Economic Effects of Climate Change on Agriculture Productivity by 2035: A case study of Pakistan

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Abstract:

Climate Change is an ever growing issue with a great importance due to wide socio-economic effects. Agriculture is the most climate sensitive economic sector that is influenced both positively and negatively by climate change. A change in temperature or precipitation could cause a significant change in crops productivity and yields. Different crop/bio-physical experts have been making efforts to process the impact of climate on crop yields through different crop modellings using input from different global climate models. In this research, the output of the crop models is used as a shock in the global computable general equilibrium economic model to evaluate the economic effects of climate change. Pakistan has two crop seasons – Kharif and Rabi- therefore two major crops i.e. Wheat and Rice have been chosen for this analysis. A Baseline scenario, representing business as usual with no change in climate, has been created using projections for GDP, population, factor supplies, and required food production. A counterfactual experiment has done using the same GDP and population growth as in the baseline but with addition of crop yield shocks from bio-physical models. A comparison of these two experiments has shown the economic effects of climate change by 2035.

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Keywords: Climate Change, Global Climate Models, Bio-physical Models, Economic Models, Agriculture Productivity, Economy-wide effects

Introduction:

1.1. Background

Agriculture is one of the most climate sensitive sectors of an economy. It requires inputs, such as temperature, precipitation, irrigation water, soil radiation etc., that are directly associated with climate change. Moreover, extreme weather events can produce catastrophic effects on agriculture productivity. Extreme temperature, uneven distribution of precipitation across different seasons, rising sea level, floods, droughts, and other climatic disasters have caused serious treats for human life as well as the socio-economic sectors of the world. The assessment of the ultimate response of producers, consumers, and other agriculture related agents requires a detailed evaluation of economic modelling using inputs from different climate and crop models.

In order to understand the potential impacts of changing climate, scientists and crop experts have united to do an integrated and collaborative research (Ruane, Winter, McDermid, & Hudson, 2015). This research begins with global climate models that analyze the interaction of weather variables using different physical, biological, and chemical principles and then estimate their responses to the rising levels of greenhouse gas emissions in the atmosphere. These models also take in to account different socio-economic projections including income and population growth, use of energy, and industrial growth that might influence the emissions of different greenhouse gases and predict earth's future climate. These global climate projections are then used by bio-physical scientists and experts in to different crop modellings to simulate the biological processes of crops' growth and productivity. They provide estimated impact of climate change on crop yield and human health. The potential impact of weather conditions on crop productivity through bio-physical models can be used as input in to different partial and general equilibrium economic models to analyze the economic response of climate change by different socio-economic agents of the society. This research has only focused on the economic component of the assessment by investigating the future endogenous response of economic model of agriculture to the different climate change scenarios by 2035. This include agriculture productivity, crop yield, crop area, consumption patterns, and role of international trade.

1.2. Climate and Agriculture

Climate change is an ever-growing concern and its impact on different socio-economic sectors has been scrutinize in the entire world. Scientists, Economists, and Policy Experts have long been worried about the fact that Climate Change is real. No one can deny the intensity and frequency of extreme climate events that produce disastrous and catastrophic effects on this planet. Nevertheless, it is a dynamic phenomenon that occurs over a longer time period (Adopted, 2014). Therefore, it should be analyzed and evaluated over a period of at least a decade. Each of the last three decades has been successively warmer at the Earth’s surface than any preceding decade since 1850 (IPCC, AR3).

Increasing concentration of anthropogenic greenhouse gases in the atmosphere is one of the major causes of climate change (Rasul, Mahmood, Sadiq, & Khan, 2012)). They are largely driven by economic and population growth. Their atmospheric concentrations are now being higher than ever. There are some natural causes as well such as solar activity and volcano, but their effects are minimal to cause a significant change in climate. Rising temperature, irregular pattern of precipitation, rising sea level, recession of glaciers and melting snow caps are some of the elements of climate change.

The effects of the climate change have been observed on the human and natural system of the world. However, the effects of climate change are not just limited to the melting of glaciers, high temperature or irregular precipitation. They reach out far and wide and now affect food production. Researchers estimated that the effects of climate change on food production would lead to the deaths of more than half a million adults in 2050 (Friel et al., 2009).

The rate of change and the nature of the resulting impacts will vary over time and across the country, affecting all aspects of our life. Scientists have projected a rise in the future earth temperature under all climate scenarios (Pachauri et al., 2014). They advocated that the extreme heat waves will hit the world more often and will last longer than ever. There will be more intense precipitation events. Moreover, the global mean sea level will continue to rise and ocean will be much warmer and acidified. Oceans normally absorb around 30% of CO2, making it acidified. (Schmalensee, Stoker, & Judson, 2006) have projected the emissions of CO2 from the combustion of fossil fuel through 2050 using the national panel dataset for the period of 1950-1990. They also analyzed the reliability of the projected data of CO2 emissions by Intergovernmental Panel on Climate Change (IPCC), and found a significant deviation from the historical data.

1.2.1. Climate Distribution of Pakistan:

Pakistan is blessed with unique geo-strategic and socio-economic realities. It has a long latitudinal area covering more than 5000 glaciers in the northern mountain range that keep frozen water to meet the country's water demand through melting process and a vast area of hyper deserts are present in the southern half of the country despite close vicinity of the Arabian Sea (Farooqi, Khan, & Mir, 2005). The mountain ranges of the country consist of Himalayan to Karakoram and some part of Hindukush which are largely covered with glaciers. Extreme warming causing the glaciers and ice caps to recede at a faster pace. Arabian Sea in the south creates a lot of moisture in the atmosphere in the form of monsoon rain that is another source of water for agriculture, industry, electricity, and domestic usage.

It, being a developing country, is not contributing much in increasing the atmospheric Greenhouse Gases (GHG). This contribution is merely 0.8 percent which is the 135th part of that other nations are producing (Bocchiola & Diolaiuti, 2013). However, according to the global climate risk index 2017, the country is on number 7 in the list of most vulnerable nations in the world due to its various geographical and climatic features. It is situated in the geographic region where increase in temperature is predicted to be higher than the global average temperature, where glaciers are receding rapidly which are the only source of feeding the rivers, where most of the land is arid and semi-arid, where more than 40% of the population is involved in the agricultural production that is highly climate sensitive, where there is variability in the monsoon rains and hence large floods and droughts are intended to hit the country (Rasul et al., 2012). As per all these factors, country is facing a serious threat of food security, water security, and energy security.

Its response to the climate change has been firmly lined up with its strategies for sustainable development goals (SDGs) and objectives of the convention on climate change[1]. The threat of climate change can be coped with identifying its effects on different socio-economic stores of a country. Adoption of the National Climate Change Policy and National Disaster Risk Reduction Policy in 2012 gave an exhaustive structure to approach objectives and activities towards mainstreaming climate change, particularly in financially and socially helpless sectors of the economy. A follow-up to these policies was the dispatch in 2013 of the Framework for Implementation of the Climate Change Policy (2014-2030), which plots the vulnerabilities of different economic sectors and recognizes proper adjustment and relief activities. The framework

[1] See Pakistan's Intended Nationally Determined Contributions 2016

document was meant to serve as an impetus for climate change concerns into decision making at national and sub-national levels and to make an environmental friendly development path. The document also involves the preparation of the National Adaptation Plan (NAP), Nationally Appropriate Mitigation Actions (NAMAs), future National Communications to the UNFCCC as well as detailed sub-national adaptation action plans.

1.2.2. The Inherent Relation Between Climate Change and Agriculture

The relationship between climate change and agriculture is quiet complex. Climate change is one of the factors affecting the food productivity of an economy(M. Ahmad & Farooq, 2010). In order to produce edible products, crops need to go through the photosynthetic process that requires a certain amount of heat, water and nutrients. All of these variables are clearly climatic in nature and, therefore, can produce mixed results on agriculture productivity (Molua, 2008). A certain amount of CO2, temperature, and rainfall is required for a crop to survive and to increase its productivity. CO2 fertilization is necessary for all type of crops (Alexandratos & Bruinsma, 2012). However, it also cause bugs and insects to grow along with the crops. Moreover, extreme natural events such as floods, droughts, wind storms, and extreme seasonal events like heat spells, periods of frost, and irregular rainfall patterns could cause serious threats for agricultural productivity (Barros & Stocker, 2012).

One of the most common economic tool used by researchers is based on partial equilibrium analysis called Multivariate Ricardian model that analyze the impact of a variety of biophysical and socioeconomic variables on the land values or farm revenues. Such models don't permit a full adjustment to changing environmental conditions by the farmer (Lobell, Baldos, & Hertel, 2013; Lobell & Burke, 2008). Of course, any statistical approach can only capture effects that are included in the data used for the analysis and hence are unable to evaluate the effects on every segment of the economy. The unanswered question is whether out-of-sample projections using parameters estimated with this process, which any projection for climate effects in 2035 would be, are plausible (Nelson, Palazzo, Ringler, Sulser, & Batka, 2009). (Kabubo-Mariara & Karanja, 2007) have estimated the impact of climate on the agricultural productivity of Kenya using Seasonal Ricardian Model. Their results show that both temperature and precipitation are non-linearly related to crop revenue. Moreover, global warming distort the crop productivity, where the temperature component is more important than the precipitation. Similarly, (Molua, 2007) advocated that climate is the most dominant factor of crop productivity in Cameroon. By surveying more than 800 farms and using Ricardian cross-sectional approach, they find out that net revenues fall as temperature increases and precipitation decreases respectively.

Agriculture sector of Pakistan plays an important role in ensuring food security and poverty reduction by contributing 19.98% to its GDP. It provides employment to more than 40% of the population of the country. It is growing at the rate 3.46 percent. It has two major crop seasons, Kharif and Rabi[2]. Kharif is sowed in summers during April to June and is harvested in the

[2] See Economic Survey 2016-17

following period of October to December. Rabi on the other hand, is the second sowing season begins in winters and reaped during April to May. Wheat and Rice are the two major crops and staple food grown in the country.

Water is an important factor of agriculture system as dry climate cause its production to decrease and increase the amount of bugs and infecting disease in the plants. Both of the crop seasons in Pakistan required significant amount of irrigation water (Nomman & Schmitz, 2011). According to the economic survey 2016-17, water availability for Kharif crops increased by 6.4 percent than the normal supplies, while almost 19 percent less water was available for Rabi crops. Kharif crops enjoy 140.9mm of monsoon rainfall in 2016 which was 25 percent more than the normal rainfall. Due to the considerable amount of irrigation water, major Kharif crops showed significant growth in fiscal year 2016-17. Nevertheless, post monsoon Rabi season received more than 8 percent less rainfall than the normal rainfall of this season.

1.2.3. Climate as a constraint in Agriculture

Climate change, along with more frequent and extreme weather episodes, have a long-lasting implications on the livelihood of people residing in the agricultural communities of the whole world (Burke & Emerick, 2016). Developing countries are the most vulnerable to the climate change while their contribution to the annual global CO2 is very minimal. (Bandara & Cai, 2014) advocated that the climate change has caused serious threat to the economic and social life of the large population of the South Asia as their livelihood is based on agricultural production. The recent high frequency flash floods in Pakistan and India destroyed their agriculture sector and kept the poor people in a perennial poverty trap. (Lal, 2011) suggested that there won't be any significant impact of climate change on food productivity of South Asia in short run, however, over a longer period of time, say 2050 and beyond, dangerous droughts and floods will effect crop productivity of both Kharif and Rabi seasons. Global food production is also challenged by the climate change. (Lobell, Schlenker, & Costa-Roberts, 2011) estimated that the global maize yield declined by 3.8% due to the climate change from 1980 to 2010.

The global climate change has already impacted the economy of Pakistan in the form of increasing frequency of floods and droughts, low crop yields, irregular weather patterns, less availability of fresh water and the loss of biodiversity. The country faced three major floods since 2010 that ruined the whole economy specifically its agriculture sector. The flood, followed by the heavy monsoon rainfall in 2010, destroyed the key infrastructure of the agriculture including fertilizers, tube wells, animal shelters, water channels, seed stocks, and people's homes (Memon, 2011). According to (Ahmed, 2013), flood caused a loss of 13.3 million tons of production of major crops. Around 1.2 million livestock and 2 million hector of crop area were destroyed. The very next year it faced another great flood in the provinces of Sindh and Baluchistan. People lost their lives particularly those who were engaged in the agricultural activities. The standing crops of rice, sugar cane, vegetables and pulses, sorghum, and cotton were all destroyed. The total damage of the flood were recorded at $3.7 billion[3]. Two year later, another gigantic flood with heavy rainfall hit the country by affecting more than 2.5 million people[4]. These statistics are strong enough to advocate that the agriculture is highly sensitive sector of Pakistan

The country has divergent geographical characteristics with some areas being extremely hot, some are very cold while some remain moderate throughout the year (Yousuf, Ghumman, Hashmi, & Kamal, 2014). Extreme seasonal variations effect the cropping season of the country (A. Ali & Erenstein, 2017). Pakistan has inadequate water storage facilities and an aging water infrastructure, including the country's vast irrigation network, making it a water stressed country (Asif, 2013). The climate models suggest that the monsoons are becoming unpredictable in the region. Calamitous droughts are expected to happen in winter that will affect the yield of cash harvest. Heavy rainfall in summers will result in riverine and flash floods in different area of the country. Its lack of capacity for flood management and wetlands produce serious implications for food and energy security. Other hydro-meteorological hazards such as glacial melt, glacial lake outburst flooding (GLOF), storms, cyclones, avalanches, desertification and heat waves are becoming more common, putting lives, property and the allied socio-economic features of country at great risk (S. Ali et al., 2017).

1.3. Rationale of the Study:

The study of climate change alone holds great importance in terms of its worldwide impacts. Scientists and experts have been warning about the possible disastrous impacts of changing climate on different sectors of the economy. Developed and advanced countries are most likely to cause change in climate due to their rapid industrial advancement while low income countries are the mostly the victims of extreme climate events. Developing countries normally don't have access to relevant adaptive mechanism and resources to mitigate the negative effects of climate change. Moreover, the livelihood of half of the population of such regions are based on agriculture, hence their incomes are highly responsive to the changing climate. Therefore, it is both academically and morally important to analyze the possible impacts of climate change on human population, plant life, wildlife, and the other sectors of the economy and put it on the research agenda as a matter of urgency.

Pakistan is the chosen country in the underlying research which is very attractive for this kind of study. It is located at a region with distinctive geographic, climatic, and economic realities. The country, itself, doesn't contribute much to the global climate change but is the most vulnerable in its effects. Farmers and farm workers hold the biggest portion of the overall population therefore country's welfare is dependent on its agriculture system that is closely related to the weather conditions and climate change.

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[3] See National Disaster Management Authority (NDMA). Flood Rapid Response Plan; NDMA: Islamabad, Pakistan, 2011.

[4] See National Disaster Management Authority (NDMA). Recovery Needs Assessment and Action Framework 2014–2016; NDMA: Islamabad, Pakistan, 2014.

2. Model and Methodology

2.1. Analytical Framework

The economic analysis of climate change begins by introducing a common set of climate change and crop yield inputs to be used as shocks in to the global economic model. The crop yield shocks are based on the projections of the Global Climate Models (GCMs) under different climate scenarios. The GCMs' scenarios combined a representative (greenhouse) gas concentration pathway (RCP) of 8.5 which is the most extreme of the emissions scenarios. The climate conditions result from GCMs by 2035 will be used in the crop yield models to simulate the impact of climate change. Decision Support System for Agro technology Transfer (DSSAT) is the underlying Crop model that comprises of crop simulation models for over 40 crops. The output of crop models such as low yield can be used in a new global economic trade model primarily linked with climate change to analyze the response of different economic agents. In order to estimate the resulting response of climate change, a baseline scenario will be created that shall describe the economy of Pakistan in 2035 with a constant unchanged climate. The baseline scenario indicates the projected macroeconomic variables such as real gdp, population, projected food demand, supplies of factors (Labor, Capital). The counter experiment can be done using the same economic and population growth with addition of crop yield shocks from the biophysical models. A comparison can then be made between the baseline scenario and the experiment to describe the effects of climate change in Pakistan's economy by 2035.

The economic model used in this dissertation is the global computable general equilibrium (GCGE) that can adequately quantify the economic response of climate change. Major benefit of the Global CGE model is its ability to relate the cross linkages within the economy. The model is based on neoclassical theory and assumes perfect competition condition. Along with, adopts constant returns to scale, and a profit maximizing behavior of firms and utility maximizing behavior of the consumer. (Blake, Rayner, & Reed, 1998) describes that a CGE model is based on neo classical theory where producers base their decisions on cost minimizing and profit maximizing and the consumer on achieving utility maximization. The model has the ability to explain the interlinkages within the economy and the behavioral equations describes the effect of a price change on the interlinkages (Minor & Walmsley, 2013). The model is consistent and captures both the economy wide different sectors and their interaction and inter linkages between the sectors of the economy.

2.2. Database and Aggregations

This research has gathered data from 7 different databases. The two major data sets are the latest available GTAP database (Aguiar, Narayanan, & McDougall, 2016) and Pakistan's Social Accounting Matrix (SAM) for the year 2010-11 constructed by International Food Policy Research Institute (IFPRI) under Pakistan Strategy support program (IFPRI,2016). The latest comprehensive Pakistan's SAM 2010-11 is incorporated in the GTAP model to augment the required data. To develop the 2035 baseline values, without climate change, this research has used projections from the base year 2011 through 2035 for GDP, population, factor supplies, and food productivity to feed the projected population. Projected data for GDP, and population have acquired from IMF World Economic Outlook 2017 database and CEPII database. The projected supply of food production to meet the demand of increased population in 2035 has been obtained from Ministry of National Food Security and Research Pakistan, and Food and Agriculture Organization of the United Nations. Projected data for Labor and capital has been gathered from ImpactEcon[5]. There are twelve different types of factors of production in Pakistan's SAM where 3 belongs to farm labor, 2 from non-farm labor, 3 from land, 1 belongs to livestock and 3 are capital types. The share of each labor and capital factor in total labor and capital supply will be calculated from SAM, and will be projected until 2050. Table 1 reports the types of factors used in Pakistan's SAM.

Table 1: Factors Types in SAM 2010-11

No	Factor Code	Factor Types
1	Flab-S	Labor - small farmer
2	Flab-M	Labor - medium+ farmer
3	Flab-W	Labor - farm worker
4	Flab-L	Labor - non-farm low skilled
5	Flab-H	Labor - non-farm high skilled
6	Flnd-S	Land – large
7	Flnd-M	Land – medium
8	Flnd-L	Land – small
9	Fliv	Livestock
10	Fcap-A	Capital – agriculture
11	Fcap-F	Capital – formal
12	Fcap-I	Capital – informal

Source: Pakistan SAM 2010-11 (IFPRI, 2016)

The Social Accounting Matrix of Pakistan also incorporates a total of 16 household's types differentiated on the basis of rural and urban types. There are 12 types of rural households which are further divided on the basis of land ownership, farm size and non-farm activity. This classification includes 6 types of farmers, 2 farm workers, and 4 types are based on non-farm activity. The small farmer owns under 12.5 acre and medium farmer owns more than 12.5-acre agriculture land. The rest of rural based types are employed in farm work but don't own land. The last four households are urban based (IFPRI, 2016). Table 2 reports the household classification of SAM.

Table 2: Household Types in SAM 2010-11

No	Household Types	HH Code	Population (million)	Income (billion)

[5] For more details see https://impactecon.com/

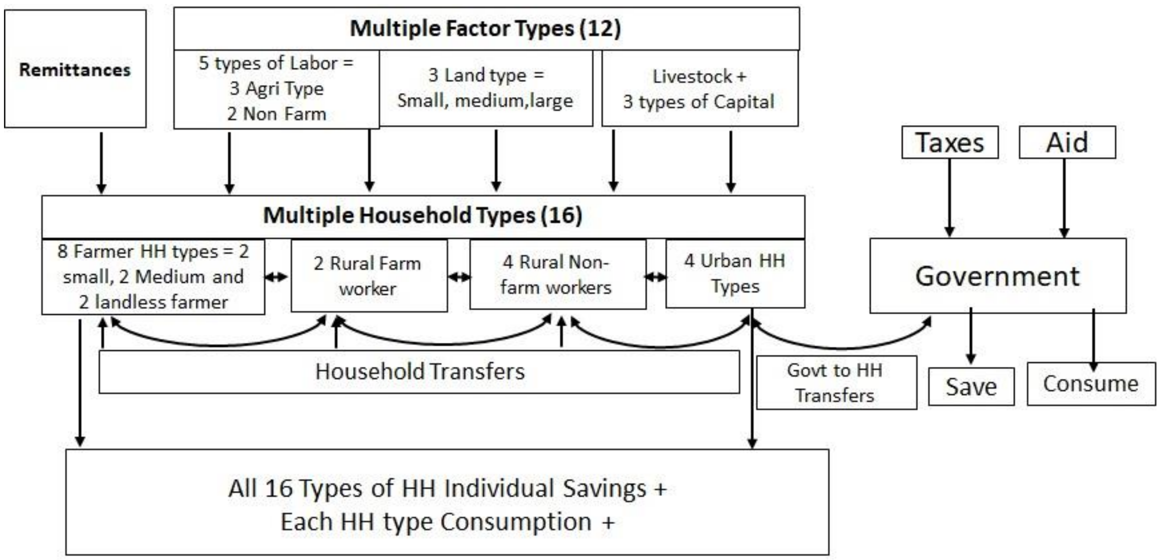
1	Rural small farmer (quartile 1)	hhd-rs1	4,193	275.6327
2	Rural small farmer (quartile 234)	hhd-rs234	15,565	2232.853
3	Rural medium+ farmer (quartile 1)	hhd-rm1	208	14.13264
4	Rural medium+ farmer (quartile 234)	hhd-rm234	2,914	853.3687
5	Rural landless farmer (quartile 1)	hhd-rl1	3,348	194.3888
6	Rural landless farmer (quartile 234)	hhd-rl234	7,292	947.8456
7	Rural farm worker (quartile 1)	hhd-rw1	6,333	238.9349
8	Rural farm worker (quartile 234)	hhd-rw234	8,305	722.2187
9	Rural non-farm (quartile 1)	hhd-rn1	12,595	481.5706
10	Rural non-farm (quartile 2)	hhd-rn2	10,888	645.3767
11	Rural non-farm (quartile 3)	hhd-rn3	9,088	849.5021
12	Rural non-farm (quartile 4)	hhd-rn4	6,316	1388.453
13	Urban (quartile 1)	hhd-u1	5,930	271.7564
14	Urban (quartile 2)	hhd-u2	8,820	657.4251
15	Urban (quartile 3)	hhd-u3	11,506	1366.653
16	Urban (quartile 4)	hhd-u4	17,080	6979.068
All households total			130,381	18,119

Source: Pakistan SAM 2010-11 (IFPRI, 2016)

2.3. Global Computable General Equilibrium (GCGE) Model

The global computable general equilibrium model is used in this study. It provides the framework for the economy to cumulate the decisions of all producers and households in response to a change in policy. The Global CGE model is supported by newly developed MyGTAP modelling framework (Minor & Walmsley, 2013) and its global database which act as the source of data for the model. It is a multi-sector, multi region modelling framework which is an extension of a standard GTAP model (Hertel & Tsigas, 1997). The standard GTAP model has just one private representative household while MyGTAP model gives the option to incorporate multiple household and factor types which help explain the comprehensive linkages between various households and their income and expenditure within the economy. The differentiated number of household based on the level of income and factors augment the model's ability to capture impact of a policy change on the welfare of all the households. The expenditure is divided on three sides, the private expenditure, government expenditure and savings. Regional households own factors of production and they supply the endowments for income to the firms, which uses them and the intermediate goods to produce goods and supply further to households and government to satisfy their demand. The private households and government saving is the total regional saving which is further channelized for investment. The new features introduced in the model are regional transfers including remittances, foreign aid and foreign income (figure 1).

Figure 1. Structure of MyGTAP Model



Source: Author's own design based on MyGTAP approach

2.3.1. Model Closure

The standard MyGTAP closures assume that there is perfect competition (zero economic profits) in all sectors. Production factors capital and labor are assumed to be fully mobile between sectors, whereas land and natural resources factors are sluggish to move. Government spending is assumed to be a constant share of government income and there is no tax replacement, hence as tariff revenue falls the government deficit expands. Foreign income flows are assumed to rise or fall with factor prices in the country in which they are located. Investment is driven by the expected rate of return and total domestic savings by the sum of private household savings and the government budget deficit. Hence the trade balance is endogenous.

However, in order to make the model more realistic, we have changed the standard closure by making one of the factors of production unemployed. This way there won't be perfect competition and full employment in the economy. Moreover, real GDP is an endogenous variable in the GTAP model. Therefore, to impose the projected real GDP shocks, we first need to swap it with total factor productivity which is an exogenous variable. This will create a baseline scenario of projected growth in the real GDP along with the projected changes in factor supplies and population.

2.4. Simulation Design

In this paper we investigated the economic effects of climate change by 2035 on both aggregate as well as at household level in Pakistan. Two simulations were undertaken to study this economy wide impact, as follow;

1) Baseline Scenario: Business as usual economy of Pakistan by 2035 without climate change using projected values of GDP, Population, Factor Supplies, and required production of wheat and rice to fulfill the demand of increased population.
2) Simulation 1: Counter Experiment by incorporating the effects of climate change on the productivity and yield of wheat and rice crop by 2035.

3. Empirical Findings and Discussion

Climate change is a growing phenomenon with a great importance due to its wide socio-economic effects. Researchers, economists, and policy makers have been making efforts to estimate the possible effects of changing climate on different stores of the country. Agriculture is the vital element of an economy as it provides raw material to many down line industries and helps in poverty alleviation. In Pakistan, this sector is contributing almost 20 percent to the GDP while employing more than 40 percent of the country's population. Its growth depends on favorable weather conditions therefore making it the most climate sensitive sector. The country has two major crop seasons i.e. Kharif and Rabi. Wheat and Rice are the biggest Rabi and Kharif crops respectively. Due to the climate change by 2035, the productivity of wheat and rice crop will decline by 14.7 and 20.5 percent respectively (A. Ahmad et al., 2015). Therefore, the real GDP will decline by 1.44%.

Table 1 reports the economic effects of climate change on wheat crop productivity. Wheat, being the largest crop of Pakistan, is contributing 9.6% to agriculture value added and 1.9% to country's GDP. It is a climate sensitive crop. High frequency flash floods in Punjab and Sindh have destroyed a vast area of wheat crop in 2010-2014. The baseline scenario depicts, business as usual, economy of Pakistan in 2035 without any change in the country's climate. If the country will follow the same climate trend until 2035, the wheat production would increase to 99.4%. However, the total output of wheat crop will decline by 5.68% due to the climate change under simulation 1. The market price of wheat would increase by 34.34 and 32.91 percent under baseline and counterfactual experiment respectively. Due to the low yield, both the producer and consumer price would increase significantly. Low production would also cause the wheat exports to decline by almost 91 percent. Therefore in order to meet the demand of increased population in 2035, the wheat import would rise by almost 233 percent. Due to the high market price, the private consumption of wheat would decline by 9.18 percent. The total import share in wheat consumption is 242.18 which is calculated by subtracting the private consumption from wheat total imports. On the other hand. The export share will decline by 85.5 percent due to low crop yield.

Table 1: Economic Effects of Climate Change on Wheat Productivity

Variables	Baseline	Simulation 1
Wheat output	99.4	-5.68
Wheat producer price	34.34	32.91
Wheat private consumption	84.7	-9.18

Wheat consumer price	34.34	32.91
Wheat Exports	-103.01	-91.18
Wheat imports	686.86	233
Import share of wheat consumption	602.16	242.18
Export share of wheat production	-202.01	-85.5

Table 2 reports the economic effects of climate change on the rice productivity by 2035. Rice is an important food and cash crop in Pakistan and it is the second staple food after wheat. It accounts for 3.1 percent in the value added in agriculture and 0.6 percent of GDP. Just like wheat crop, the total output of rice crop will decline by almost 10% due to climate change. Low production along with high demand will increase the market price by 42 percent. Such a high price would, however, cause a decline in the private consumption. In order to meet the domestic demand for rice, country's import of rice would increase by almost 300 percent. Therefore, the import share of rice consumption would increase while the export share of rice production would decline by more than 80 percent.

Table 2: Economic Effects of Climate Change on Rice Productivity

Variables	Baseline	Simulation 1
Rice output	96.0	-9.44
Rice producer price	-13.33	42.16
Rice private consumption	306.7	-82.63
Rice consumer price	-13.33	42.16
Rice Exports	184.1	-94.25
Rice imports	12.58	294
Import share of Rice consumption	-294.12	376.63
Export share of Rice production	88.1	-84.81

4. Conclusion:

Pakistan, like any other developing country, is facing serious threats from climate change. The effects of climate change on its agriculture sector has been observed by different existing researchers. In this paper, we have estimated the economy wide impact of climate change on the agriculture sector of Pakistan by employing a new global economic trade model primarily linked with climate change by using different types of comprehensive data sets[6]. This type of integrated model is well suited and tailor made to evaluate the economic effects of climate change at macro as well as at household level.

[6] The details of datasets, that will be used in this study, are in section 3

Wheat and Rice are the major crops and largest staple food of agriculture sector in Pakistan. A yield decline of 14.7 and 20.5 percent of wheat and rice crop has been estimated by (A. Ahmad et al., 2015). As the production of both wheat and rice deceases due to the climate change, their market price would shoot up. Consumers are reluctant to consume the domestically produced wheat and rice. In order to feed the growing population, the country would have to import food products from other countries such as India and Bangladesh. This puts a negative pressure on country's terms of trade.

In a nutshell, climate change would have an adverse effect on the economy of Pakistan by 2035. In order to secure the food production, it should have a sound agricultural policy that must have an important role in influencing its ability to adapt successfully to climate change.

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APPENDIX

Appendix I: Features of MyGTAP

1) MyGTAP has several new characteristics that are helpful in the multiregional context of the standard GTAP model. These features include:
2) More flexibility in the treatment of government savings and spending. This is achieved by removing the regional household of the standard GTAP model and replacing it with a separate government and private household.

3) The inclusion of transfers between government and households and among household groups, remittances and foreign capital incomes.
4) Allowing the assessment of a policy impact on different household groups and production factors within an economy of interest, should additional data such as a SAM be available (Minor and Walmsley, 2012b)
5) Allowing the allocation of private household expenditure across commodities using either the Constant Difference Elasticity (CDE) or Linear expenditure system (LES) specifications depending on the studied situation (Sidig *et.al* 2013 :Minor and Walmsley, 2012).

Appendix II: Sectorial Aggregation Used in this study

Code	Description
Pdr	Paddy rice
Wht	Wheat
Gro	Cereal grains nec
v_f	Vegetables, fruit, nuts
Osd	Oil seeds
Sugar	Sugar cane, sugar beet, crop nec
Pfb	Plant-based fibers
Sugar	Sugar cane, sugar beet, crop nec
Ctl	Cattle,sheep,goats,horses
Animalprod	Animal products nec,raw milk,wool,silk worm cocoons
Frs	Forestry
Fsh	Fishing
minerals	Coal
Oil	Oil
Gas	Gas
minerals	Coal
Processed Food	Processed rice, meat products nec, food products nec,
Vol	Vegetable oils and fats
Mil	Dairy products
Meatfood	Meat: cattle,sheep,goats,horse
b_t	Beverages and tobacco products
Tex	Textiles
Wap	Wearing apparel
Lea	Leather products
Wood	Wood products, paper products
p_c	Petroleum, coal products
Crp	Chemical,rubber,plastic prods
Nmm	Mineral products nec
Metals	Ferrous metals, metal products, metal nec
Autoparts	Motor vehicles and parts, transport vehicles
Ele	Electronic equipment
Ome	Machinery and equipment nec
Omf	Manufactures nec
utilities	Electricity,water,gas manufacture, distribution

Cns	Construction
Trd	Trade
Transport	Transport nec,see transport, air transport
Cmn	Communication
AllServices	services, businesservices,recreation,dwellings,pubadmin,defense,health,education

Source: Author's own aggregation using GTAP 8.1 Data Base

Appendix III: Mapping of SAM Sectors to GTAP Sectors

Pakistan SAM 2007-08		GTAP Sectors Version 8	
Code	Description	Code	Description
A-WHTI	Irrigated wheat	wht	Wheat
A-WHTN	Non-irrigated wheat	wht	Wheat
A-PADI	Rice IRRI (irr) 1/3	pdr	Paddy Rice
A-PADB	Rice basmati (irr) 2/3	pdr	Paddy Rice
A-COTT	Cotton (irr)	pfb	Plant based fiber
A-CANE	Sugar cane (irr)	Crb	Cane and beet
A-OCRP	Other field crops	gro	Other grains
A-HORT	Fruits/vegetables	v_f	Veg & Fruits
A-CATT	Livestock (cattle, milk)	ctl	Cattle
A-POUL	Livestock (poultry)	Oap	Other Animal Prod
A-FOR	Forestry	Frs	Forestry
A-FISH	Fishing	Fsh	Fishing
A-MINE	Mining	Minerals	Minerals
A-VEGO	Veg Oils	vol	Vegetable Oils
A-WHTF	Wheat Milling	Processed Food	Processed Food
A-RICI	Rice Milling (Irri)	Processed Food	Processed Food
A-RICB	Rice Milling (Bas)	Processed Food	Processed Food
A-SUG	Sugar	sgr	Sugar
A-OTHF	Other food	Processed Food	Processed Food
A-LINT	Cotton gin (lint)	tex	Textiles and man-made fibers
A-YARN	Cotton spin (yarn)	tex	Textiles and man-made fibers
A-CLTH	Cotton weave (cloth)	tex	Textiles and man-made fibers
A-KNIT	Knitwear	wap	Wearing Apparel
A-GARM	Garments	wap	Wearing Apparel
A-OTXT	Oth Textiles	tex	Textiles and man-made fibers
A-LEAT	Leather	lea	Leather
A-WOOD	Wood	Wood	Wood
A-CHEM	Chemicals	crp	Chemical rubber products
A-FERT	Fertilizer	crp	Chemical rubber products
A-CEM	Cement, bricks	nmm	Non-Metallic Minerals
A-PETR	Petroleum refining	p_c	Petroleum and Coke
A-MANF	Other Manufacturing	omf	Other Manufacturing
A-ENRG	Energy	utilities	Utilities
A-CONS	Construction	cns	Construction
A-TRADW	Trade-wholesale	trd	Trade
A-TRADR	Trade-retail	trd	Trade

A-TRADO	Trade-other (rest, hotel)	trd	Trade
A-RAIL	Transport-Rail	Transport	Transport
A-ROAD	Transport-Road	Transport	Transport
A-TRWAT	Transport-Water	Transport	Transport
A-TRAIR	Transport-Air	Transport	Transport
A-TROTH	Transport-Other (pipes)	Transport	Transport
A-HSNG	Housing	Utilities	Utilities
A-OWNH	Imputed Rent	Utilities	Utilities
A-BSERV	Business Services	Allservices	All services
A-HSERV	Health care	Allservices	All services
A-ESERV	Education	Allservices	All services
A-PERSV	Personal Services	Allservices	All services
A-OSERV	Other Priv Services	Allservices	All services
A-PUBS	Public Services	Allservices	All services
A-FIN	Finance and insurance	Allservices	All services

Source: Author's own mapping using GTAP 8.1 Data Base and Pak SAM 2007—08

Appendix IV: Pakistani Household Types and Characteristics

	Household Types	HH Code	Population (million)	Income shares (percent)	Population shares (percent)
1	Large and medium farm Sindh	H-MF1	0.8	1.5	0.6
2	Large and medium farm Punjab	H-MF2	2.4	6.1	1.8
3	Large and medium farm other	H-MF3	0.6	0.8	0.4
4	Small farm Sindh	H-SF1	3.1	1.8	2.4
5	Small farm Punjab	H-SF2	16.0	11.5	12.2
6	Small farm other Pakistan	H-SF3	5.6	3.3	4.3
7	Landless farmers Sindh	H-0F1	2.5	1.4	1.9
8	Landless farmers Punjab	H-0F2	3.6	1.8	2.7
9	Landless farmers other Pakistan	H-0F3	1.7	0.7	1.3
10	Landless agri. Lab Sindh	H-AGW1	3.0	1.5	2.3
11	Landless agri. Lab Punjab	H-AGW2	3.3	1.4	2.5
12	Landless agri. Lab other Pakistan	H-AGW3	0.4	0.2	0.3
13	Rural non-farm quintile	H-NFQ1	8.2	2.8	6.2
14	Rural non form quintile 2	H-NFQ2	8.9	3.3	6.8
15	Rural non-farm quintile other	H-NFOTH	27.7	17.3	21.2
16	Urban quintile 1	H-UQ1	8.6	2.6	6.6
17	Urban quintile 2	H-UQ2	8.6	3.4	6.6
18	Urban other	H-UOTH	25.7	38.7	19.7
All households			130.6	100.0	100.00

Source: Pak SAM 2007-08 and HIES 2007-08

Appendix V: Factors types in Pakistan SAM 2007-08 used in the Study

Code	Description	Code	Description
LA-AGL	Labor - agric (own)-large	LN-MD1	Land - irrigated - med Sindh
LA-MF1	Labor - agric (own)-med Sindh	LN-MD2	Land - irrigated - med Punjab

LA-MF2	Labor - agric (own)-med Punjab	LN-MD3	Land - irrigated - med OthPak
LA-MF3	Labor - agric (own)-med OPak	LN-SM1	Land - irrigated - sm Sindh
LA-SF1	Labor - agric (own)-sm Sindh	LN-SM2	Land - irrigated - sm Punjab
LA-SF2	Labor - agric (own)-sm Punjab	LN-SM3	Land - irrigated - sm OthPak
LA-SF3	Labor - agric (own)-sm OPak	LN-DR1	Land non-irrig - sm/m Sindh
LA-AGW	Labor - agric (wage)	LN-DR2	Land non-irrig - sm/m Punjab
LA-SKU	Labor - non-ag (unsk)	LN-DR3	Land non-irrig - sm/m OthPak
LA-SK	Labor - non-ag (skilled)	K-LVST	Capital livestock
LN-LG1	Land - large- Sindh	K-AGR	Capital other agric
LN-LG2	Land - large- Punjab	KFORM	Capital formal
LN-LG3	Land - large - OthPak	KINF	Capital informal

Source: Pakistan SAM 2007-08