climate change for two reasons. The first is that the impact literature can be directly related to a change in mean temperature, such as Parry and others (2007), Dell, Jones and Olken (2008). The second reason is that changes in mean temperature have a direct relationship with GHG concentrations. However, it is relatively difficult to relate the other indicators directly to GHG concentrations.

² For details of estimation methodologies see Wooldridge (2002; 2005); Baltagi (2005).

A brief description and details of the data used in this study are presented in table 2.

Table 2. Data sources

| S.# | Name of variable | Data source | Comment |
|-----|------------------------------|---|---|
| 1. | GDP growth rate (y) | WDI ³ | GDP growth rate |
| 2. | Population growth rate (pop) | WDI | Population growth rate |
| 3. | Urbanization (ur) | WDI | Urban population as percentage of total population |
| 4. | Human capital (hc) | Data maintained by Easterly (2001) and WDI | Secondary school enrolment |
| 5. | Agriculture (Ag) | WDI | Agriculture value addition in US\$ |
| 6. | Manufacturing (Mn) | WDI | Manufacturing value addition in US\$ |
| 7. | Services (Sr) | WDI | Services value addition in US\$ |
| 8. | Temperature (tmp) | Terrestrial Air Temperature and Precipitation database, Gridded monthly time series | Annual temperature is calculated by using the monthly data. |
| 9. | Precipitation (pr) | Terrestrial Air Temperature and Precipitation database, Gridded monthly time series | Annual precipitation is calculated by using the monthly data. |

V. ESTIMATION RESULTS

Before estimating the empirical model (A), the Hausman test was used to select the appropriate estimation methodology, which would be either a fixed effect model or a random effect model. The significant Chi-square test statistics suggest that the use of a fixed effect model would be appropriate instead of using the random effect model in all three specifications.

³ World Development Indicators.

Table 3. Hausman test results

| | Chi-sq. statistic | Chi-sq. d.f. | Prob. |
|-----------------|-------------------|--------------|-------|
| Specification 1 | 17.792 | 4 | 0.001 |
| Specification 2 | 26.362 | 4 | 0.000 |
| Specification 3 | 34.194 | 5 | 0.000 |

The results of estimation of equation (A) by using the fixed effect model (fixed period) are summarized in table 4.

Table 4. Single equation estimation results (fixed effect model)

| Variable | Specification 1 | Specification 2 | Specification 3 |
|--------------------|---------------------|-------------------|-------------------|
| Constant | 9.08 (2.12) | 0.12 (1.68) | 0.59 (3.30) |
| hc | 0.19* (4.67) | 0.04* (6.77) | 0.13* (7.75) |
| pop | -0.009** (-1.89) | -0.05* (-2.40) | -0.04* (-2.52) |
| ur | 0.35* (2.26) | 0.01** (1.87) | 0.06* (3.45) |
| tmp | -0.69* (-49.21) | — | -0.82* (-1.97) |
| pr | — | 0.97* (12.55) | 0.10* (2.67) |
| R-squared | 0.986 | 0.860 | 0.964 |
| Adjusted R-squared | 0.986 | 0.849 | 0.961 |
| Durbin-Watson stat | 1.975 | 1.951 | 2.024 |
| F-statistic | 96.402 | 50.618 | 24.447 |
| Prob (F-statistic) | 0.000 | 0.000 | 0.000 |

Notes: Values in parenthesis are the t-statistics; * and ** denote significance at 5% and 10% respectively.

The results reveal that human capital has a positive and significant impact on economic growth. This is in accordance with the theory that human development enhances economic growth. It is also supported by numerous studies on the subject, including, among others, Romer (1986), Barro and Sala-i-Martin (2003) and Naqvi (2010). The results also support the Malthusian theorem, which states that population growth leads to slowing economic growth of a country. These findings are supported by Coale and Edger (1958). It has also been found that urbanization plays a positive and significant role in economic development. Lucas (1988), Shumway and Otterstron (2001) and Naqvi (2010) also suggest that urbanization has a positive impact on economic growth. An increase in precipitation has a positive impact while an increase in temperature will negatively affect economic growth. Hence, changes in temperature and precipitation negatively affect the economic growth of the selected countries. In relative terms, changes in temperature are more harmful for growth in comparison with precipitation. It may also be noted that the coefficients of climate-related variables are highest in all the specifications, revealing that climate change is the major factor affecting GDP growth. The diagnostic test suggests the non-existence of autocorrelation and significance of the overall model.

The results of estimating the empirical model (B) - the reduced model of various sectors of economic growth - by using the seemingly unrelated regression (SUR) are summarized in table 5.

The results show that human capital has a positive relationship with all sectors of GDP while the other variables, namely population growth, temperature and precipitation, have a negative and significant impact on all the sectors. They reveal that impacts of various variables on different sectors are not evenly distributed. Human capital stimulates manufacturing the most and agriculture the least. Similarly, in Asia, population growth rate has the highest negative impact on the services sector and the negative impacts of the population growth rate are limited to the agriculture sector. It sheds light on the issue that agriculture has a comparatively higher labour absorption capacity. As far as climate-related effects are concerned, the agriculture sector is the most adversely affected by a reduction in precipitation in comparison to a rise in temperature. The severe impacts of climate change on agriculture are highlighted in earlier studies on the subject including by Reilly (1999) and Mendelsohn and Dinar (1999).

In the manufacturing and services sectors, precipitation has an insignificant impact on economic growth. It was also found that both the manufacturing and services sectors are negatively and significantly affected by rising temperatures.

Table 5. Seemingly unrelated regression (SUR) estimation results

| Variables | Specification 1 | Specification 2 | Specification 3 |
|--|--|--------------------|-------------------|
| Agriculture: | $Ag_{it} = \alpha_0 + \alpha_1 hc_{it} + \alpha_2 pop_{it} + \alpha_3 tmp_{it} + \alpha_4 pr_{it} + \xi_{it}$ | | |
| Constant | 39.44* (10.90) | 21.26 (0.27) | 29.08* (2.67) |
| hc | 0.70* (3.04) | 0.41* (2.51) | 0.39* (2.32) |
| pop | -0.38** (-1.74) | -0.30** (-1.80) | -0.37* (-2.43) |
| tmp | -5.69* (-5.05) | — | -0.78* (-2.11) |
| pr | — | 0.54* (2.78) | 1.39* (3.77) |
| R-squared | 0.097 | 0.103 | 0.157 |
| Adjusted R-squared | 0.0876 | 0.092 | 0.143 |
| Manufacturing: | $Mn_{it} = \alpha_0 + \alpha_1 hc_{it} + \alpha_2 pop_{it} + \alpha_3 tmp_{it} + \alpha_4 pr_{it} + \psi_{it}$ | | |
| Constant | 33.69* (8.55) | 35.41* (2.13) | 22.45* (3.14) |
| hc | 1.84* (7.31) | 1.18** (1.77) | 1.11* (2.59) |
| pop | -0.72* (-3.04) | -0.96* (-4.63) | -0.48* (-6.12) |
| tmp | -4.99* (-4.07) | — | -0.33* (-2.61) |
| pr | — | 0.30** (1.74) | 0.35 (0.88) |
| R-squared | 0.212 | 0.260 | 0.399 |
| Adjusted R-squared | 0.203 | 0.237 | 0.363 |
| Services: | $Sr_{it} = \alpha_0 + \alpha_1 hc_{it} + \alpha_2 pop_{it} + \alpha_3 tmp_{it} + \alpha_4 pr_{it} + \delta_{it}$ | | |
| Constant | 38.24* (10.35) | 32.11 (1.03) | 29.22 (1.62) |
| hc | 1.39* (5.90) | 1.06* (4.29) | 0.99* (3.57) |
| pop | -0.87* (-3.92) | -0.70* (-2.67) | -0.63* (-2.20) |
| tmp | -4.67* (-4.93) | — | -0.20* (-2.14) |
| pr | — | 0.26 (1.01) | 0.12 (1.65) |
| R-squared | 0.186 | 0.178 | 0.264 |
| Adjusted R-squared | 0.176 | 0.160 | 0.248 |
| Determinant residual covariance of the model | 0.023 | 0.029 | 0.036 |

Notes: Values in parenthesis are the t-statistics. * and ** denote significance at 5% and 10%, respectively.

VI. CONCLUSIONS AND POLICY IMPLICATIONS

The present study has carried out panel data research on the relationship between changes in weather patterns (an indicator of climate change) and economic growth for the Asian economies. The results show that temperature and precipitation have negative and significant relationships with GDP growth as well as with the productivity in agriculture, manufacturing and services sectors. However, the severity of these negative effects is higher in the agriculture sector as compared to the manufacturing and services sectors. These results support the findings of Parry and others (2007) that an increase in temperature will negatively affect agriculture.

The study results assert that if climate change is not controlled, the economic growth of these countries will be reduced considerably. Of note, however, Asian countries alone can do very little with regard to controlling climate change as their share of GHG emissions in comparison to developed countries is small. Hence, there is a need for an international policy regarding the adoption of mitigation strategies to control climate change. The United Nations Framework Convention on Climate Change⁴ is an excellent attempt in this regard. The reduction in economic growth will also result in increasing poverty. Although the poor contribute the least to causing climate change, they are the most adversely affected by this phenomenon due to their dependency on agriculture and their limited ability to pay for the resources necessary to adopt the preventive measures and adaptation strategies. Therefore, control of climate change is not only important for economic growth of Asian countries but it is also crucial for poverty alleviation.

It is noteworthy to reiterate that there is a very large variation in climate and geographic features among the Asian countries. Therefore, further analysis in the contexts of the spatial variation in the Asia is needed. Single country analysis as well as studies at the subnational levels should be conducted. In that direction, in the future, the study will be extended to explore the impacts of climate change on economic activities in various provinces of Pakistan and on the various states of India.

⁴ United Nations, *Treaty Series*, vol. 1771, No. 30822.

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